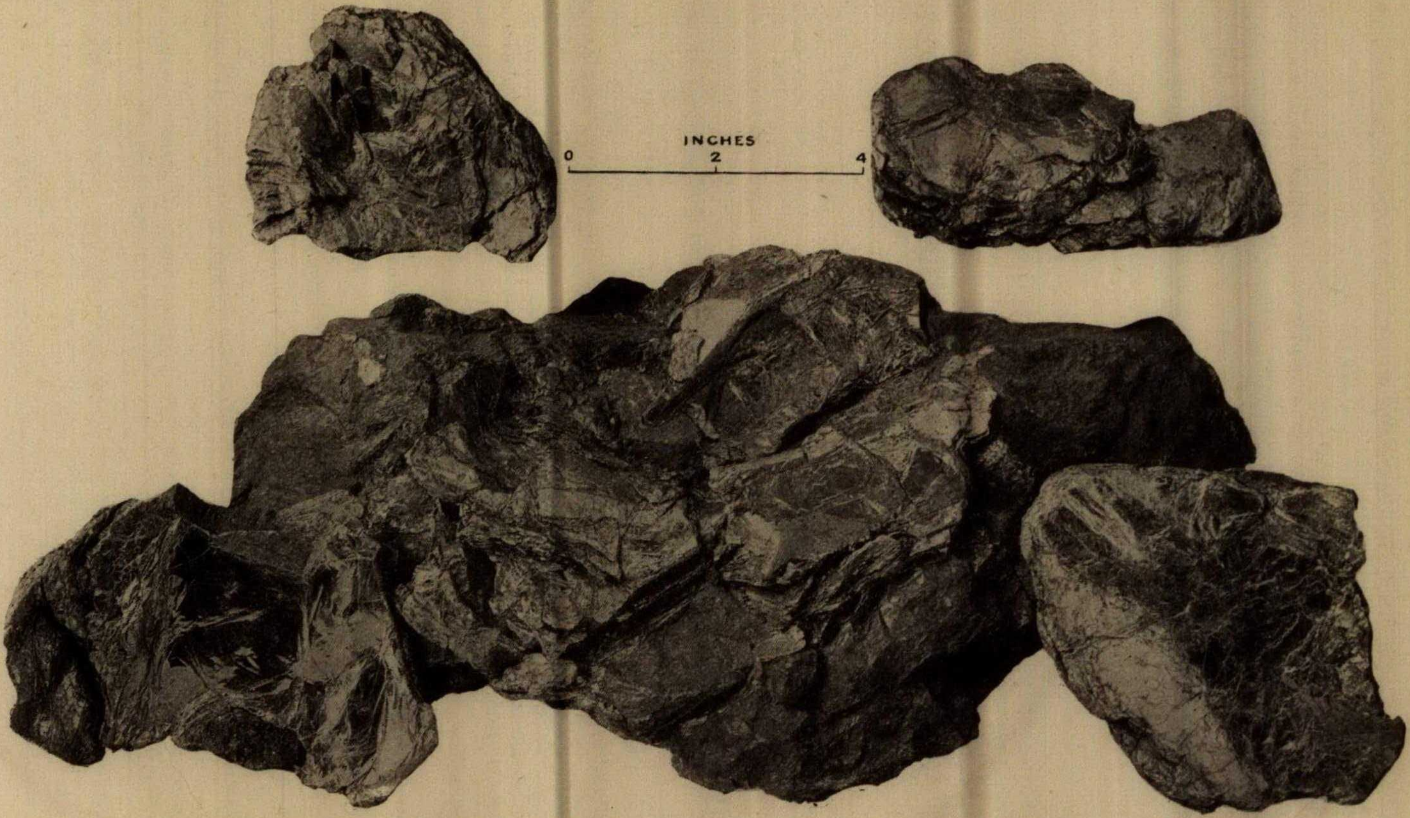
Frontispiece PLATE I



Molybdenite crystals from Spain mine, Griffith township, Renfrew county, Ont.

CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN McLEISH, DIRECTOR

MOLYBDENUM

METALLURGY AND USES
AND THE
OCCURRENCE, MINING AND CONCENTRATION
OF ITS ORES

BY

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OTTAWA
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MOLYBDENUM

INTRODUCTORY

Prior to the opening of the twentieth century molybdenum was regarded mainly in the light of academic and scientific interest; its commercial uses being almost exclusively limited to the chemical industry. A few years before the European war, however, its value in steel alloys began to be recognized by British and German steel makers. The results of these investigations were kept secret; but just before hostilities broke out in 1914, Germany began buying up all the available supplies of molybdenum ores. This strategic policy of cornering the world's supply may have been momentarily successful, but it had the compensating effect of causing an intensive search for the ores of the mineral, and it was soon found that molybdenite—the chief ore of molybdenum—was not nearly so rare as had been formerly supposed. In a short time the known deposits in Canada alone, increased from a few dozen to several hundred.

Early experiments with the metal, especially by the British steel makers, were confined to tool steels having a high molybdenum content. These, however, often proved unreliable in workshop practice, and this defect acted as a setback to the industry. It was on this account, and perhaps also owing to the fact that at that time there had been almost no domestic production of the metal or its ores in the United States, that the American steel makers did not regard molybdenum favourably as an alloy for tool steels. Nevertheless, experiments were made, and after a short time several patents were taken out for low molybdenum structural steels. Remarkable results are claimed for these steels, and to-day the United States is said to be preparing to make large quantities of low molybdenum alloy steels. The European steel makers are also conducting carefully guarded experiments, and it is confidently believed that they also recognize the commercial value of low molybdenum steels.

The stagnation in the molybdenum industry at the present time may be attributed to some of the following causes:—

When the abnormal war demand suddenly ceased, there remained large stocks of molybdenite and ferro-molybdenum. A quantity of these stocks came from producers all over the world and were of very doubtful grade, and unreliable. Markets having disappeared, producers were forced to close down, many of whom were just beginning operations on a large scale. As the great majority of these molybdenum steels were utilized solely for war purposes, very little attention had been paid to their industrial application. Consequently, when the war demand ceased, the manufacturers were not specially conversant with, or convinced of the possibilities of these steels and a long series of experiments were needed to demonstrate the superior quality of low molybdenum steels.

The situation up to the present has been that the steel manufacturer, although probably realizing the immense possibilities of molybdenum steel alloys, will not undertake contracts for the supply of these steels until he is positively assured of a regular and continuous supply of the raw materials of standard grades, and at reasonable prices.

The molybdenum producer, on the other hand, will not go to the expense of re-starting operations unless he is equally assured that he will find a regular market for his products, and at a satisfactory price. Furthermore, the making of new contracts, or sales of new materials, are retarded by the fact that there are still stocks of molybdenum ores and ferromolybdenum throughout the world.

The question of price is vastly more important to the producer than to the consumer. A difference of 25 or 50 cents per pound of raw material will not materially affect the price of a low molybdenum steel to the ultimate consumer, but it means that the producer can either profitably operate his mines, and supply all the demands of the consumer, or else the production of the ore will probably be intermittent, and will be undertaken by so few that the supply cannot be guaranteed; in which case the markets will be fluctuating and the quality unreliable.

The purpose of this monograph is to aid in bringing about co-operation and understanding between the consumer and producer, by supplying the former with detailed information regarding the Canadian sources of supply of molybdenum, together with a brief statement of the resources of the world generally; to lay before the producer a brief account of the uses, markets, and progress made by the consumers of molybdenum; to help the prospector to recognize the localities where the mineral occurs, and to economically follow up any discoveries; and at the same time, to assist the producer, by giving him information as to the various methods of concentration adapted to different types of molybdenum ores, as well as different tests and analyses.

It is to be regretted that almost all the molybdenite properties visited by the writer in Quebec and Ontario were closed down, and in many instances the workings were filled with water.

Free use has been made of the numerous publications and reports dealing with molybdenum and the occurrence of its ores. Among these may be mentioned the special reports on Canadian molybdenite deposits by A. L. Parsons, T. L. Walker, M. E. Wilson, and J. C. Gwillim; and by F. W. Horton of the United States Bureau of Mines; and E. C. Andrews of the New South Wales Department of Mines. Individual acknowledgments are made in the text.

The author is very much indebted to A. W. G. Wilson from whom the bibliography and references to molybdenum were largely obtained; and to the various members of the Mines Branch ore dressing plant, especially W. B. Timm and C. S. Parsons, for criticisms and data supplied.

The author also wishes to express his appreciation and thanks to H. H. Claudet, of Ottawa, who has freely given him the benefit of his wide experience, for criticisms and suggestions; to the numerous owners of the properties visited for many courtesies and kindnesses; to many who furnished information by correspondence; and to the Bureau of Mines and the numerous metallurgists of the United States who have so readily supplied him with information concerning the metallurgy and production of molybdenum.

PART I

CHAPTER I

HISTORY OF MOLYBDENUM, PRICES, USES, AND PROPERTIES

Historical

For almost a century and a half the metal molybdenum has been known to chemists and mineralogists. The name molybdaena, which occurs in the writings of Pliny, is derived from the Greek word meaning lead, the word being employed originally as a designation for a variety of substances containing lead. Later, the name was used to signify galena, or substances of similar appearance; and to these minerals was also given the name of plumbago, or black lead. At a still later period, the word molybdaena was applied solely to graphite and the mineral molybdenum sulphide, which now bears the name of molybdenite. Galena was the first of these three substances—previously considered similar—to be differentiated. Graphite and molybdenite, on account of their great similarity, were not separated until the year 1778, when the great Swedish chemist, Karl Wilhelm Scheele, showed that, unlike graphite, this other mineral forms a "peculiar white earth" when treated with nitric acid, and that when subjected to blowpipe heat, sulphurous fumes are given off. From this powder he produced molybdic acid, which has become the chemist's most reliable agent for the determination of phosphorus in iron or steel.[1]

The isolation, and actual proof of the new element, molybdenum, was not, however, completed till 1790, when P. J. Hjelm prepared it in the form of a metallic powder, and it was later proved to contain neither lead nor carbon.

It is of interest to note that an ancient Japanese sword blade, made by Masamuné about 1330 A.D., was analysed by a German steel expert, and found to contain molybdenum.[2]

During the nineteenth century, very little was done with the metal, except to use it in certain chemical compounds and dyes; but in 1893, molybdenum entered a new era. The German chemists, Sternberg and Deutsch, made notable progress, obtaining a 96 per cent pure metal by reducing molybdate of lime with carbon, and then separating the lime with hydrochloric acid. The metal, however, still contained 3 per cent carbon, and was sold for 86 cents per pound, at which price a ready market was found in Germany. Experiments were made to utilize the metal in tool steel, with the object of replacing tungsten. Tests made a few months previous to the German experiments were not successful, chiefly owing to the quantity of phosphorus and sulphur present in the molybdenum.

In the following year molybdenum was first obtained by means of the electric furnace, when the grey oxide obtained by igniting ammonium molybdate was mixed with sugar, and heated by a current of 350 amperes and 70 volts for about 7 minutes. The resulting metal contained 9 per

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[1] Mineral Foote Notes, May, 1917. O. J. Stewart.

[2] "Molybdenum as an alloy element in Structural Steels." Proc. Am. Soc. for Testing Materials, June 22, 1920. G. W. Sargent.

cent carbon, chiefly in the form of graphite, which rendered it so hard that it scratched glass. Shortly after this Henri Moissan, the French chemist, also made extensive experiments in the reduction of the metal by means of the electric furnace,[1] and succeeded in obtaining metallic molybdenum 99·98 per cent pure. Moissan then devoted a considerable amount of study to its physical and chemical properties, and succeeded in establishing its atomic weight and in determining many other of its now known properties. He also obtained several new molybdenum compounds.[2] These experiments and results were sufficiently successful to cause the metal to be considered commercially important for the first time.

Several new discoveries of the ores of molybdenum were made in the United States and other parts of the world. The first records of production of ferro-molybdenum, and the pure metal, in America, appear to be 11,650 pounds in 1898, and 36,000 pounds in 1899,[3] mainly from Arizona and New Mexico. Previous to this, the world's supplies came chiefly from Scandinavia, with smaller quantities from Australia. For the next three or four years there was a fairly steady production of molybdenum and ferro-molybdenum, the United States contributing about 25 tons annually. In 1902 the first production in Canada was recorded, and experiments were conducted in the concentration of Canadian ores. In 1903 the production in the United States amounted to 795 short tons, valued at $61,000. This caused an over-production of the metal, so that during the latter part of the year the price dropped and further production ceased. In 1904, the United States output was only 14 tons, and for the next ten years the production was not recorded, as it amounted to only a few tons, the price varying according to demand. Almost all the metal in use during this period was obtained from Australia, with a little from Norway. (See table of world's production.)

Thus the expected growth of the molybdenum industry, which looked so encouraging between 1900 and 1904, was not maintained, although the results of experiments on molybdenum steels, obtained by French chemists at the Creusot works, France, were very favourable.[4]

This lack of commercial utilization was due to the following causes: metallurgical difficulties in extracting the pure metal from its ores; uncertainty as to volume and quality of available ores; metallurgical difficulties in producing the steel alloys, together with their unreliability, which gave the metal a bad name; and the rapid advance of tungsten, due to its more plentiful ores, from which the metal could be extracted with much less difficulty and expense than in the case of molybdenum.

Regarding the above-mentioned difficulties, the first has been almost entirely overcome; the quality and quantity can be assured; the third difficulty has been entirely overcome since the unreliability was mainly due to using impure metal, and to lack of knowledge of proper heat treatments, and it can now be said that molybdenum is almost as common, and as easy to handle as tungsten, and as both metals have their own special uses they are not likely to compete with each other to any great extent.

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[1] Detailed description, Comptes Rendus de L'Academie des Sciences, Vol. CXX, p. 1320.

[2] Mineral Industry, 1896, p. 468.

[3] Mineral Industry, Vol. VIII, 1899, p. 429.

[4] For results and analyses of steels see: (a) Iron and Steel Magazine, 1904, E. Saladin, Creusot; (b) Revue de Metallurgie, 1904, Leon Guillet, De Dion Bouton Cie, France; (c) Journal, Iron and Steel Inst., 1906, Leon Guillet.

During the active years of molybdenum production in America, the Primos Chemical Company, which was the largest buyer and manufacturer on the continent, produced annually over 50 tons of molybdenum,[1] but in 1906 dropped to 2 tons a year for the next six years, after which there was a slight increase.

United States Tariff.

Just about this time, however, the United States tariff law of October 13, 1913, considerably curtailed production in America. Under the previous schedule (act of 1909) the duty on molybdenum, or ferro-molybdenum, was 20 per cent if valued at more than $200 per ton, and 25 per cent for that valued at less. In 1913 the rate was changed to 15 per cent in all cases. In both schedules crude ore was on the free list. The new tariff that has recently come into force[2] calls for a duty on molybdenum ore, or concentrates, of 35 cents per pound on the metallic molybdenum contained therein. This is equivalent to about 18 cents per pound of 85 per cent molybdenite concentrates. The duty on ferro-molybdenum and all molybdenum alloys, salts or compounds, is 50 cents per pound on the molybdenum contained therein and 15 per cent ad valorem.

Shortly before the European war there was a sudden demand, and consequent rise in the price of the metal; this was mainly attributed to the demand by Germany, who apparently looking forward to the war, and knowing that it was impossible to lay up enough tungsten, was buying molybdenum to take its place. Although this German demand considerably increased activities in the molybdenum world, it was not until after the commencement of the war that the British government realized the urgent necessity of obtaining supplies of the metal.

The uses to which molybdenum was put during the war were open to so much speculation, and contradictory statements were so prevalent, that the metal was dubbed "the metallurgical mystery."

FUTURE OUTLOOK

During 1903, those interested in molybdenum predicted a future for the metal, but these expectations were not realized. Again, in 1918, when the demand for molybdenum products for war materials ceased, there were many optimists who predicted a continuation of the demand for the metal for use in commercial steels. The peace time uses of molybdenum, however, had not been sufficiently developed to absorb the production, and the market soon became stagnant.

As a result of careful study and experimentation on the part of the steel makers, it is believed that the earlier production will shortly be duplicated. Great strides have been made in demonstrating the unique properties of low molybdenum steel, and costly experiments in the utilization of molybdenum alloys have been and are being made throughout the metallurgical world, the successful results of which, backed by the practical results attained during the war, should soon lead to commercial production on an unprecedented scale.

Authentic figures are almost impossible to obtain, but even in 1919 it was stated that over 4,000 tons of steel containing molybdenum was consumed monthly in the United States alone.[3]

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[1] Mineral Industry, Vol. XXI, 1912, p. 598.

[2] Eng. and Min. Jour., Aug. 26, 1922, Extracts from Pub. No. 318, 67th Congress, H. R. 7456.

[3] "Molybdenum market in 1919." Eng. and Min. Jour., Jan. 17, 1920. Ch. Hardy.

Numerous patents have been taken out, the most notable of which are those by Mr. C. H. Wills, of Detroit, Mich.[1] Recently, articles made of molybdenum steels have been put on the market, including shovels and automobile parts.

The importance of, and space devoted to molybdenum in the United States tariff revision of 1921, before the Ways and Means Committee, is significant, both in indicating the contemplated future use of the mineral and the fear of outside competition with regard to the raw materials.[2]

It was stated during these hearings that half the steels for the automobile industry, etc., would be molybdenum steels which would mean about a million tons yearly, worth from sixteen to eighteen million dollars.

Canada's Outlook.—As far as the Canadian production is concerned, it is impossible to estimate, even approximately, the probable annual output of molybdenite. At the time the demand suddenly ceased the United States and Canada were by far the largest contributors to the world's output.

A large number of operators, believing that there would be a regular and constant demand for the mineral, were preparing to increase the capacity of their plants, and others were preparing to begin production, when suddenly all had to close.

Allan Kissock, president of the Steel Alloys Company,[3] in agreeing with W. E. Simpson's[4] remark that "the future of molybdenum depends on two factors, namely, assurance of supply and price," states that unfortunately, heretofore, many small and sanguine mine owners and producers throughout the world have entered into contracts to deliver and have failed to live up to their agreements. This has given the impression that a reliable supply of molybdenum could not be depended upon, and has proved a serious obstacle to further development. However, when the demand again arises there are responsible concerns now able to assure an ample supply.

It is believed that the majority of the larger Canadian producers still have considerable untouched molybdenum ore-bodies. Besides this, there are many partly developed properties that have not yet produced, but whose development has exposed fairly large blocks of commercial ore. Amongst these may be mentioned the region about Kewagama lake, an area of approximately 500 square miles, in central Témiscamingue, Quebec; Masham township, Quebec; southeastern Pontiac, Quebec; and new discoveries in the Wilberforce area, Ontario.

Although the aggregate quantity of molybdenite in Canada is vast, the deposits in most cases are quite small, and scattered over wide areas. Deposits such as the Moss mine at Quyon will probably be extremely limited in number, and it is not likely that any considerable body of ore will run over one per cent mill feed unless it be in British Columbia. For this reason a system of co-operation and careful control will have to be maintained in operating these Canadian deposits.

Canada, in many respects, is advantageously placed as to the occurrence and production of molybdenite. Geographically, the majority of the largest and most promising deposits are within easy distance of railway

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[1] U. S. Pat. No. 1,278,082, Sept. 3, 1918, "Alloy Steel."

[2] Tariff Information, 1921. "Hearings on general Tariff Revision before the Committee on Ways and Means." House of Representatives. Part II, Schedule C., pp. 746-748.

[3] Min. and Sci. Press, Feb. 7, 1920, p. 184. Allan Kissock.

[4] Min. and Sci. Press, Dec. 20, 1919. W. E. Simpson.

or seaport. Economically, these deposits are all close to sources of waterpower, timber, and fuel. The molybdenum ores of eastern Canada are as a rule freer from deleterious impurities and are easier to concentrate than the average foreign ores.

PHYSICAL PROPERTIES OF MOLYBDENUM

Pure, compact molybdenum is a silvery white metal, quite malleable, softer than steel. It can be filed and polished with ease and is not hard enough to scratch glass. Its appearance depends largely on the method of production. When obtained by reducing molybdenum oxides or sulphides by hydrogen, it is a grey powder which under heat and pressure may be compacted into a metallic bar that is brittle and even fragile. When produced by alumino-thermic methods, or by reduction in the electric furnace, it is compact; but, owing to the absorption of carbon, it is not so pure and has different physical properties than the carbon-free metal. Another form, manufactured by a chemical process, is a metallic crystalline powder of a dark blue colour.

Crude, grey molybdenum, an electric furnace product which is made direct from molybdenite, has a composition of approximately 92 per cent molybdenum, 2 per cent iron, and 6 per cent carbon.[1] It is very brittle and has a hardness greater than that of quartz. Ductile forms of molybdenum that can be drawn into fine wire, ribbons and sheets are also produced. Its fusion point is very high, being about 2,500° C., which is 745° C. above platinum. Osmium, tantalum, and tungsten are the only three metals listed by the Bureau of Standards as having higher melting points. The atomic weight of molybdenum is 96, and its specific gravity, as determined by Moissan,[2] is 9·01, but more recent study of the metal shows that the specific gravity increases with the amount of mechanical working to which it is subjected. The tensile strength as determined by Fink[3] increases with the fineness of the wire, and varies from 200,000 to 310,000 pounds per square inch. This is about one-half the tensile strength of tungsten wire.

The electrical resistance of ductile molybdenum is 5·6 microhms per cubic centimetre for hard-drawn wire, and 4·8 for annealed wire.[4] The coefficient of electrical resistance between 0° and 170° is 0·0050[5]. The specific heat as determined by Defacqz and Guichard is 0·072.

Crude, grey molybdenum has a much lower melting point than pure molybdenum; also, its specific gravity ranges from 8·6 to 8·9, depending on the amount of carbon present. When pure molybdenum is surrounded with carbon and heated to about 1,500° C. it absorbs carbon and becomes hard and brittle. Inversely, if this carbonized molybdenum is melted with molybdenum dioxide, the carbon is oxidized and the molybdenum is refined and takes on the physical properties of the pure metal.[6] Molybdenum burns in oxygen at 500-600° C. with great brilliancy, even after the source of heat has been removed.

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[1] Queensland Geol. Surv., Molybdenite: Art. 4, 1920, p. 109. B. Dunstan.
[2] Traite de Chemie Minerale, t. 4, 1904, p. 687. Henri Moissan.
[3] Ductile Tungsten and Molybdenum. Trans. Am. Elect., Vol. 17, 1910, p. 229. G. C. Fink.
[4] Loc. cit.
[5] Loc. cit.
[6] Traite de Chemie Minerale, t. 4, 1904, p. 689. Henri Moissan.

CHEMICAL PROPERTIES OF MOLYBDENUM

Metallic molybdenum is only slowly oxidized at ordinary temperatures and retains its lustre almost indefinitely, especially the drawn wire. On prolonged heating at a dull red heat it becomes covered with a white coating of molybdic trioxide, and at 600° C. it oxidizes rapidly and the trioxide thus formed sublimes. Pure molybdenum is not volatile, except at exceedingly high temperatures, but it is the oxide above referred to which is volatile at low temperatures.

Molybdenum is attacked by fluorine at ordinary temperatures; by chlorine at a dull red heat; and by bromine at a cherry red; but iodine does not attack it appreciably at temperatures as high as 700° to 800° C. The metal is readily attacked by nitric acid, and by hot concentrated sulphuric acid, but is not affected by hydrochloric acid. Fused oxidizing salts, such as potassium chlorate, potassium nitrate, etc., attack it rapidly, but fused alkalies act only slowly on the metal.

Molybdenum and its oxides combine with a large number of other elements to form a series of compounds. The metal forms several oxides, the most stable of which are the sesquioxide, Mo_2O_3; the dioxide, MoO_2; and the trioxide, MoO_3[1].

A large number of elements combine with molybdic oxide to form molybdates, the commonest of which are sodium molybdate, Na_2MoO_4; potassium molybdate, K_2MoO_4; and ammonium molybdate, $(NH_4)MoO_4$. The first two are formed by fusion of the trioxide with the requisite amount of sodium, or potassium carbonate, and the latter is formed by the action of concentrated ammonia on the trioxide. The heavy metals such as barium, calcium, lead, etc., form molybdates which are insoluble, and use of this property is made in analytical work. There are many other complex molybdates.

Molybdenum forms several stable compounds with the halogens. One of these, $MoO_3 \cdot 2HCl$, is of importance as it is volatile at 250° C. and its formation affords a means of separating molybdenum from tungsten.[2]

Molybdenum forms two principal sulphides, MoS_2 and MoS_3. Both are insoluble in dilute sulphuric and hydrochloric acids.

Roscoe and Schorlemmer[3] made a study of the chemical properties of molybdenum. By referring to these writers and to Moissan[4] more complete details may be obtained.

USES OF MOLYBDENUM

The following is a list of uses to which molybdenum and its salts have been successfully put:—

Metallic Molybdenum:

Commercial alloy steels.
Acid proof alloys for cutlery and other purposes.

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[1] U. S. Geol. Surv., Bull. 111, p. 19. F. W. Horton.
[2] U.S. Geol. Surv., Bull. 111, p. 19. F. W. Horton.
[3] A treatise on Chemistry, Vol. 2, 1913, pp. 1059-1082. H. E. Roscoe and C. Schorlemmer.
Traite de Chemie Minerale, t. 4, 1904, pp. 685-758. Henri Moissan.

Electrical appliances:
  Lamp filament supports, winding for electric resistance furnaces, contact making and breaking devices, spark plug points, X-ray apparatus, voltage rectifiers, thermocouples, arc lamp electrodes, plates used in wireless telegraphy.

Other uses:
  In dentistry, in jewellery.

Salts of Molybdenum:
  As re-agents in analytical determination; fireproofing of fabrics; disinfectants; colouring of pottery; dyeing of cloth, silk, wool, leather, rubber, etc.; by the medical profession; blue print manufacture; in explosives.

The principal use of molybdenum is in the manufacture of alloy steels, to which the metal imparts many desirable properties, particularly in conjunction with chromium, vanadium, cobalt, nickel, manganese, tungsten, etc. The uses and metallurgy of these molybdenum steels will be more fully discussed elsewhere.

There are many other uses for molybdenum and its salts, the principal of which are as follows:—

USES OF METALLIC MOLYBDENUM

Molybdenum Wire. Owing to the ductility of pure metallic molybdenum,[1] it can be drawn into very fine wire, and is used for supporting the filaments in incandescent electric lamps. The wire is also used for winding electric resistance furnaces, and for this use has proved both cheaper than, and superior to platinum, because of the quicker heating and the higher temperatures attainable.[2] For this work it must be protected from the air to prevent oxidation. Among other patents taken out for electric furnaces is the F. G. Keyes[3] patented and electric tube furnace, in which the resistance wire is made from the alloy obtained by reducing a mixture of WO_3 and MoO_3 with hydrogen at a temperature of 800-1,000°.

Substitute for Platinum. Molybdenum has been successfully substituted for platinum and for platinum-iridium in electrical and other uses. Fahrenwald[4] wrote an interesting paper dealing with the substitutes for platinum and its alloys, in which molybdenum can be successfully employed. For various electric contact making and breaking devices it is just as successful as platinum. On account of its high heat conductivity in the ductile form, and because its relative cheapness permits its use in large masses, the formation of heavy coatings of non-conducting oxide are thus to a great extent prevented, and under the conditions existing in these contacts any thin coatings of oxide formed are conductors. Molybdenum is sometimes used as an alloy with tungsten for the points of spark plugs in internal combustion engines.

The Coolidge X-ray tube and a voltage rectifier have a considerable proportion of ductile molybdenum in their construction.

In dentistry, gold-covered molybdenum wire is used to a considerable extent.

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[1] See Coolidge, W. D., U.S. Patent 1082933, Dec. 30, 1913. Process for obtaining ductile molybdenum.
[2] Winne, R. and Dantsizan, C. Jour. Ind. and Eng. Chem., Vol. 3, Oct. 1911, p. 770.
[3] Keyes, F. G. Patent 1308907, July 8, 1919.
[4] Am. Inst. Min. Eng., Bull. No. 109, Jan., 1916, pp. 103-149. Fahrenwald, F. A.

For jewellery purposes it is a good and desirable substitute for platinum, being free from tarnish, permanent in lustre, of a beautiful colour, and capable of being worked like platinum, and of course very much cheaper.

G. A. Thompson took out two patents in 1910 for arc lamp electrodes in which molybdenum was used, and in which an arc of great brilliancy can be obtained. A brilliant arc can also be obtained with a 10 per cent molybdenum and 90 per cent iron electrode.

Experiments by Fahrenwald showed that molybdenum can be successfully used with tungsten as a thermocouple for the measurement of high temperatures. The voltage curve of this molybdenum-tungsten couple was previously studied by E. F. Northrup.[1] The advantage in the use of these metals is that they have much higher fusing points than platinum, platinum-iridium, or platinum-rhodium couples, such as are ordinarily used; and although they oxidize at high temperatures they may be protected from the air by covering them with fused magnesia, or a similar substance.[2]

The two main objections to the molybdenum-tungsten alloy as a substitute for platinum are: (1) relative ease of oxidation; (2) difficulty with which it can be soldered; but these are both overcome by coating with a precious metal, or another alloy.[3]

A considerable amount of molybdenum made by the Fansteel Products Company[4] goes to vacuum tubes and audion manufacturers for plates in wireless telegraphy. The low coefficient of expansion of the metal allows it to be welded to Pyrex glass and this makes it extremely desirable in this connexion.

Acid Proof Alloys. At present, stainless cutlery for domestic purposes is very popular, and it is of interest to mention that certain molybdenum alloys are acid proof and possess the required hardness and lustre to make them suitable for this use.

One type of these alloys known as stellite,[5] which contains about 22 per cent of molybdenum, has been successfully used for domestic purposes, and is also said to possess remarkable high speed qualities when used for cutting tools. These alloys will also doubtless find larger use for pump shafts, driving shafts, ship propellers, etc., and to a certain extent replace bronze. Their application to concrete work that is exposed to salt water also suggests an important use for these alloys.

Use of Molybdenum in Chemicals. Molybdenum was first commercially used in the form of its salts as far back as 1785, when Scheele, having isolated the metal from the ore, made from it various salts, such as molybdic acid, which is the basis of the molybdenum reagents and from which is produced ammonium molybdate.

Ammonium molybdate is the principal salt, and is used chiefly as a reagent in the quantitative determination of phosphorus in iron and steel, various ores, fertilizers, soils, etc., also in the quantitative determination of lead. Ammonium molybdate is sometimes used for fireproofing muslins and other textile fabrics, and, as it is a strong germicide, as a disinfectant for cloth.

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[1] Tungsten and Molybdenum. Met. Chem. Eng., Vol. 11, Jan., 1913, p. 45. E. F. Northrup.

[2] U. S. Geol. Surv., Bull. 111, 1916, p. 28. F. W. Horton.

[3] Engineering, Vol. 104. July-Dec., 1917, p. 222.

[4] Chem. and Met. Eng., Oct. 27, 1920, p. 837.

[5] Alloy of Cobalt with Chromium and other Metals. Tr. Am. Inst. Min. Eng., Vol. XLIV; 1912, p. 576. E. Haynes.

Sodium molybdate, Na_2MoO_4, is occasionally used to dye silks and woollens blue. It also gives a blue colour to pottery and glazes. Dyeing and colouring were among the early uses of molybdenum salts but in pottery works molybdenum appears to have been replaced to a certain extent by cobalt compounds. As a blue dye molybdenum indigo, Mo_5O_7, is used for colouring rubber and is not injurious to the material. Molybdenum tannate with logwood extracts imparts fast colours in a large variety of shades, to leather, silk, wool, and rubber.[1]

Phosphomolybdic acid is used in medicines for purifying and recovering many alkaloids, such as cocaine and quinine, etc., and the cryogenine in urine is easily identified by a certain molybdenum compound.[2]

Some salts of molybdenum are sensitive to light, or re-act chemically upon certain more or less complex organic compounds in the presence of light, and are used in the blue print industry. Certain compounds of this metal with uranium are at the same time sensitive to light and radioactive.[3] The optical and photoelectric properties of molybdenite have been discussed in detail by Coblentz and Kahler[4], giving interesting data on the changes in electrical conductivity of the mineral when exposed to thermal radiations of wave lengths extending from the ultra-violet to beyond the infra-red, also on the polarization by reflection from molybdenite.

Molybdenite was sometimes used in the past as a substitute for graphite in stove polishes and lubricants.

Uses of Molybdenum in Explosives. It has been reported that a process involving the use of molybdenum for the preservation of cordite in hot climates has been discovered in France.[5] The necessity for some stabilizer is said to have arisen from an investigation concerning the destruction of French warships by the decomposition of explosives on board. The report which came through English papers was spread largely throughout Australia, and later in the United States, and is said to have stimulated production and sales of molybdenite, but it afterwards became known that the greatest demand for molybdenum was from Germany and it is thought that the story of its use as a stabilizer may have been spread by Germany to cover exceptional purchases in anticipation of war; at all events it was later conclusively proved that molybdenum was not used as a stabilizer for explosives. It is said, however, that the Japanese used molybdenum extensively in the manufacture of their smokeless powder, shemose.[6]

STANDARDS FOR THE SALE OF MOLYBDENUM ORES AND PRODUCTS

The basis upon which molybdenum ores and concentrates are marketed varies in accordance with the contained molybdenum mineral which may be molybdenite, wulfenite, etc.

On the American continent, the short ton of 2,000 pounds is used, the unit of weight being usually either per pound, or per unit—which is one hundredth of a ton, or 20 pounds. In every English-speaking country

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[1] Queensland Geol. Surv., Art. 4. Molybdenite, 1920, p. 113. B. Dunstan.
[2] Mineral Foote Notes, May, 1917. O. J. Stewart.
[3] Loc. cit.
[4] Dept. of Commerce, Sci. paper of Bur. of Stand., No. 338, pp. 121-162. W. W. Coblentz and H. Kahler.
[5] Editorial. Molybdenite. Min. and Sci. Press. Vol. 108, 1914, p. 860.
[6] Mining American, May 19, 1917, p. 8. C. V. Holman.

outside this continent the long ton of 2,240 pounds, and a unit of 22·4 pounds, are used.

Molybdenite Concentrates. In Canada, the only commercial ore is molybdenite, and is purchased on the basis of its contained pure molybdenum sulphide (MoS_2), the usual quotation price being per pound of pure molybdenite contained in an 85 per cent MoS_2 concentrate; but a sliding scale to cover various grades is often used, depending on the ultimate use for which the mineral is required. For special purposes, a 90 per cent or even a 95 per cent concentrate is specified, on the other hand, a 60 to 65 per cent concentrate is considered to be high enough by some ferro-molybdenum, or molybdenum salt manufacturers: providing that the objectionable elements are at a minimum. War demands naturally upset standards to a certain degree. F. W. Horton[1] states that up to 1914 it was difficult to sell molybdenite concentrates with less than 80 per cent molybdenite, but that during 1916, concentrates as low as 20 per cent molybdenite were marketed. It therefore appears that the range is very wide, but in normal times the demand is not likely to be in excess of the production, so that the probable standard would be an 80 or 85 per cent molybdenite concentrate, with a minimum of 65 per cent—unless of course it is required for special purposes.

Buying of Molybdenum Ores. This is generally by arbitrary arrangement, but sales have been made along the following lines:[2]

Ores containing 0·5 to 3·0 per cent molybdenite—70 to 92 per cent of the sulphide mineral contained being paid for after deducting a suitable treatment charge ($5 to $6 per ton).

During the war the Imperial Munitions Board, through the Department of Mines, Canada, used certain standards that might be useful as a future guide, and which will be found in detail in Summary Report, Mines Branch, Canada, 1916.

Wulfenite. Molybdate of lead ($PbMoO_4$ approx.), which is economically mined in the United States, Austria, etc., is bought and sold either on its molybdenum content, or as the oxide, MoO_3. This mineral is rarely absolutely pure, but when pure contains approximately 26 per cent molybdenum or 39 per cent MoO_3.

Ferro-Molybdenum. This is purchased on the basis of its metallic molybdenum content. The percentage of molybdenum in the alloy is, like the ores, very variable. The Imperial Munitions Board, during 1916, set the following specifications:—

Molybdenum, not less than............	70·0 per cent
Carbon, not more than................	4·0 "
Sulphur, not more than...............	0·4 "
Iron, remainder......................	25·6 "

There are, however, many makers of ferro who are satisfied with a 50 per cent molybdenum content. When in excess of 80 per cent molybdenum, however, the liquid metal becomes difficult to pour.

Objectionable Impurities. Objectionable impurities depend very largely on the uses to which the molybdenum products, derived from the concentrates, are destined, and on the methods employed by the manufacturer in producing the final products. The following elements are stated

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[1] U. S. Bur. of Mines, Bull. 111, 1916, p. 37. F. W. Horton.
[2] Colorado School of Mines No. 2. January, 1919. H. J. Wolf.

to be detrimental: copper, tungsten, bismuth, arsenic, antimony, nickel, tin, and to a small extent, calcium, barium, and phosphorus. The presence of copper in excess of 1 per cent, even in a high-grade molybdenite concentrate, is in most cases sufficient to render the material unmarketable. The only other impurity that is likely to affect the Canadian ores, especially those from British Columbia, is arsenic. On the other hand, some dealers have no objection to the presence of small quantities of arsenic and bismuth in the concentrates, as these elements are readily volatilized when the ore is roasted. Metallic iron (usually in the form of pyrites) should not be above 10 per cent. Mr. J. W. Evans, manager of the Tivani Steel Company, Belleville, Ont., stated that they only allow a trace of copper and no arsenic in either the steels or salts, and that concentrates containing 30 per cent iron pyrites had been successfully treated.

Recent experiments have shown that there are many advantages in utilizing calcium molybdate, instead of ferro, as the agent for introducing molybdenum into steel. Amongst the advantages it is claimed that the presence of copper and iron in the concentrates does not interfere with the production of the salt.[1]

Most of these impurities can now be almost entirely eliminated in the process of concentration; and, owing to the present use of molybdenum in the form of low molybdenum steels, where only 0·2 to 0·5 per cent of the metal is required, the final percentage of these impurities in the steel will be so small as to be almost negligible.

It would seem, therefore, that the great majority of the owners of molybdenite deposits in Canada should have little to fear from the presence of any objectionable impurities in their ores.

PRICES OF MOLYBDENUM MINERALS AND PRODUCTS

Molybdenum is almost unique for fluctuations and elasticity in price. In the early days, prices of molybdenite (MoS_2) were not quoted, the mineral being sold in small lots for chemicals, dyes, experimental purposes, and museum specimens, and for which prices ranging from 15 cents to $2 per pound were obtained. How, in 1868, mentions that a price of three shillings per pound was offered in London. From 1900 to 1911 the price varied from $300 to $625 per ton of molybdenite concentrates containing 92 per cent molybdenite, or 15 to 30 cents per pound. The prices paid on the American continent seem to have been higher than those in Europe.

Owing to the expected increase in the use of the metal in tool steels in 1900, the price and production rose for two or three years; but, when the expectation was not realized, both fell again. During the Balkan war the price for a short period was 63 cents per pound of molybdenite, which was the highest since 1900, after which it declined to 45 cents per pound. The German prices from 1909 to 1911 are of interest, and will be found in the accompanying chart (Figure 1). In 1914, on account of heavy German buying and the opening of war, the price of molybdenum in the United States rose from $1.45 per pound in January to $6 per pound towards the end of the year. Although these high prices were being obtained in

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[1] Chem. and Met. Eng., June 2, 1920, p. 1018, "Calcium Molybdate as an Addition Agent in Steel Making," by Allan Kissock.

the United States, a British Columbia producer sold an 85 per cent concentrate for 20 cents per pound of molybdenite, and for 50 cents at the close of the year.

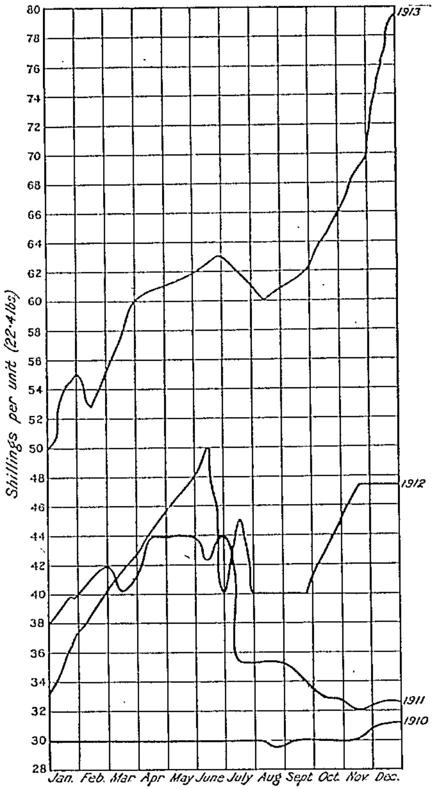

Figure 1. Pre-war German market prices of molybdenite.

CONTROLLED PRICES AND THE EMBARGO

From the latter part of 1915 until the spring of 1919 the Imperial government placed molybdenum ores and compounds in all British possessions under an embargo that prohibited their export to any country outside the British Empire, except by a special licence allowed after January, 1918. The official price for all sales of molybdenite ores from the British Empire made to the Imperial authorities was fixed at 105 shillings per unit (22·4 pounds) of the pure mineral, delivered f.o.b. Liverpool. This was standardized in Canada at the rate of \$1.09 per pound of pure molybdenite (MoS_2), f.o.b. Ottawa.

During the first week in January, 1918, the Imperial Munitions Board was informed that the immediate requirements of the British government were supplied, and that Canadian producers might export their products under licence to the United States and France.

The Department of Mines, Ottawa, acting as agents of the Board, controlled the supply and sales, and issued the licences.

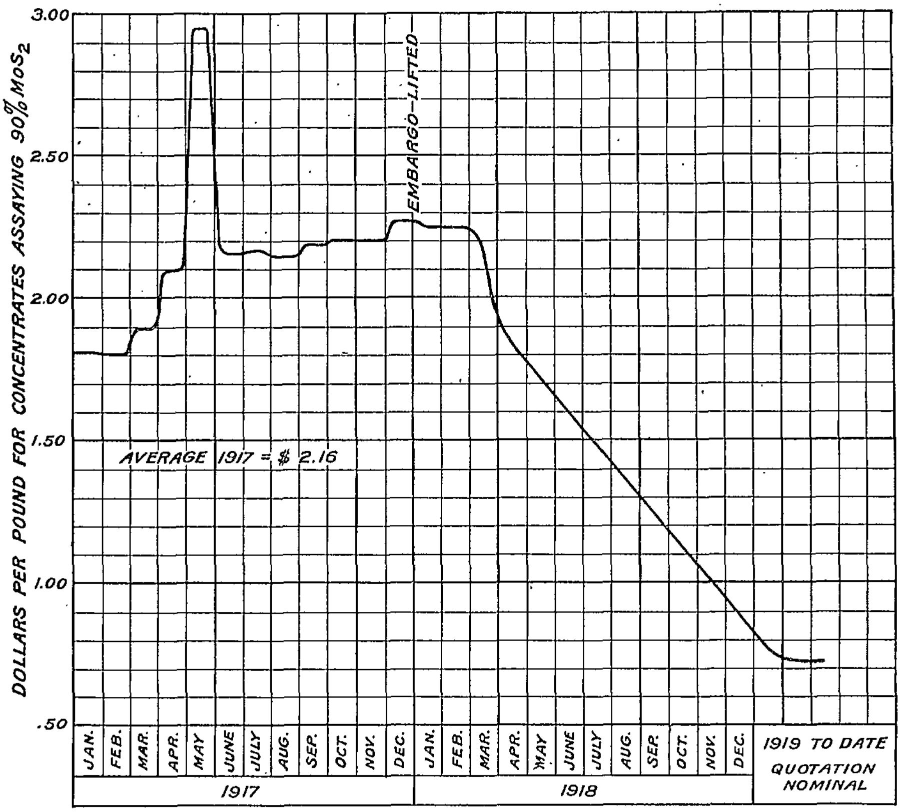

Figure 2. New York molybdenite prices since 1917.

The open market prices outside the Empire were always higher than the official British quotations. In the United States, the price in 1917 was approximately $2.25 per pound of pure molybdenite delivered at buyer's works. (See graphic curve, Figure 2.) It was contended by Canadian producers that this difference in price unduly favoured production outside the British Empire, but as the British government was filling all its requirements within the Empire, the higher price in the United States was chiefly due to the inadequate supply in that country. It is probable that if the embargo had not been enforced, the open prices would have been uncertain and fluctuating and would have fallen to the Imperial standard, or perhaps lower.

Although some Canadian producers were momentarily pleased to have the opportunity of obtaining a better price for their concentrates after the embargo was lifted, it was soon found to be extremely difficult to make any sales, and the Canadian production became far larger than the market could absorb.

In March, 1919, the industry was brought to a full stop by the issue of a special cablegram from the Ministry of Munitions. The following extract was sent to all Canadian molybdenite operators and clearly indicated the situation in Great Britain:—

> . . . . . . That sufficient stocks are on hand to supply the home market and any export trade for about two years, that these stocks will have to be sold at a considerable loss, as they will have to be released at the demand of the manufacturers, and at the market price current at that time. That under these conditions, no further shipments under contract will be accepted unless en route before April 30, 1919. That it is advised that producers curtail their operations until the greater portion of the stocks are exhausted and market conditions are more favourable.

Although the demand and prices caused by the war were not expected to remain so high after the signing of the armistice, it was nevertheless confidently expected that the new uses for molybdenum which the war had demonstrated, would be continued and applied to the peaceful arts to which the various alloy steels are adapted. Owing mainly, however, to lack of co-operation and understanding between the producer and the consumer, the industry suddenly collapsed, so that during the last five years hardly a pound of molybdenite has been produced in Canada.

As it was not possible to impose the British controlled price of 105 shillings per unit of molybdenite on Norwegian producers, their prices locally rose to extraordinary figures.

The Norwegian unit is a kilogram of pure molybdenite, and the krone is the unit of value—18 kronen is normally equal to one pound sterling, but for calculation purposes, it is based as 15 kronen.

In 1917 the price was 35 kronen (£2 6s. 8d.) per kilogram. This figure was established for molybdenite contained in 70 per cent concentrates, with a penalty of half a krone per unit below 70 per cent. At these rates a ·75 per cent concentrate was worth £1,750, or $8,317 per metric ton. These startling figures clearly indicate the inflation of the molybdenum industry in Norway at that date.[1]

In 1919 stocks were offered to English buyers for 80 kronen per unit (22·4 pounds) f.o.b. Scandinavian ports. Even this price, which is less than a third of the 1917 price, apparently did not stimulate buying.

Wulfenite. The demand and price for the molybdate of lead is very fluctuating, as its chemical composition is variable, and the impurities in it are not always desirable.

In 1912, wulfenite containing at least 25 per cent molybdic oxide was quoted at $100 per ton—during the war this price was doubled, and sometimes trebled.

Molybdite. There is no sale for this mineral, and its molybdenum content in molybdenite and wulfenite ores is not usually allowed, since the mineral is soluble it has not yet been successfully recovered in the concentrates.

Molybdenum and Ferro-Molybdenum. Are quoted per pound of contained molybdenum; 50 to 80 per cent of molybdenum being present in the alloy. The price of ferro is practically that of metallic molybdenum.

In 1910-1913, molybdenum was worth $1.40 to $1.50 per pound; but soon after the beginning of the war prices up to $6 were obtained for small quantities. During 1916, the usual price was $3 to $4 per pound. New York prices of ferro in 1917 were around $4.35 per pound of

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[1] Tr. Inst. Min. and Met., January, 1918, "Molybdenum in Norway." E. R. Woakes.

contained molybdenum. The average price for Canadian ferro-molybdenum was $3.25 per pound f.o.b. plant. The prevailing price in the United States at the end of 1922 for ferro was $2 per pound of molybdenum contained.

Tungsten. Since tungsten has always been regarded as a competitor of molybdenite a few notes as to its prices will be of interest.

In 1913, the Imperial government fixed the following prices: molybdenite, 105 shillings per unit (22·4 pounds), at least 90 per cent molybdenite concentrates; wolframite or scheelite, 55 shillings per unit (22·4 pounds), at least 65 per cent WO_3 concentrates. F. W. Horton[1] mentions that some well-known European metallurgists were understood to prefer molybdenite ore at 120 shillings per unit of MoS_2 to tungsten ore at 55 shillings per unit of WO_3. In the United States, however, the demand for tungsten was far in excess of that for the then comparatively little known mineral molybdenum.

In 1918 a comparison between the Australian and New York prices is as follows:—

Australia......	$12.86 per unit of WO_3 in 65 per cent concentrates.
New York.....	29.22 per unit of WO_3 in 62 per cent concentrates.

In 1919 the Imperial government lowered the price to 40 shillings ($9.76) per unit. During the latter part of 1921, English brokers report that tungsten ores were selling at a low price—11s. 6d. to 13s. per unit, or about 14 cents per pound, the leading producer being China.[2]

Future Prices. It is impossible to deduce a standard of prices, that must necessarily be a compromise between the producer and the user.

Taking the average grade of the molybdenite deposits on the American continent, it is doubtful if profits can be made on concentrates (say 85 per cent), selling under at least 85 cents per pound of contained molybdenite. On the other hand, steel makers claim that the price is controlled by tungsten, which is usually about half that of molybdenum, but molybdenum and tungsten steels are now to a large extent used for different purposes; moreover, molybdenum alloy steels contain usually less than half of 1 per cent of molybdenum. The price per ton of the molybdenum alloy would not be materially increased even if the above quotation of the raw product was increased by 50 per cent or even doubled. A. Cressy Morrison[3] states as follows:—

> Only small quantities of ferro-alloys are used per ton of steel . . . . . As an instance of the infinitesimal cost of the alloy to the steel makers when charged against a ton of the steel into which it enters, we find that in a ton of structural steel and steel rails the average cost of the ferro-silicon runs from 12 to 18 cents. In a ton of automobile steel the approximate cost of the ferro-chrome used is only $2.80 . . . . .

Of course molybdenite is considerably more expensive than chromium ores. When molybdenite was controlled at $1.09 per pound and ferro-molybdenum at $3.25, the approximate cost of the ferro-molybdenum used per ton of auto steel would be about $24.

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[1] U.S. Bur. of Mines, Bull. 111, 1916, p. 40. F. W. Horton.

[2] Figures supplied by the courtesy of Mr. F. W. Dingwall of Everitt and Company, Liverpool, England.

[3] Tariff Information, 1921, Hearings on General Tariff Revision before the Committee on Ways and Means, House of Representatives. Part II, Schedule C., p. 730.

CHAPTER II

ORES OF MOLYBDENUM, GENERAL OCCURRENCES

THE MOLYBDENUM MINERALS, OCCURRENCES, AND TESTS

Molybdenum is never found free in nature, but always chemically combined with other elements.

In the following table will be found the known molybdenum minerals, in the approximate order of their importance, together with their composition and characteristics:—

TABLE I

Mineral	Composition	Usual colour	Lustre	Streak	Hardness	Specific gravity	Per cent Mo.
Molybdenite	MoS_2	Lead-grey	Metallic	Blue-grey-green.	1–1·5	4·7	59·95
Wulfenite	$PbMoO_4$	Orange yellow.	Resinous	White	2·75–3	6·7–7·0	26·15
Molybdite	Fe_2O_3, $3MoO_37H_2O$	Pale yellow.	Earthy, silky.	Straw-yellow.	1–2	4·5	39·63
Powellite	$CaMoO_4$	Dull grey	Resinous		3–5	4·25	47·98
Ilsemannite	MoO_2, $4MoO_3$	Blue-black					68·18
Belonesite	$MgMoO_4$	White	Transparent				52·08
Pateraite	$CoMoO_4$	Black					43·84
Achrematite	$3\ (3Pb_3As_2O_8,PbCl_2)\ 4\ (Pb_2MoO_5)$	Orange to brown.	Resinous	Pale brown.	3–4	6·0	3·40
Eosite	$Pb_3V_2MoO_{16}$	Deep red		Orange-yellow	3–4		Variable
Koechlinite	$Bi_2O_3MoO_3$	Green					18·6
Doubtful Minerals							
Molybdurane	$UO_2UO_3\ 2\ MoO_4$						
Molybdoferrite.	$FeMoO_4$	Apple-green.			3·0		
Knightite	Phosphate of Mo						
Chillagite	Molybdo-tungstate of lead.	Yellow	Vitreous		3·5	7·5	10 to 14
Jordisite	MoS_2 (amorphous)	Lead-grey					59·95
Molybdosodalite.	$Na_4\ (AlCl)\ Al_2\ Si_3\ O_{12}+Mo.$						1·3

Molybdenite and wulfenite are the only ores of commercial value and all the remainder, with the exception of molybdite, are rare; this latter mineral is an oxidation product of molybdenite, but has no economic value.

MOLYBDENITE

Molybdenite is the commonest of the molybdenum ores. It is the bisulphide of molybdenum, having the formula MoS_2, and containing 59·95 per cent molybdenum and 40·05 per cent sulphur.

Colour. Resembles freshly cut lead; in appearance is similar to graphite; but is more of a bluish grey colour.

Streak. Blue-grey on paper; on porcelain it leaves a grey-green tinge.

Characteristics. It occurs in flakes or scales, having a prominent basal cleavage, and in most cases can be split into thin flexible non-elastic mica-like leaves.

Crystallization. Molybdenite crystallizes in the hexagonal form, the crystals in many cases being found as tabular and slightly tapering prisms. These prismatic planes are horizontally striated, and on the base of some crystals, there are striae normal to the edges, that sometimes exhibit a distinct radial formation; these rosettes have been found in many Canadian deposits. Individual molybdenite crystals over 5 inches long and 3 inches in thickness have been reported.

Identification. Molybdenite has often been confused with graphite on account of its many similar characteristics. It is, however, twice as heavy, and is of a more blue-grey colour and streak. If the crystals are sufficiently large to split and are slightly opened, this blue is very clearly seen by reflected light between the leaves; moreover, on heating a fragment of molybdenite in a closed tube a strong sulphurous odour is given off, while graphite is entirely unaffected. Galena is very much heavier and is comparatively hard and brittle. Joseite, a gold-bismuth telluride, has all the physical characteristics of molybdenite, except that its colour is a darker shade of grey and the bluish tinge is absent.[1]

Occurrence. A brief review of the world's tabulated production of molybdenite will show that it occurs in a large number of countries. About three-quarters of these occurrences are in acid igneous rocks, and the most of the remainder in metamorphic rocks (see General Geology).

Field Tests for Molybdenite. (*a*) When rubbed on porcelain, or a white enamelled cup or plate, it leaves a grey-green streak (graphite is dull grey).

(*b*) When heated in an open tube molybdenite gives off sulphurous fumes, and a pale yellow crystalline sublimate of molybdenum trioxide (MoO_3) is formed on the sides of the tube.

(*c*) The mineral is infusible before the blowpipe and imparts a yellow-green colour to the flame.

(*d*) The powdered mineral when heated on charcoal in the oxidizing flame emits a strong sulphurous odour, and deposits a coating of molybdic oxide, which is yellow when hot and white when cold, but closer to the heated mineral the coating is copper red. If the white coating is touched intermittently with the reducing flame it becomes deep blue.

(*e*) Molybdenite is decomposed by a strong solution of nitric acid, leaving a residue of white or greyish molybdic oxide.

MOLYBDITE

Molybdite, sometimes called molybdic ochre, is a hydrated iron molybdite. Until recently it was supposed to be an oxide with the formula MoO_3, and most of the present text books on mineralogy persist in this error.

The true oxide of molybdenum, MoO_3, has never yet been found in nature. In the case of several reported occurrences the mineral was proved either to contain iron, or to be powellite, $CaMoO_4$.

Characteristics and Formation. Molybdite is an alteration product of molybdenite, and occurs in the presence of this mineral with iron. It is probably formed by the interaction of limonite and molybdic acid, the latter being liberated by the oxidation of the molybdenite. The formation of the limonite may have, in many cases, resulted from the weathering of

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[1] Queensland Geol. Surv., Article 4. Molybdenite. B. Dunstan.

pyrite, which is commonly associated with the molybdenite, simultaneously with, or previous to the weathering of the molybdenite. It has often been found in exposed surfaces in conjunction with molybdenite and mica.

Occurrence. Being an alteration product of molybdenite, the occurrences and associated minerals of molybdite are always the same as those of the former mineral when in the presence of iron.

The presence of the yellow incrustation often serves as a guide to the prospector as indicating the presence of molybdenum. It appears, usually, only in the weathered or exposed surfaces, although at the Climax Molybdenum Company's deposit in Bartlett mountain, Colorado, molybdite has been found over 500 feet below the surface.

This mineral has not been found in commercial quantities, and, moreover, it has not yet been successfully concentrated. Until a successful method has been found no allowance should be made for its presence in molybdenite, or wulfenite ores.

The name ferri-molybdite has been suggested for this mineral.

WULFENITE[1]

Wulfenite, lead molybdate, $PbMoO_4$, is next in importance to molybdenite as an ore of molybdenum. The impurities generally found present in wulfenite are chromium, calcium, copper, iron, vanadium, and aluminium.

Occurrence. It occurs in veins with other lead ores, and is especially likely to be associated with vanadinite and pyromorphite.[2] It is said to have been first discovered at Bleiberg in Carinthia, and was named in honour of the Austrian mineralogist, Wulfen (1728-1805) who wrote a monograph on the Carinthia lead ores, in 1785. It has been commercially mined in Austria, Spain, Jugo-Slavia, and in many parts of the United States, and it occurs in lesser quantities in a large number of other countries in association with lead ores. There are no authentic records of this mineral in Canada; but it is of interest to note that in certain parts of eastern Ontario lead deposits are found not far from molybdenum-producing localities, so that its presence may be expected.

POWELLITE

Powellite is a molybdate of lime, $CaMoO_4$, with the molybdenum content varying from 39 to 45 per cent, but when pure it contains 47·98 per cent molybdenum and 28·0 per cent lime. The mineral in many cases contains, in addition, some calcium tungstate, but this is a mechanical impurity. Dana[3] states that calcium tungstate is present in the mineral, and quotes an analysis showing 10·28 per cent WO_3.

Occurrence. Powellite sometimes occurs as an oxidation product in molybdenite and scheelite deposits. The writer has found several occurrences of the mineral in Canada, where, owing to surface decomposition, it occurs as a pseudomorph after molybdenite. In many cases the alteration has, however, been only partial. So far the largest occurrence noted is in the Joiner property near Wilberforce, Haliburton county, Ont., but indications show that the mineral is probably fairly common when molybdenite occurs in lime-bearing rocks, but no tungsten has as yet been noted.

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[1] Dana, E. S., A System of Mineralogy, 6th Ed., p. 989.

[2] U.S. Bull. No. 14. Molybdenum Deposits of Colorado, 1919, p. 9. P. G. Worcester.

[3] Dana, E. S. A System of Mineralogy, 6th Ed., p. 989.

The mineral is named after Major J. W. Powell, Director of the United States Geological Survey.

ILSEMANNITE

Ilsemannite is a double oxide of molybdenum, or molybdate of molybdenum, $MoO_2\ 4MoO_3$, and contains 68·18 per cent molybdenum. It is a blue-black cryptocrystalline mineral, that is soluble in water, giving a deep blue solution. Upon evaporating the solution dark blue crystals appear. The mineral is said to result from the decomposition of metallic molybdates, and when molybdenite weathers it sometimes becomes tinged with this bluish colour. A. L. Parsons[1] says that it is probably owing to the presence of this mineral that pyrrhotite and pyrite when associated with molybdenite are tarnished so as to be readily mistaken for bornite and chalcopyrite, a case in point being on the old dump of the Chisholm mine, Sheffield township, Ont. Parsons further suggests the presence of this bluish film as an indication of the occurrence of molybdenite.

The mineral is named after the German mining commissioner, J. C. Ilsemann (1727-1822).

A lengthy and interesting article on ilsemannite was written by H. F. Yancey, in 1918.[2]

KOECHLINITE

A bismuth molybdate, with a formula determined by Schaller[3] as Bi_2O_3, MoO_3. A. L. Parsons[4] states that two points of interest are to be borne in mind. The association is the cobalt-silver association, and so indicates the possibility of the existence of this mineral in Ontario. The possibility of a similar mineral containing sulphur instead of oxygen at greater depth is to be considered. The association of molybdenite and bismuthinite is common, and it is desirable to examine such deposits carefully for unknown minerals. Another possible Canadian source for these minerals may be found in the Kewagama area, northern Quebec, where specimens of bismuthinite have been found embedded in, and also as pseudomorphs after, molybdenite.

"MOLYBDO"—MINERALS THAT DO NOT CONTAIN MOLYBDENUM

Molybdomenite.—A lead selenite. *Molybdophyllite.*—A lead magnesium silicate. *Molybdic silver.*—The mineral wehrlite, a bismuth-tellurium-silver sulphide, which was first reported as an ore of silver and molybdenum.

A description and occurrences of the numerous rare minerals mentioned in Table I will be found in textbooks on mineralogy, such as Dana; also Queensland Geological Survey, Molybdenite, Article No. 4, B. Dunstan; and United States Bulletin 111, F. W. Horton.

Artificial Molybdenum Minerals.—The following minerals have been produced by chemical means. Molybdenite, first prepared by Carl Wilhelm Scheele; molybdite, prepared by W. T. Schaller; wulfenite, first formed accidentally in a lead furnace at Bleiberg, Carinthia; powellite,

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[1] Ont. Bur. of Mines, 1917, p. 277. A. L. Parsons.
[2] Chemical and Metallurgical Engineering, Aug. 15, 1918, p. 186. H. F. Yancey.
[3] U.S. Geol. Surv., Bull. 610, p. 10.
[4] Ont. Bur. of Mines, 1917, p. 277. A. L. Parsons.

ilsemannite, eosite, and jordisite. A full description of these experiments can be found by referring to the Industrial Australian and Mining Standard.[1]

WORLD'S GEOLOGICAL DISTRIBUTION

Sydney H. Ball[2] gives an excellent geological review of the occurrences of molybdenite, showing its world-wide distribution, its close associations with a large number of metallic minerals both rare and common, its connexion with many different kinds of rocks, and the various types of deposit in which the mineral occurs.

About 75 per cent of the world's reported molybdenite occurrences are in acid-igneous rocks such as granites, pegmatites and syenites. Next in order are the metamorphic rocks represented by gneisses, serpentines, amphibolite, chlorite, talc, and mica schists; then sedimentary rocks such as conglomerates and limestones; finally in basic-igneous rocks. All these types are represented in Canada, and in the same order as above, except that the association of the mineral with limestone is much more common than is indicated.

It is beyond the scope of this report to enter fully into a discussion of these types of deposits and their various gradations into one another, or to enumerate in any detail the large number of metallic minerals throughout the world that are not only merely associated with, but often actually sources of supply, or indicators of molybdenite. These points are, however, of interest and of some commercial importance, and the producer of molybdenite would do well to study Mr. Ball's report referred to above.

The same author states that molybdenum is about as abundant a constituent of the world's crust as tungsten and bismuth, and he believes that it may be more common than tungsten, but like it, high-grade oreshoots are small and erratic.

The association of molybdenite with the tungsten and bismuth minerals is characteristic of, and almost universal in the Australian deposits, and in several of those of the United States and other countries, but in Canada it is exceptional. Although these minerals are often sources of supply of molybdenite, they are nevertheless detrimental in many ways, and their absence is a decided advantage.

The characteristic "pipe" deposits of Australia are rarely met with outside that continent. These deposits are in most cases inclined, irregular, pipe-like formations occurring in granite, and consisting mainly of quartz or silicified material, carrying to a varying degree within them, or in their immediate vicinity, tungsten, bismuth, and molybdenum minerals. These occurrences are more fully dealt with in the section describing the Australian deposits.

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[1] Indust. Aust. and Min. Stan., April 18, 1918, p. 368, and April 25, 1918, p. 400.

[2] Eng. and Min. Jour., Aug. 25, 1917, p. 33. "Molybdenite and its Occurrences." S. H. Ball.

CHAPTER III

HISTORY AND TYPES OF CANADIAN DEPOSITS

EARLY HISTORY

The occurrence of molybdenite in Canada has been known for about 70 years, the first discovery having been made by Dr. Murray in 1852[1], in a dike of granite on the west side of Terrace cove, lake Superior. About the same time the mineral was noted in two or three other localities by the same author, including river Doré above Michipicoten harbour and St. Jérôme, Quebec. During the next few years very little mention was made of the mineral, but in 1863[2] the Geological Survey of Canada published a description of the molybdenite deposits on the north shore of the gulf of St. Lawrence. A few years later several occurrences were noted in Nova Scotia[3].

Several records and descriptions of molybdenite deposits distributed over a wide area were published by the Geological Survey in the middle eighties. Since then the number of known deposits has increased, and the mineral has passed from the phase of mere scientific interest to one of commercial importance.

In 1910 the government sanctioned a special investigation of the molybdenite deposits in Canada by the Mines Branch. The results of this investigation by T. L. Walker[4] were given in a bulletin of 60 pages, in which about 50 occurrences are described, and 30 others throughout the Dominion mentioned.

Up to that time practically no ore was mined for commercial purposes, but a few small parcels of molybdenite were sent to various museums, and for experiments in concentration. Among these may be mentioned samples sent from Aldfield, Egan, and Romaine townships, in Quebec.

The first record of commercial shipments was in 1902, when John Webber shipped 3¼ tons of ore, valued at $400,[5] from the Horscroft mine in Victoria county, Ontario. In the following year the Chisholm mine in Sheffield township, Ontario, shipped 85 tons of ore, valued at $1,275.

RECENT HISTORY

No shipments are recorded from 1903 until 1914, when the increased use of the mineral by Germany aroused the interest of producers throughout the world, and Canada produced 15½ tons of selected ore, valued at $2,063.[6] Most of this came from the Ross mine in Aldfield township, Quebec, and was concentrated by the Department of Mines, Ottawa. Soon after the outbreak of war the use and demand for molybdenum increased to such an extent that molybdenite became one of the essential war minerals. The Mines Branch, Department of Mines, Ottawa, in the spring of 1915, offered its services to the Imperial Munitions Board, and,

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[1] Geol. Surv., Can., 1852-53, p. 40.

[2] Geol. Surv., Can., 1863, Montreal, pp. 503 and 754.

[3] Mineralogy of Nova Scotia, 1868, p. 61. How.

[4] Molybdenum Ores of Canada, 1911. T. L. Walker.

[5] Ont. Bur. of Mines, 1903, p. 25.

[6] Department of Mines, Production of Copper, Gold, etc., 1919, p. 45.

a year later, the Department was authorized by the Board to purchase molybdenite in Canada. Crude molybdenite and selected molybdenite ores were sent to Ottawa from all over the Dominion, for concentration and sale in accordance with a schedule of prices laid down by the Board. As a result of this work, methods of concentration were greatly improved, enabling small operators to produce and ship, and the experience gained by the Board was given to the producers, some of whom, acting on this advice, erected their own concentrators. The Dominion Molybdenite Co. Ltd., was by far the largest producer in Canada, contributing over 80 per cent of the total Canadian output from 1916 to date. In its first year, it was, for a period, the world's largest individual producer.

TYPES OF MOLYBDENITE OCCURRENCES IN CANADA

A brief description of the geological associations of molybdenite in the various provinces of Canada is given under the general remarks relating to occurrences in each province; and reports on this phase of the subject have been written by various Canadian geologists,[1] to which references have been made.

Molybdenite is widely distributed throughout eastern Canada and British Columbia. Up to the present, the main molybdenite-producing area has been almost entirely confined to a zone of Precambrian rocks bounded on the south by the lower Ottawa valley in southern Quebec and passing southwest through Renfrew county to southern Haliburton county in Ontario.

M. E. Wilson[2] classifies the types of molybdenite deposits occurring in this area as follows:—

(1) Segregations of pyrite, pyrrhotite, fluorite, quartz, and orthoclase in quartz syenite.
(2) Veins of pyrite, pyrrhotite, and quartz in granite gneiss.
(3) Pegmatite dikes, and feldspathic quartz veins.
(4) Contact metamorphic deposits.

The first type is confined to a comparatively small area in which the molybdenite is disseminated in small flakes. The mine of the Dominion Molybdenite Company near Quyon, Pontiac district, Quebec, the most important Canadian producer, is an example of this type.

The second type is similar to the first, but with the flakes of molybdenite slightly larger, and more irregularly disseminated throughout the mass. A typical example is found in the mines of the International Molybdenum Company, on mount St. Patrick, in Renfrew county, Ontario. These deposits do not appear to go to any great depth, the molybdenite is very scattered, and they are not likely to yield a large quantity of ore.

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[1] Geol. Surv., Can., Sum. Rept., 1919, Part E. "Mineral Deposits in the Ottawa Valley," also
Geol. Surv., Can., Sum. Rept., 1917, Part E., p. 43 E, "The Arnprior-Quyon District, Ontario and Quebec." M. E. Wilson.
Economic Geology, June, 1918, p. 302, "A Pegmatite Origin for Molybdenite Ores." E. Thomson.
Trans. Can. Min. Inst., 1915, p. 247, "Geology of the Molly Molybdenite Co. Mine, B.C.," also
Geol. Surv., Can., Mem. 77, 1915, p. 70, "Geology and Ore Deposits of Rossland, B.C." C. W. Drysdale.
Ont. Bur. Mines, 1917, p. 275, "Molybdenite Deposits of Ontario." A. L. Parsons.
Mining Operations in Quebec, 1917, p. 35, "Molybdenite Deposits in Huddersfield tp., Quebec" also
Mining Operations in Quebec, 1912, p. 230, "Geology of the Harricanaw river, NW. Quebec" also
Mining Operations in Quebec, 1911, p. 186, "Geology of the Kewagama Lake region." J. Austin Bancroft.
Mines Branch, Dept. of Mines, 1911, "Molybdenum Ores of Canada." T. L. Walker.
Mun. Res. Comm., Can., 1920, p. 123. J. C. Gwillim.

[2] Trans. Can. Min. Inst., 1920, p. 419. Molybdenite in the Lower Ottawa Valley. M. E. Wilson.

Occurrences of the pegmatite type are very common. They are usually irregular and the mineral content not very consistent. Owing to the fact that the molybdenite generally occurs in pockets, or as large flakes within the pegmatite zones, some of these deposits might be profitably worked on a small scale by cobbing. The Jamieson mine in Lyndoch township, and the Spain mine in Griffith township, Ontario, are typical examples. From the latter mine, almost the whole output was in the form of hand-picked flake, and the mine was the most spectacular in the Dominion, showing in places solid lumps of molybdenite weighing 20 pounds.

In the fourth type, molybdenite is intimately associated with green pyroxene in the contact pyroxenite of the Grenville series, or in the partially digested rock caused by this process of silication. This type of occurrence is widespread and includes the great majority of deposits of southeastern Pontiac, Quebec. Two typical examples are the Squaw Lake deposits in Huddersfield township, Que., and the property of the Renfrew Molybdenum Mines, Ltd., at Mount St. Patrick, Renfrew county, Ont. In many of these deposits, masses and also large well-formed crystals of molybdenite occur in a massive, green pyroxenite rock, which is quite free of other metallic sulphides. They are spectacular in appearance, but on the whole are of doubtful commercial value.

In most of the British Columbia deposits, as well as several in western Ontario and western Quebec, the molybdenite usually occurs in quartz fissure veins within the granite, or disseminated in cracks and joint-planes throughout the rock in close proximity to a contact. The mineral is almost invariably intimately associated with various metallic sulphides, principally those of copper, iron, and arsenic, and sometimes bismuth. In many cases the molybdenite is of the semi-amorphous, or cryptocrystalline variety, especially when copper-bearing minerals are present. In some deposits, on account of its association with other minerals of commercial value, molybdenite has been of secondary importance, and until recently was discarded because of the difficulty of separation.

Generally, the average molybdenite content of the ores in the western type of deposit is higher than in any others, and as in most true fissure vein ore-bodies, the mineral has been found at comparatively great depths.

At the Molly mine, Nelson, B.C., the molybdenite occurs around the outer edge of a granite intrusive into schist and limestone. The much jointed granite is crossed by numerous reticulating veinlets of molybdenite, the whole mass being rich enough to mine on a large scale.

Crystals of molybdenite have been found in a variety of rocks and other minerals. In the small area visited by the writer, in which about one hundred occurrences of molybdenite were seen, the large number of different associations of the mineral was very noticeable.

ORIGIN OF MOLYBDENITE

Probably at least 75 per cent of the known occurrences of molybdenite are in acid-igneous rocks such as granites, pegmatites, and syenites, and the mineral is very rarely found except in association with igneous intrusions.

Pegmatitic Origin. The presence of pegmatite dikes has been noted in the great majority of Canadian molybdenite deposits, especially in the east. In the numerous instances in which the mineral is found actually within these dikes, there can be little doubt that the origin is associated with the pegmatites.

Where molybdenite occurs in Precambrian granites and syenites, as at the Moss mine, Quyon, Quebec, its pegmatitic origin is not quite so obvious. One of the noticeable features of this deposit is the intimate association of molybdenite with fluorite; and, as fluorite is a characteristic feature of the pneumatolytic phases of pegmatite intrusion it would of itself suggest that a pegmatitic agency had been in operation in the immediate vicinity. This seems to be further corroborated by the presence of an occasional crystal of tourmaline. The agent is seen in the form of a large pegmatite dike cutting both the country rock and the ore-body. E. Thomson[1] in discussing this, states that small flakes of molybdenite in this dike further indicate its relation to the ore-body, and that the combination of intrusive fracturing and movements prior to the pegmatite intrusion probably furnished channels through which the pegmatitic solutions might operate. Furthermore, molybdenite, fluorite, and tourmaline are confined to the fractured ore zone, and are not found in the undisturbed granite.

M. E. Wilson[2] suggests several possibilities for the origin of the Moss mine ores. The similarity of the ore rock to its enclosing quartz-syenite, the complete marginal graduations from the syenite into the ore rock, and the small aggregates of quartz, fluorite, and molybdenite at numerous points within the syenite seem to indicate that the material contained in the ore deposits originally formed part of the syenite mass, and had segregated together into ore masses.

Molybdenite very commonly occurs intimately disseminated throughout the contact pyroxenite of the Grenville series, as in the Squaw Lake deposits in Pontiac district, Quebec. It is not likely to have been an original constituent of the pyroxene, but was probably brought in by later intrusions, and is a result of impregnations of the pyroxenite by mineralizers from the acid rocks.[3]

J. A. Bancroft[4] believes that the molybdenite in the Squaw Lake type of deposit has been developed under the influence of processes of intense contact metamorphism, and is plainly the result of mineralizing fluids and probably gases which emanated from the cooling granitoid magma and permeated portions of the then crystallizing sedimentary rocks. The geological relations of these molybdenite occurrences indicate that they developed at great depth and under conditions of high temperature and pressure.

From the invariable association of the molybdenite with the pyroxenite the conclusion is inevitable that the deposition of the ore is closely connected with the process of metamorphism resulting from the contact between acid igneous magma and the limestone lenses of the Grenville series. This process has been at work all through southeastern Ontario and southern Quebec, but in most cases no sulphides are associated with the pyroxene. It would seem, therefore, that when these lenses of pyroxenite carry molybdenite or other metallic sulphides, some special agencies must have been at work.

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[1] Economic Geology, Vol. XII, June, 1918, p. 306. "A Pegmatite origin for Molybdenite Ores." E. Thomson.
[2] Can. Min. Jour., March, 1918, p. 78. "Molybdenite Deposits of Quyon, Quebec." M. E. Wilson.
[3] Mines Branch, Dept. of Mines, "Mica," 1912, p. 287. H. S. deSchmid.
[4] Mining Operations in Quebec, 1917, p. 39. J. A. Bancroft.

In support of the pegmatitic origin theory, Thomson states that the presence of much scapolite associated with the molybdenite affords good indirect evidence of the pneumatolytic phases of pegmatite activity. The scapolite was evidently formed from the soda-lime feldspars by the addition of chlorine, as can be seen in a partially complete stage in portions of the Squaw Lake deposit. Thomson finds further evidence in the constant association of titanite with the deposits of this type, this mineral being formed from rutile or ilmenite, which are characteristic features of pegmatitic action, whereas in the barren zones titanite is noticeably absent.

In summing up the evidence concerning the origin of the contact metamorphic molybdenite zones of the Hunt mine, Mount St. Patrick, Renfrew, which was the leading producer in Ontario, M. E. Wilson says:[1]

> Following the intrusion of the pegmatite into the limestone, emanations containing silica, molybdenum, iron, sulphur, and other elements were involved from the pegmatite along the margin, the siliceous portions of which reacted with limestone to form diopside and scapolite, whereas the molybdenum, iron, and sulphur were deposited as molybdenite, pyrite, and pyrrhotite.

The deposit at the Molly mine, British Columbia, already referred to, may be considered typical of the occurrences in which molybdenite has been introduced after the granite solidified.

According to S. H. Ball,[2] molybdenite in granite gneiss and schist is usually of secondary origin, and it is doubtful if it was ever an original constituent of the granite.

MOLYBDENITE AT DEPTH

A tendency to diminish with depth seems to be general in the molybdenite deposits of eastern Canada. The evidence of this is, however, purely circumstantial, for no work has been done at depth. The fact that, in a few isolated cases, where diamond drilling has been done to depths of 400 feet, it has been shown that the last portions of the holes have been either barren or contained only traces of molybdenite, is not sufficient in itself to prove the non-existence of the mineral, either within or below the area penetrated.

In the case of the true fissure vein type of deposit, such as occurs in the Kewagama Lake region in western Quebec, or in the majority of the British Columbia deposits, the mineral has been traced down fairly continuously, the known depths being limited only by the extent of the work done. An example of molybdenite in depth is at the Marble Bay copper mine, Texada island, B.C., where it was found and extracted at a depth of 1,000 feet below sea-level.

PROSPECTING FOR MOLYBDENITE

Molybdenite has been known to occur in so many different phases, or types of deposit that hard and fast rules as to its mode of occurrence are necessarily out of the question.

In eastern Canada where molybdenite has been the most extensively found and mined, the most favourable areas are near the borders of granite masses, especially when these are in contact with crystalline limestone. Particular attention should be paid to bands of dark green pyroxenite that may occur between these two rocks, or within

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[1] Geol. Surv., Can., Sum. Rept., Part E., 1919, p. 41 E. M. E. Wilson.
[2] Eng. and Min. Jour., Aug. 25, 1917, p. 333, "Molybdenite and its Occurrences." S. H. Ball.

the granite, or granite-gneiss. Pyroxenite is, however, very common in these areas, and is very often barren of sulphides, but since the origin of molybdenite has been attributed to pegmatite dikes, the presence of these dikes in close proximity to the above-mentioned rocks should further assist in locating molybdenite occurrences. In zones where the mineral is known, or believed to occur, contacts of pegmatite dikes should always be carefully examined. Rocks in the immediate vicinity of known large molybdenite deposits should be carefully studied for their characteristics, so that similar rocks may be recognized elsewhere.

Experience has shown that irregularity in the form of molybdenite-bearing ore-bodies is very common, and the failure to locate an ore-body at points along its expected line of strike does not necessarily mean that the body has entirely petered out.

There are many instances in which molybdenite exposed on the surface has been subject to oxidation, and the altered mineral subsequently dissolved, or washed away. In these cases the surface, for a few inches in depth, is usually barren and the mineral is overlooked. As a rule, however, the occurrence of mineral stains, or white powder, induces the prospector to put in a shot and thus expose the molybdenite if it be present. In many cases, however, this white powder has proved to be sulphate of iron. The yellow powder molybdite, or ferri-molybdite as it is sometimes called, is a more useful guide.

On the surface of the rocks in which molybdenite is expected to occur the presence of small empty vugs or crevices is sometimes indicative of the mineral that has been leached out. This is not at all unusual on the surface of quartz veins or massive dark green pyroxenite; in the latter a narrow brown ring is often found surrounding the cavity. In the Joiner prospect, near Wilberforce, Ontario, the surface of the rock is smooth and barren; but, a foot below the surface, molybdenite is found. Careful examination has shown that the surface molybdenite has been altered to powellite (calcium molybdate), a grey-green powdery mineral that took the exact shape of the original molybdenite (pseudomorph) and had then been washed away, or possibly dissolved; so that this reaction, resulting in the formation of the comparatively unstable powellite, should be borne in mind when searching for molybdenite, especially where the rocks contain calcium minerals.

With regard to prospecting for molybdenite that occurs in fissure veins as in British Columbia, the special characteristics of these occurrences have not yet been sufficiently studied to be able to differentiate them from those of any other vein mineral. The association of the mineral with limestone in western Canada is almost lacking, but it is probable any deposits of molybdenite that are found will be near the contact of granite and the basic igneous rocks.

CHAPTER IV

CANADIAN MOLYBDENITE OCCURRENCES AND DEPOSITS

Canadian Molybdenite Production

The earliest record of the mining of molybdenite in Canada was in 1886, when about 150 pounds of the mineral was sold for cabinet specimens.[1] In 1909, Col. John Carson and associates, of Montreal, shipped about 2 tons of ore from Romaine, Quebec, on the north shore of the gulf of St. Lawrence. The ore was utilized mainly for experiments in concentration. During 1902 between three and four tons of ore was mined at Laxton, Victoria county, Ontario. This is believed to have come from the Horscroft property, which is one of the original discoveries in the Dominion. In 1903 about 800 tons of crude ore, from 1,200 tons mined, was shipped from the Chisholm mine, Sheffield township, Addington county, Ontario.

On various occasions a few hundred pounds of ore was mined for museum and collector's specimens, some fine examples of molybdenite crystals being obtained, in 1894, by the Foote Mineral Company, from the old Ross property in Aldfield township, Pontiac district, Quebec.

Practically the whole Canadian molybdenite output has been confined to the war period 1914-1918; the maximum being reached in 1918, when the sudden fall in the market caused the collapse of the industry.

The approximate quantity of molybdenite mined or shipped from each individual property, can be seen by glancing through the provincial tabulations of the occurrences and deposits.

The following tabulation shows the Canadian molybdenite production up to 1921.

TABLE II

Canadian Molybdenite Production[2]

Year	No. of shipping properties (*c*)	Men employed	Wages	Production				Shipments		Exports (*c*)	
				Ore mined	Ore treated	MoS_2 recovered	Value (*a*)	Tons	Value (*a*)	MoS_2	Value
			$	Tons	Tons	Pounds	$		$ (*b*)	Pounds	$
1886.....	1	2	....	......	......	150	100	....	100	....	....
1902.....	1	3	100	3	3	800	400	3·3	400	....	....
1903.....	1	5	1,000	800	85	1,800	1,275	85·0	1,275	....	....
1914.....	3	13	5,600	166	16	3,814	2,063	16·5	2,063	....	....
1915.....	8	52	16,990	2,242	216	29,210	28,450	39·0	28,920	....	....
1916.....	20	262	122,072	13,522	9,106	156,461	156,461	610·0	188,316	....	....
1917.....	32	501	260,692	26,871	22,605	288,705	288,705	1,554·3	320,006	64,700	81,173
1918.....	20	306	274,945	34,060	33,965	378,406	435,133	461·3	428,807	351,600	402,435
1919.....	4	105	35,536	7,600	6,813	83,472	69,530	46·0	69,203	113,500	84,226
1920 (*d*)..	1	3	....	100	50	255	180	....	....	....	....
1921 (*d*)..	2	2	....	1	1	36	25	....	....	....	....
Totals...	75	1,254	707,935	85,365	72,860	943,109	982,322	2,815·1	1,039,090	529,800	567,834

(*a*) Estimated at average market value of molybdenite.
(*b*) Value as given by operators.
(*c*) Statistics after first three months of 1918 only available.
(*d*) Mainly shipped to Mines Branch, Ottawa, for experimental purposes.
(*e*) Different properties from which over 100 pounds of MoS_2 was actually shipped.

Note.—During 1909 two tons of molybdenite ore was shipped from Romaine, gulf of St. Lawrence, Quebec.

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[1] Geol. Surv., Can., Vol. II, 1886, p. 7 S.

[2] Statistics taken from various reports on the Mineral Production of Canada and from The Production of Copper, Gold, etc., and other Metals in Canada, and including ores treated for experimental purposes by Mines Branch, Ottawa.

BRITISH COLUMBIA

GENERAL

The first mention of molybdenite in British Columbia was in 1886, when Dr. G. M. Dawson reported it from Cortes island, west of Carrington bay, in small quantities in quartz veins. Later, in 1888, it was found at Spuzzum creek, Texada island, Jarvis inlet, Salmon Arm, Knight inlet, Cowichan river, Lillooet river, and other places.

Many occurrences are mentioned in Federal and Provincial government reports, about 60 of which are recorded in the following pages. The first collected information on the molybdenite deposits of British Columbia was compiled by T. L. Walker,[1] in 1910. From the twenty occurrences and deposits then mentioned no shipments had been made. The molybdenite deposits of the province occur over a very wide scattered area; some of them are very difficult to reach, and of others, all records have been lost, or descriptions are very indefinite.

Molybdenite in British Columbia is found in most places associated with granite rocks. The mineral occurs in quartz veins, or diffused from seams, or disseminated in pegmatite dikes. In some cases the younger granites have engulfed older rocks, especially limestones, and made them carriers of molybdenite. Most of the molybdenite occurs as the semi-amorphous, or fine-grained variety associated in some way with other sulphides. In nearly all cases where copper or arsenic is present, the molybdenite assumes the fine-grained character.

J. C. Gwillim, who examined the British Columbia molybdenite deposits in 1917, divided the occurrences into three classes, as follows:—[2]

> (1) Quartz veins with flake or amorphous molybdenite rather free from other sulphides, as at Pitt lake, Knight inlet, and Alice Arm. (2) Impregnations of granite or adjacent rocks, sometimes associated with garnet and copper or iron sulphides, as at the Index and Molly mines, the Golconda mine near Ollala, and the Kennallan mine near Grand Prairie; and (3) Pegmatite, or granitic zones, with large bright flakes and very little of other sulphides, as at Stave lake and on Jarvis inlet.
>
> So far the shippers belong to classes 1 and 2. The others may become milling properties, but show little evidence of producing hand-sorted, or high-grade ore.

Generally, the British Columbia molybdenite ores are of considerably higher grade than those in any other province in Canada; but their complexity and association with deleterious minerals, such as copper and arsenic, make their clean separation in the concentrators a difficult matter. Unfortunately, during the war, when the mineral was badly needed, concentration methods were not so far advanced as they are to-day, and many properties carrying high values in molybdenite were abandoned. Modern methods of concentration, although not yet perfect, make possible the effective treatment of these complex ores. The small amount of copper in the concentrates will probably not materially affect the low molybdenum steels. By the use of calcium molybdate as an addition agent to steel, in preference to ferro-molybdenum, these deleterious minerals in the original concentrate can be still further eliminated. With regard to the arsenic, very little is known.

The production of molybdenite from British Columbia is confined to a very few mines. War demands, and increased prices in 1914-15, encouraged production, the first shipments being from the Molly mine,

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[1] Molybdenum Ores of Canada, 1911, pp. 49-56. T. L. Walker.
[2] Mun. Res. Comm., Can., 1920, p. 123. J. C. Gwillim.

Lost creek, consisting of two carloads of 12·0 per cent ore sent to the Henry E. Wood concentrating plant, Denver, Colorado.

The following is a list of producers that have shipped over 500 pounds of ore to various concentrators.

TABLE III

Company or mine	Mining Division	Locality	Quantity	Approx. per cent	Approx. MoS_2 content
			Tons	MoS_2	Pounds
Molybdenum Mining and Reduction Co.	Skeena	Alice Arm	383·0	2·00	15,320
International Molybdenum Co., "Molly"	Nelson	Lost creek	202·5	5·89	23,840
New Hazelton Gold Cobalt Mines, Ltd.	Omineca	New Hazelton	27·1	1·42	765
Index mine	Lillooet	Texas creek	8·0	15·70	2,512
Coxey mine	Trail Ck.	Rossland	2·7	14·00	756
Golconda mine	Osoyoos	Ollala	2·2	17·11	753
Timothy mountain	Clinton	Lac la Hache	0·4	30·00	240
Totals			625·9	3·68	44,186

In addition to the above list of shippers, there are several possible producers, and some who have done considerable development, and who have stored quantities of hand-picked ore, awaiting a favourable market. Among these may be cited—Grand Prairie, Kamloops mining division; Pitt Lake and Stave Lake properties in New Westminster mining division; together with other mines in the Skeena and Portland Canal mining divisions; Texada island; and Nanaimo mining division.

There is no doubt that when a demand for molybdenum again arises many of these deposits will be opened and become producers. It is, however, essential that the ores should be treated locally in mills specially designed to treat the complex amorphous ores for it is doubtful if any existing concentrator could be successfully adapted, or converted.

The following is a detailed account of the most important of the recorded molybdenite deposits in the province.

Ainsworth Mining Division

Kootenay Lake, Grays Creek. In 1916 five claims were staked by the Swanson brothers on Grays creek on the east shore of Kootenay lake, below Pilot bay, about one-half mile from the end of the Lindsay subdivision. The molybdenite occurs in granite in a quartz lead, about 4 feet wide. Mr. Swanson states that up to 1918, 140 feet of tunnels had been driven into the hillside and that he had a small air compressor plant and jack hammer. Samples of ore taken out were said to run 5·0 per cent MoS_2 and to be fairly free from impurities.

Duncan River.[1] In 1917 two molybdenite claims were staked by Messrs. Garvey and Foss of Poplar, on the east side of Duncan river, opposite Stevens creek, north of Kootenay lake. The mineral occurs in a series of quartz veins that crosscut grey mica schists. The ore is of the semi-amorphous variety and the quartz is stained by the yellow ochre. Numerous open-cuts have revealed a mineral zone of about 40 fissure

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[1] Geol. Surv., Can., Sum. Rept., 1917, p. 40 B. M. F. Bancroft.

veins from 2 to 18 inches wide, besides three main veins about 36 inches wide. Average samples are said to run 3·0 per cent MoS_2. Several tons of picked ore have been laid aside containing 15 per cent MoS_2, with values of $1 in gold and $4 in platinum.

Arrow Lake Mining Division

Lower Arrow Lake: Tunnel Station. This property, owned by Fred. Nothiger, lies southwest of the lake, close to Tunnel station. A considerable amount of prospecting work has been done, and a tunnel 75 feet long has been driven at an elevation of 5,500 feet, and 4 or 5 tons of sorted ore, assaying 3·5 per cent MoS_2, was set aside.[1]

Ashcroft Mining Division

Gnawed Mountain: Tamarack Group. This group, near Gnawed mountain, Highland valley, 25 miles southeast of Ashcroft station on the Thompson river, was originally located for molybdenite, but was afterwards worked by the Highland Valley Mining and Development Company of Spokane, as a copper mine. It is now in the hands of the Ashcroft Copper Company, Ltd.

Dr. Walker,[2] gives a detailed description, and says that molybdenite of the semi-amorphous variety is found in most of the claims along cracks and joints in the granite, associated with the copper, but that the Tamarack was the only claim worthy of consideration. In 1904 a shaft was sunk to a depth of 20 feet, and one ton of the best molybdenite was shipped for experimental purposes to a firm in Pennsylvania. However, owing to the hardness of the quartz gangue, the amorphous structure of the molybdenite, and the presence of considerable copper, the results obtained were very far from satisfactory. Horace F. Evans, who made several trips to the property in 1904 gives a detailed description of the occurrence at that date.[3] Mr. F. Keffer of Spokane, president of the company, states that there are about 50 tons of rock on the dump that carries under 1 per cent MoS_2. The mine, which was last worked for copper, closed down in 1918.

Clinton Mining Division

Lac la Hache: Timothy Mountain. Molybdenite was discovered in the fall of 1917 on Timothy mountain, a cone-shaped granodiorite hill on an outlying ridge of the Cariboo mountains, about 35 miles northeast of Lac la Hache station, on the Pacific Great Eastern railway. L. Reinecke,[4] who visited the property in 1918, describes the country rock as a grey granitoid quartz-diorite made up mainly of hornblende and labradorite. The veins are banded fissure fillings, orthoclase and pyrite lying on the outside, with molybdenite and quartz in the centre. Bands of almost pure molybdenite, nearly an inch across, are not uncommon, the mineral being found entirely inside the veins which vary in width from one inch to 3 feet.

Outcrops have been uncovered over a horizontal distance of 1,900 feet, and the greatest proved distance between veins across the strike

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[1] Mun. Res. Comm., Canada, 1920, p. 128.
[2] Molybdenum Ores of Canada, 1911. T. L. Walker.
[3] The Mining World, Oct. 21, 1905, p. 443.
[4] Trans. Can. Min. Inst., 1919, Vol. XXII, p. 357.

is 75 feet. Several other outcrops, at varying distances apart, have been located both in the creek and at points at an elevation of 450 feet above it.

Mr. Wm. J. Ryan, of Lac la Hache, owns about five claims that have been staked to cover the known outcrops. According to the owner, development work consists of a 50-foot tunnel driven along a small basic dike that cuts a 4-foot molybdenite-quartz ledge. A crosscut tunnel has been run for about 30 feet, in which several stringers showing molybdenite were encountered. Besides this there are 3 or 4 small entry tunnels each about 20 feet long, a shaft 8 by 9 by 8 feet deep, and numerous other small open-cuts. Representative samples of several of the cross-veins taken by Mr. Reinecke were assayed by the Mines Branch, Ottawa, and yielded an average of 1·43 per cent MoS_2.

Another set of assays made in 1917 were as follows:—[1]

	MoS_2
Across 5 feet at good looking place.........	4·0 per cent
Grab sample from open-cut 100 yards west of creek............................	1·6 "
Across 7 feet............................	3·2 "
Roughly selected ore......................	9·2 "

Early in 1918, Mr. Ryan sent 761 pounds of hand-picked ore to the Mines Branch, Ottawa, from which 210 pounds of pure molybdenite was recovered and sold to the Canadian General Electric Company. In addition, about 200 pounds of 75 per cent ore was sold elsewhere.

There is plenty of timber available for mining purposes. The claims are connected with Lac la Hache station by a 20-mile pack trail and a 15-mile wagon road.

Fort Steele Mining Division

East Kootenay: St. Mary's River. Molybdite and molybdenite are reported from St. Mary's pass[2] about 20 miles west of Marysville station on the Cranbrook-Kimberley line, the locations being the Sunnyside I and II and Sunset mineral claims. The molybdite is the decomposition product from a fine-grained molybdenite associated with pyrrhotite and chalcopyrite. Molybdenite in commercial quantities associated with bismuthinite also occurs at the forks of the St. Mary's river.[3]

Kamloops Mining Division

Township 17, Range 14, Grand Prairie Mine. Molybdenite has been found on several claims within 3 miles south and west of Grand Prairie, in the Salmon River valley, about 20 miles south of Ducks station on the Canadian Pacific railway. Some of the localities are: Highland valley, Kennallan group on the Monte hills 300 to 600 feet above the river[4]; Key claim[5]. This occurrence was recorded in 1895[6] when specimens were sent to the geological museum by Mr. McEvoy.

In the Kennallan group there appear to be four distinct mineralized zones. Hornblende-granites, intruding Cache Creek quartzites and carboniferous limestones, have sent out spurs causing intense metamorphism.

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[1] Ann. Rept. Min. of Mines, B.C., 1917, p. 135.
[2] Molybdenum Ores of Canada, 1911, p. 56. T. L. Walker.
[3] Ann. Rept. Min. of Mines, B.C., 1917, p. 180.
[4] Ann. Rept. Min. of Mines, B.C., 1915, p. 216.
[5] Molybdenum Ores of Canada, 1911, p. 53. T. L. Walker.
[6] Geol. Surv., Can., 1895, p. 14 R.

The ore-bearing material is a 2-foot band of hard, greenish siliceous rock, with much garnetite.[1] It strikes approximately north and south, and dips at a fairly flat angle to the west, lying between the quartzites that form the foot-wall and the limestone that forms the hanging-wall. There are four outcrops of this type of mineralized zone, on all of which some work has been done. In the first zone on the Silver Wedding claim, the band has been followed continuously by open-cuts for a distance of 300 feet. The greater part of this is too low grade to be worked, but at its northwestern extremity, where it enters the Kennallan claim, the vein looks decidedly promising; samples taken over a distance of 150 feet varied from 1·5 to 2·0 per cent MoS_2.

On the second zone, which is parallel to the first, and which is exposed on the Bonaccord and Kennallan claims, there is an inclined shaft about 40 feet deep. Although this shaft is in barren rock at the bottom, representative samples in the mineralized portion showed 1·8 per cent MoS_2. On other parallel veins on this claim, at points where the contacts have been broken by intrusive granite dikes, several excavations have been made from which 50 to 75 tons of 1 to 2 per cent ore has been taken. A sample from these sent to the Mines Branch, Ottawa, about 12 years ago, assayed 3·61 per cent MoS_2 and was free from copper and gold. The molybdenite occurs in large flakes. The mineral has been found on the other two zones, but from the work done the ore-body does not appear very promising.

This property deserves more development and, although it has so far proved to be neither rich nor very extensive, it is probably in the same class as the Molly, Lillooet, and Alice Arm deposits. Shipping ore could be conveniently hand-picked, and the property can be developed as cheaply as almost any of the other British Columbia mines.

Other claims on which molybdenite is found near Grand Prairie, are the Alice, Hay, and Nelson claims, where the mineral is associated with gold and copper.[2]

Lillooet Mining Division

Texas Creek: Index Mine. The Index group consists of the following claims: Index, Last Chance, Globe, Iron Crown, C. P. Fraction, Legal Tender, Ground Hog, and Fractions. These claims are situated on a high divide (about 8,500 feet above sea-level) between the headwaters of the north fork of Texas creek and Phair creek (locally known as Cottonwood creek), which is a tributary of Cayuse creek. The property is about 15 miles southwest of the town of Lillooet, or 11 miles from Seaton Lake station on the Pacific Great Eastern railway.

The claims were located in July, 1915, by Mr. J. B. Perkins, who two months later sold his interest to Mr. A. F. Hautier, and during the same month they were acquired by Mr. N. W. Emmens of Vancouver, who worked the property and made some shipments. In 1918 the property was taken over by the Index Mining and Milling Company. Detailed reports were made on this property by W. Fleet Robertson, in September, 1916[3]; by the late C. W. Drysdale in the same year[4]; and in 1918 by W. S.

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[1] Mun. Res. Comm., Can., 1920, p. 132.
[2] Ann. Rept. Min. of Mines, B.C., 1899, p. 733 P.
[3] Ann. Rept. Min. of Mines, B.C., 1916, p. 272.
[4] Geol. Surv., Can., Sum. Rept., 1916, p. 54.

Bacon, M.E.; and from these reports the following information has been derived.

Geology. The Index mine is located on what now forms the apex of an intrusive quartzose granite mass, which forms an elongated, irregular, oval-shaped mountain extending for a mile in a northeast and southwest direction. The granite is intrusive into schists and limestones that form bold outcrops encircling the ore-bearing granite mass, the schists being cut by numerous porphyry dikes. Another parallel granite body of slightly coarser texture occurs a short distance to the east, and outcrops along the Texas trail. The main mass on the summit dips at a high angle to the west, with a very steep slope to the south.

Character of the Ore. The main ore-body is confined to a fracture about two feet wide, running along the course of the granite. This fracture is richly mineralized, the ore in some places carrying 76 per cent molybdenite. Mr. Bacon states that blocks of ore weighing 3,000 pounds, carrying 48 per cent MoS_2, were taken from an opening where the width of the ore-body exposed was four feet. The ore also occurs along closely spaced joint-planes in the fine-grained quartzose members, as well as impregnations in the granite. The main exposure is about 300 feet along the apex of the mountain, though the ore can be traced for several thousand feet. The mineral zone, in places, is at least 200 feet wide and is full of small, platy joint-planes carrying molybdenite. This zone probably assays from 4 to 8 per cent MoS_2, and representative samples taken over the richer zones average 10 to 12 per cent. Dr. Drysdale describes several other mineralized outcrops on the mountain, in which commercial quantities of molybdenite occur, the ore being found over a vertical distance of 1,200 feet from the summit downwards.

The lower grade ore, which runs from 1 to 2 per cent MoS_2, could be easily concentrated, as the mineral occurs in rosettes and flakes, uniformly distributed throughout the granite gangue, and is very free from deleterious minerals. The whole side of the mountain is strewn with molybdenite-bearing boulders. There is a certain amount of the yellow molybdite present, especially where the sulphide is in rusty vitreous quartz veinlets cutting the granite. These quartz veins are regarded as a good indicator of the ore zone.

Development. During 1916, Mr. Emmens quarried some high-grade ore, and exposed a face about 8 feet high, from which he shipped 8½ tons of 15·01 per cent ore to the International Molybdenum Company's concentrator at Renfrew, Ont.

In 1918 the property was taken over by the Index Mining and Milling Company. Mr. Ryan reports that a crosscut tunnel was driven for 30 feet, and cut several stringers of molybdenite. About 50 feet from the tunnel a 4-foot quartz ledge containing the mineral was opened up by means of a trench 35 by 5 by 6 feet. A number of pits and open-cuts have been made at different points on the five claims, and about 8 tons of high-grade ore was extracted and stored on the property. Since then only a little development work has been done. During 1919 the company built a good road with maximum 8 per cent grades from Seaton lake. Water can be obtained from the valley about two miles distant.

Summary. Although the quantity of high-grade ore is probably decidedly limited, there is undoubtedly a large tonnage of the lower grade ore (1 to 3 per cent) which could be concentrated locally by means of a small mill.

Molybdenite has also been found about 30 miles to the northwest of the Index mine, between the Lillooet and Bridge rivers.

Nanaimo Mining Division

Texada Island. Molybdenite of the semi-amorphous variety is found in the copper mines on the north side of Texada island. The northern part of the island is largely composed of sedimentary rocks, that have been altered by the intrusion of igneous masses. Ore-bodies of copper-bornite and chalcopyrite have been formed, in which molybdenite in very fine grains occurs.

Dr. Walker[1] reports that in 1910 the Marble Bay, Cornell, Copper Queen, and Little Billy mines were worked for copper, the ore being cobbed and sorted by Chinamen, who picked out the molybdenite and sacked it separately. No record of the amount so obtained is available.

It is of interest to note that in the Marble Bay mine the mineral was observed in the 1,060-foot level, which is nearly 1,000 feet below sea-level, where the associated copper is in the form of bornite.

A sacked sample of the mineral sent to the laboratory of the Mines Branch assayed: molybdenite, 8·88 per cent; copper, 1·85 per cent; gold, 0·08 oz. per ton.

In the other three mines the molybdenite is, as a rule, found in the lime silicates, but the rock does not carry much copper. In the Cornell mine molybdenite is quite abundant at the 360-foot level. This ore, which is not in direct contact with any appreciable quantity of copper, is more flaky. This semi-amorphous phase of molybdenite, associated with copper deposits, has been noticed in nearly all the copper-molybdenite deposits throughout the Dominion.

Nelson Mining Division

Lost Creek; Molly Mine. The Molly mine is situated to the south of Lost creek, on the old Dewdney trail, about 15 miles by wagon road south of Salmo. The property includes a group of four Crown-granted claims—Molybdenum No. 1, Molybdenite, Bromyrite, and Bromyrite King. The claims were located in July, 1913, by Messrs S. N. Ross, H. E. Bennett, and J. A. Benson, and were worked by them during that year. In 1914 the property was leased for six months by Bell Bros. of Salmo. In 1915 Merton Merrill of the British Columbia Molybdenite Company had a $100,000 lease for a year on the property, and in 1916 the mine was under lease by the International Molybdenum Company of Renfrew. This lease expired, and the mine is now in the hands of the original owners and their associates.

During 1915 the property was visited by the late Dr. C. W. Drysdale,[2] who investigated the geological structure in detail. The ore-body is

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[1] Molybdenum Ores of Canada, 1911, p. 50. T. L. Walker.

[2] Notes on the Geology of the Molly mine, Lost creek, B.C. C. W. Drysdale. Can. Min. Inst. meeting, Rossland, 1915.

associated with the upper border of a large intrusive mass of granitic rocks that have been laid bare by erosion. The country rock consists of slate and shale, intruded by a granite mass which has been cut by pegmatite dikes, and along which the ore occurs. At certain localities, near the contact of the shale and granite, the rock has been altered to schist, and the granite contact with the sedimentaries is irregularly circular in shape. The chilled border of the granite forms a hard fine-grained shell about 6 feet thick, through which a few flakes of molybdenite are scattered. This capping, which in some localities has been entirely removed by erosion, overlies the molybdenite ore zone, which is characterized by platy, or sheeted jointing of the granite. The jointing gives it an almost sedimentary appearance, and it is chiefly in these joint places that the molybdenite lies. In places where the ore zone is not so sheeted, and is more blocky, the deposit is leaner or even barren.

The ore zone as exposed in the main cut appears to vary from 10 feet to 20 feet in width; the granite, however, for a considerable distance from the ore zone is impregnated with molybdenite, much of which might be milled profitably. Regarding the origin of the molybdenite, Dr. Drysdale says:—

> The molybdenite appears to be the result of impregnation at the time of, or following, pegmatitic intrusions rather than an original constituent of the granite. If this be the case the heaviest deposition of the mineral might reasonably be expected where the granite is most cut up by pegmatite dikes.

Mr. Bennett states that the ore was first found in the centre of the claims, but that the main workings are in the northwest quarter, on the Bromyrite King claim. The southern contact lies about 30 feet from this working. In the vicinity of this contact, the granite is cut by a series of east and west shearings, running parallel to the lines of contact, which are in turn cut by a series of north and south shearings. The ore seems to occur along the line of the latter in the vicinity of the pegmatite intrusions. Development has apparently not been carried to the actual contact and all the ore taken out has been from the shell workings.

The work done consists of an open-cut in the hillside, 50 feet long and 30 feet deep, at the bottom of which is an underhand stope 20 feet deep. About 60 feet below this is No. 1 crosscut tunnel, from which there is a raise that proved the ore to go through, and a connexion has been made with the surface workings. From No. 1 crosscut, a winze has also been sunk for 10 feet, at the bottom of which the best ore on the property has been found. The richest part of the ore zone is stated to run 4 per cent MoS_2, a larger part 2 per cent, and a considerable area will average about 1 per cent. The property has been developed to a depth of about 150 feet and the ore zone is said to have been traced on the surface by prospect pits for 1,200 feet. The geological structure of the ore-body, the small amount of mica and copper in the ore, coupled with an ample supply of water and fuel, indicate that the mine may later be a profitable producer.

The following are the recorded shipments from the Molly mine, until it closed down in 1917:—

TABLE IV

Shipments from Molly Mine, B.C.

Date	Shipments	Place of extraction	To whom sent	Pounds dry ore	Per cent MoS_2	Remarks
1914.....	1	Surface showings.	Henry E. Wood, ore testing plant, Denver, Colo.	17,119	9·335	85% of MoS_2 contents at 20c. per pound.
	2	"	"	822	30·175	"
	3	"	"	29,895	10·250	"
1915.....	1	Top of shoot....	"	48,202	12·26	90% of MoS_2 contents at 50c. per pound.
	2	Ore samples....	New York..........	4,000	9·50	At schedule rates
1916.....	2	Underground...	International Molybdenum Co., Renfrew.	22,810	10·36	" (hand-cobbed)
1917.....	4	"	"	181,000	3·84	At schedule rates.
	1	"	Mines Branch ore testing plant, Ottawa.	44,924	3·14	"
	2	"	....	56,148	3·31	"
Totals...	....	....	....	404,920	5·88	

The average recovery from run-of-mine ore would seem, therefore, to have been about 3½ per cent.

New Westminster Mining Division

Pitt Lake. A. Hewitt and associates own six claims, comprising 306 acres, on Canon creek, 12 miles northwest of the head of Pitt lake. The elevation of these claims ranges from 1,050 to 3,000 feet. Fine-grained molybdenite occurs in a network of quartz and calcite veinlets traversing a large area of granite and granodiorite rocks. Within this area are tongues of limestone and coarse-grained, dark coloured intrusive dikes. The ore-body in which the network of stringers occurs is almost flat.

Massive iron pyrites is abundant in all the surface showings. The ore zone had been traced for over 600 feet in width and 9,000 feet in length. The molybdenite is closely associated with the iron pyrites and traces of gold, silver, zinc, and vanadium have also been found.

Development has been by a series of small open-cuts and tunnels. Two of these open-cuts are approximately 8 feet and 10 feet long, and three tunnels are each about 25 feet long. All the workings show the same network structure of veins as on the surface. One stringer, about 20 inches wide, assayed 8 to 10 per cent molybdenite. (Figure 3).

In July, 1917, a number of samples were sent to the Henry E. Wood Ore-testing Company, Denver, Colo., for experimental concentration. Two of these samples assayed 5·90 per cent and 10·5 per cent MoS_2 respectively, and a low-grade ore sample assayed 0·9 per cent MoS_2. Copper and arsenic were absent, and traces of vanadium were found. Good results were obtained, the only difficulty being with the iron pyrites, which by modern methods of concentration can now be entirely eliminated.

Timber and waterpower are available, the one drawback at present being the lack of a road to the Government wagon road in the Upper Pitt River valley. The region appears to be well mineralized throughout[1] and is worthy of further investigation.

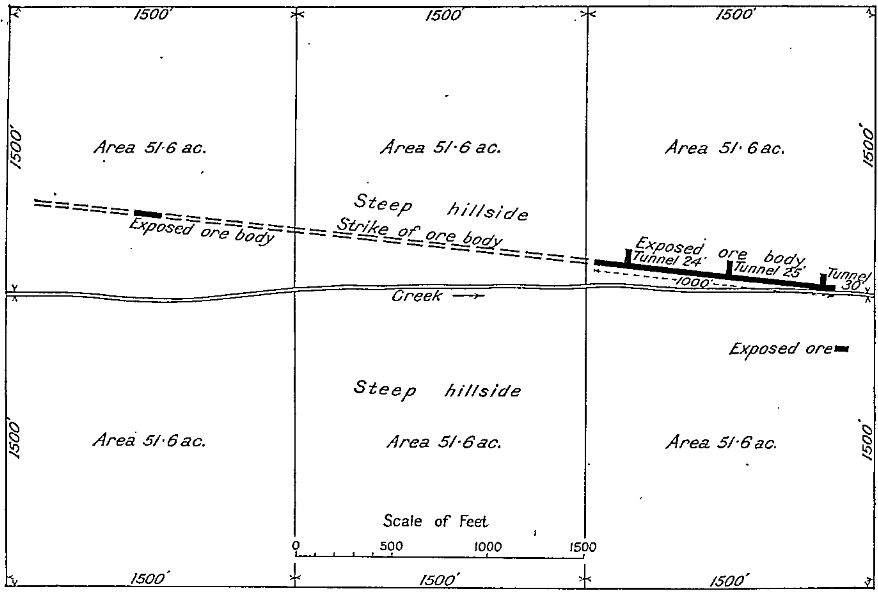

Figure 3. Sketch of molybdenum properties, 12 miles northwest of head of Pitt lake, New Westminster mining division, B.C.

Stave Lake. This property owned by Messrs. D. and M. Boucher, of Hatzic, lies 7 miles north of the north end of Stave lake, on Stump creek about 70 miles northeast of Vancouver. The presence of float molybdenite had been noticed at the head of the lake for over 30 years, and the location of its source in 1915 attracted considerable attention, but no ore has been shipped. The country rock is a sheared granite and has a banded gneissic structure. Wide fissures in the granite are filled with quartzose rock, in which occur disseminations of molybdenite varying in sizes from mere flakes to chunky crystals two inches square. The vein-matter varies in width from 15 feet to 75 feet.

As no work has been done, it is difficult to estimate the proportion of mineralized quartzose rock in the ledge. The present appearance is that of a high, bare rock wall with precipitous face, in which lumps of molybdenum are plastered at intervals.[2]

Grab samples taken from the ore zone at the widest part showed 0·78 per cent MoS_2. Two selected samples taken from the big slide of rocks showed 2 and 1·3 per cent MoS_2. Barely more than a trace of gold, silver and copper was found.

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[1] Special Report by J. C. Smith. Mun. Res. Comm., Can., 1920, p. 126. J. C. Gwillim.

[2] Ann. Rep. Min. of Mines, B.C., 1918, p. 289 K.

Omineca Mining Division

New Hazelton Gold-Cobalt Mines, Ltd. The property comprising about 264 acres consists of 8 Crown-granted claims on the western slope of Rocher Deboule mountain. The upper workings, which are at an elevation of about 5,600 feet, are reached by trail from Carnaby station, 11 miles west of New Hazelton. Some work was done on these claims previous to their being taken over by the present company in July, 1916. During the next three or four years the company carried on development work, but until 1918 made no serious attempt to save the molybdenite.

Ore-bodies.—

On the Victoria, Hazelton View, and Indian groups of mineral claims there are six well-defined veins, three of which are gold-cobalt, and three copper-gold veins. The latter are extensions of the veins of the Rocher Deboule Mining Company, (an adjoining property).

It appears that the molybdenite is mainly confined to the cobalt veins, which occur between walls of granodiorite. The vein filling consists of hornblende, quartz, altered wall rock and, in places, metallic sulphides. Arsenopyrite is the most abundant sulphide and carries almost all the gold, cobalt, and silver values. Small quantities of pyrrhotite and pyrites, associated with the arsenopyrite also carry gold values. In places considerable amounts of molybdenite are found in rich pockets.

Detailed descriptions of the ore-bodies and development work are given in John D. Galloway's reports.[1]

Figures 4 and 5 show plan and section of the mine workings.

Mr. N. Thompson, the chairman, reports that in the 450-foot winze of No. 1 tunnel the ore assayed over $400 to the ton in gold and over 12 per cent flake MoS_2, with good values in cobalt and nickel.

A considerable amount of development work has been done on the surface of these claims, mainly in exposing the gold-cobalt-silver ores.

Mr. Dalby B. Morkill states that some of the highest grade molybdenite ore was found near the end of the upper tunnel at a depth of 600 feet. This occurrence in depth of molybdenite-bearing ores is of interest, as there have been few opportunities in Canada to test this much discussed point. On the other hand these true fissure veins of British Columbia are different from the metamorphic deposits of eastern Canada.

Shipments.—

The following samples and shipments were sent to the Mines Branch, Ottawa, during 1917 and 1918:—

Pounds dry ore	Per cent MoS_2	Per cent Molybdite	Other values
30	6·76	....	Au 0·76 oz. per ton. Co 0·64%
870	1·98	0·10	Au 1·32 oz.
53228	1·40	0·18	Au 1·24 oz. Co 1·12 per cent. Ni 0·60 per cent As 8·98 per cent.

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[1] Ann. Rept. Min. of Mines, B.C., 1917, p. 104 F; 1918, p. 112 K.

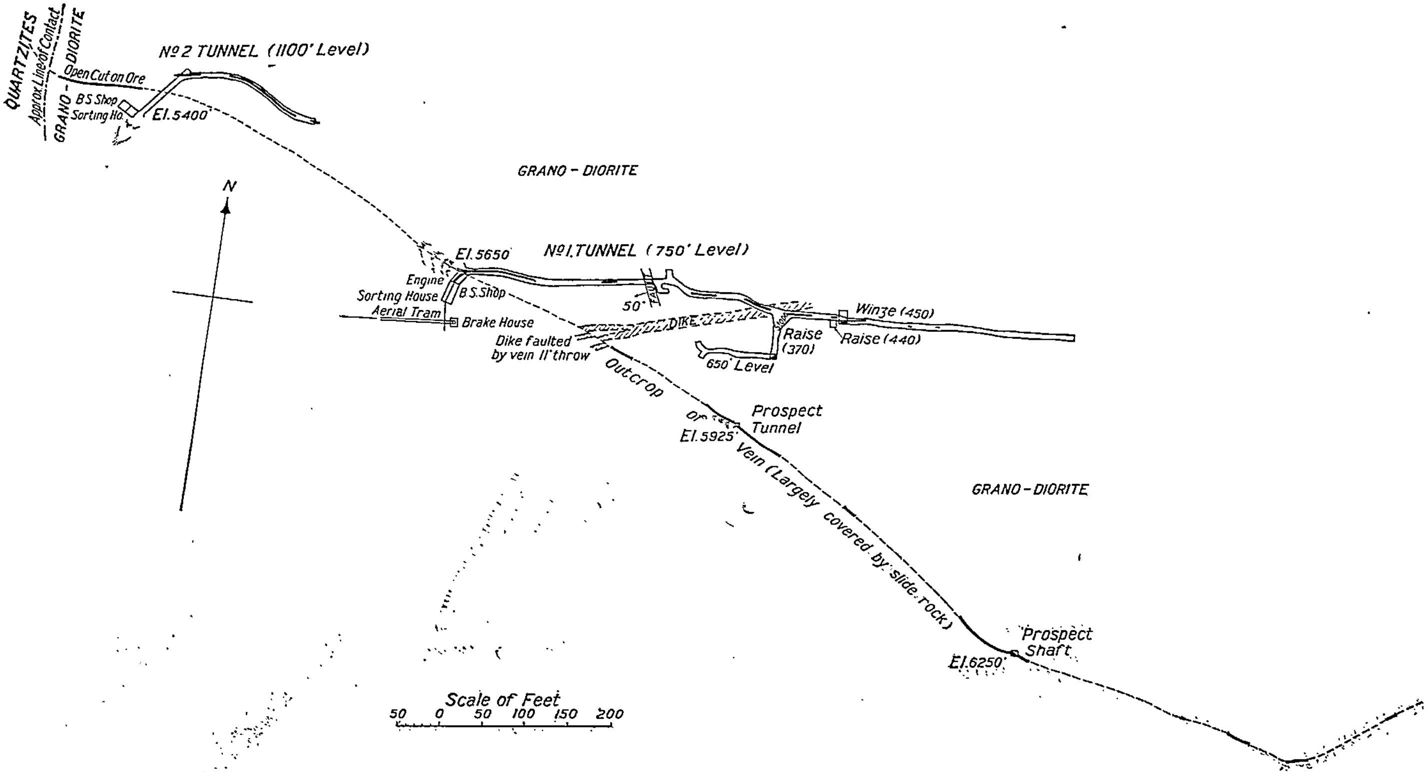

Figure 4. Plan of Victoria vein workings, Hazelton View mine, B.C.

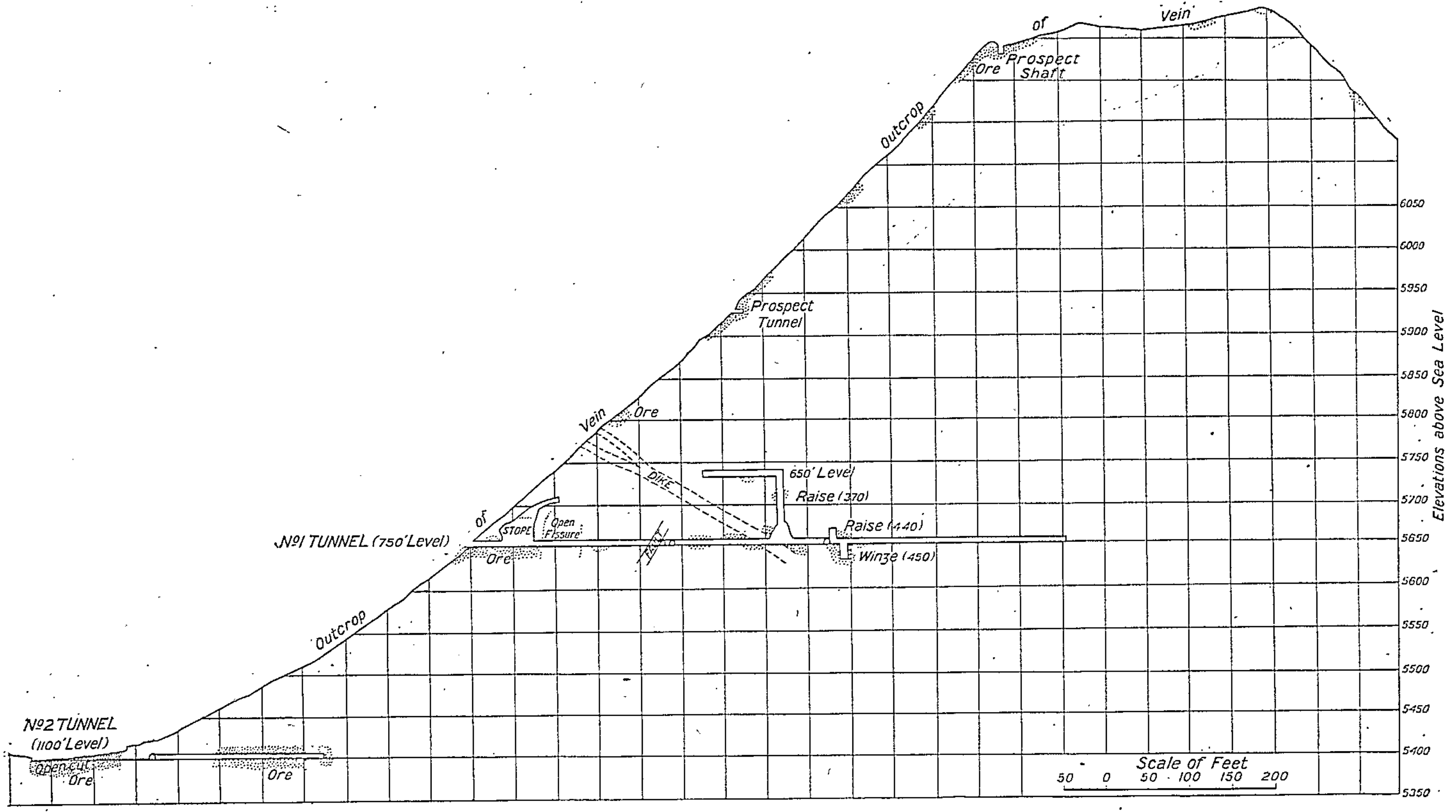

Figure 5. Profile Victoria vein workings, Hazelton View mine. B.C.

The total amount of pure molybdenite recovered amounted to about 430 pounds, which was contained in a concentrate assaying as follows:—MoS_2, 54·06; Co, 0·50; Ni, 0·22; As, 2·92; Au, 0·16 ozs. per ton.

This carload of ore was taken from the raise and 650-foot level of No. 1 tunnel. Two shipments, totalling 44 tons taken from stope near the portal, were sent to the Anyox smelter from which $50 net per ton in gold was recovered. The other minerals were apparently not saved, excepting the small amount of silver present, amounting to 0·3 oz. per ton in the original ore.

Plant.—

In 1918, a 1,000-foot, 2-bucket tram was installed from the portal of the upper tunnel to the camp at the bottom of the hill and from the end of the tram the ore is packed down to the railway. A considerable tonnage of molybdenite could be obtained from this property were it not for the difficulty of concentration which involves the economic separation and saving of the other valuable minerals present in the ore.

Osoyoos Mining Division

Golconda Mine, Ollala. This property which lies one mile west of and 1,100 feet above the town of Ollala, two miles north of Keremeos station, was worked by McEachern Bros., in 1917-18 and 1920.

At the outcrop, which is a few feet wide, a mass of decayed pyroxenite shows yellow molybdic ochre. The molybdenite, which carries copper sulphate, is slickensided and amorphous, but possesses a bright lustre.[1]

A shaft 20 to 30 feet deep shows the ore-shoot to be lying against a steep fault-plane or slip, running almost at right angles to the surface outcrop. The ore-body is wedge-shaped and tapers to a few inches in width at the bottom of the shaft. From 1918 to date tunnels totalling 280 feet in length have been driven into the hillside and have shown that molybdenite is almost entirely absent. However, a good grade of chalcopyrite was encountered, from which 10 tons of ore carrying 18·6 per cent copper was sent to Trail smelter.[2] In 1917, 4,390 pounds of 17·11 per cent MoS_2 was sent to the Mines Branch, Ottawa, from which 691 pounds of pure molybdenite was recovered. The property deserves some attention as the present flotation methods may allow it to become a producer.

Portland Canal Mining Division

Molly B.—This group of claims is located half a mile north of Stewart on the east bank of Bear river. Work was first started on this property in 1906 since which time annual assessment work has been done. Geo. A. Clothier[3] describes the rock formation as an altered greenstone. The ore-body, which is a quartz vein from 6 to 10 feet wide, is probably of contact metamorphic origin. It has been exposed by an open-cut at the edge of the river, and about 20 feet higher there is a stripping and another small cut.

The most prominent mineral is pyrite, with scattered chalcopyrite and very fine-grained molybdenite. The latter is disseminated in small amount throughout the whole vein, mainly associated with a greenish hornblendic rock. Mr. Clothier estimated the vein to average 2 per cent

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[1] Mun. Res. Comm., Can., 1920, p. 133. J. C. Gwillim.
[2] Ann. Rept. Min. of Mines, B.C., 1918, p. 213 K.
[3] Ann. Rept. Min. of Mines, B.C., 1918, p. 75 K.

MoS_2. A sample from 5 tons of cobbed ore on the dump assayed 9 per cent MoS_2. In addition there is a stock pile of about 10 tons of low-grade ore.

Since Mr. Clothier's report an open-cut has disclosed the vein about 250 feet farther up the hill. In the fall of 1921, G. D. B. Turner examined the vein and reported favourably on it. The vein is strong and well-defined and is well located for transportation, timber, and water, and can be easily developed by tunnels.

Similkameen Mining Division

Champion Creek.[1] Molybdenite occurs in little quartz stringers cutting schists that are in contact with granite at the Nickel Plate mine, Champion creek. The mineral is associated with pyrite and a little blende in a gangue of reddish garnet, green epidote, and quartz. Samples taken across the vein showed 2 per cent MoS_2. The vein is 8 to 12 feet wide, and the ore seems to be of milling quality. The property is owned by Mr. D. Galarneau.

Skeena Mining Division

Alice Arm, Molybdenum Mining and Reduction Co. This company owns about twenty claims at the northeast end of Alice Arm. Six of the claims are surveyed and Crown-granted, namely, the Blackwell, Success, Molybdenum, Silver Top, Molly No. 1, and Monarch.

Geology. The formation, as a whole, is sedimentary, consisting of slates, or argillites, which have many dikes and dislocations. It is not far from the intrusive granite masses which appear farther up the mountain side.

Ore-bodies. The ore occurs in a series of irregular quartz veins of the contact-fissure type which are dislocated in places by shearing and dike formations. Mineralization consists mostly of amorphous molybdenite in the form of thin seams parallel to the walls, and in some places where the seams are curved and crumpled by pressure they attain a thickness of about one-fourth of an inch. The ore tends to break along these seams or cleavage joints, giving it a deceptively solid appearance. Small quantities of iron pyrites are present; but there are no other associated minerals.

Workings. The main workings consist of about 600 feet of tunnels on the Success claim, at an elevation of 1,200 feet, and begin in a gully, in which bare rock is exposed for over 1,200 feet.

For the first 100 feet the main tunnel follows a quartz fissure and then a quartz lens for 50 feet (Figure 6). Two crosscuts show rock with large and small quartz veins, but the western or hanging-wall side is probably not reached, although the foot-wall side penetrates over 25 feet of dike. Most of the crosscuts are in quartz slightly mineralized with molybdenite in fine seams. In this tunnel, comprising the east fork, a 12-foot crosscut was driven in a lens of quartz carrying molybdenite. From this drift a raise of 30 feet reaches the surface and around it a stope has been worked. Prof. J. M. Turnbull[2] gives a good description of this stope and other workings. A large body has been stoped out, from which almost the whole output of the mine has been taken. From the many outcrops

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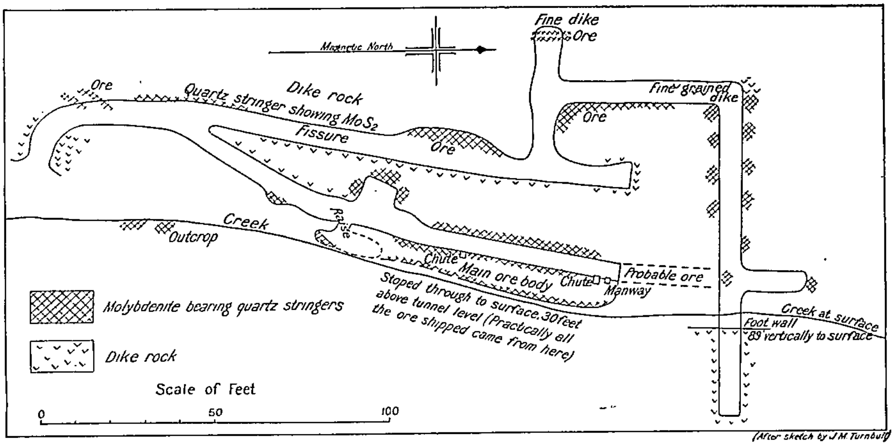
[1] Mun. Res. Comm., Can., 1920, p. 127. J. C. Gwillim.
[2] Ann. Rept. Min. of Mines, B.C., 1916, p. 66 K. J. M. Turnbull.

exposed along the creek, it would appear that the creek runs parallel to, and in the centre of the mineral zone, which is from 40 to 50 feet wide. W. B. Timm, of the Mines Branch, Ottawa, who visited the property in 1915, gives a detailed description of the workings on both sides of the creek, having traced the vein for upwards of 1,000 feet; and describes some spectacular showings of molybdenite.

J. C. Gwillim[1] who examined the property in 1916 considered that the ore from the underground workings would average about 1 per cent or a little less.

Tonnage of Ore. J. M. Turnbull, after a careful investigation, estimated that there were about 500 tons of definite ore, carrying 2 to 3 per cent MoS_2; 700 tons of 1 to 1½ per cent MoS_2; and 6,000 tons of possible ore in sight above the tunnel level. Shipments have since shown, however, that the best ore averaged under 2 per cent MoS_2.



(After sketch by J.M. Turnbull)

Figure 6. Plan of lower tunnel, elevation 1200 feet, Molybdenum Mining and Reduction Co., Alice Arm, B.C.

Of the 383 tons of ore that were shipped, all except 5 tons was sent to the International Molybdenum Company's concentrator at Renfrew. Owing to the average grade of the ore being 1·60 per cent MoS_2 instead of 3 per cent as was expected, and to its complex nature, the Renfrew company were unable to make a concentrate and refused to accept most of the shipments. About 45 tons of the tailings, which appeared to be almost as rich as the original ore, was sent to Ottawa and re-concentrated, as a result of which 1,368 pounds of molybdenite was recovered.

The Department of Mines was approached with a view to treating the remaining ore at Renfrew, but the molybdenite market had then collapsed and the ore was not shipped.

Equipment.—A description of the equipment and mill is given by J. M. Turnbull, who says:—

> The mine is connected with the mill by a Leschen 2-bucket aerial tramway 4,075 feet long, with a drop of about 1,100 feet, and a nominal capacity of 100 tons in twenty-four hours. Bunker capacity of 80 tons at the upper and 200 tons at the lower end is provided.

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[1] Mun. Res. Comm., Can., 1920, p. 129. J. C. Gwillim.

The mill consists of crushing and separating plants in separate buildings. The crushing plant building is set on the side of a steep bank, and the foundations do not look very solid. The crushing is done dry. The plant consists of a jaw-crusher, followed by coarse rolls, then by fine rolls, connected in series by 2-bucket elevators. The crusher and rolls are on the same level. The fine rolls operate by choke-crushing in closed circuit with a set of gently sloping shaking screens, the final product being 40 mesh. A short trial run showed that the fine screen tended to blind probably due to slight moisture and sticky material in the ore. A ball or conical mill for fine crushing may prove necessary. The separating plant contains flotation machines, and was not completed, some details remaining to be worked out. The mill appears to be more or less of an experiment, and may require some remodelling before successful operation is attained. Poor results at the start, if they occur, may be more the fault of the mill than of the ore, which appears to have given good results in experimental preliminary tests for concentration.

Power is furnished by two 50-h.p. wood-fired Leonard return-tubular boilers, which also operate a 500-cubic foot Leyner air-compressor, from which a pipe-line leads to the mine. The mill has a nominal capacity of 100 tons a day. The mine is equipped with one Denver Dreadnaught and one Sullivan hammer-drills. Owing to a flat portion on the tramway at the top, power is required to start the loaded bucket, which is furnished by a small oil-engine.

Since the above was written, a Nissen stamp mill was installed in the concentrator to follow the rolls, but a new ball mill has not yet been installed. Mining was done with air drills. All who have visited the property have been favourably impressed; but, aside from litigation troubles, a reconstruction of the concentrator and flow-sheet is necessary.

The company's officers are: Messrs. J. D. Ross, superintendent, W. F. Teetzel, Stilwell Bros., and C. P. Riel, manager.

Trail Creek Mining Division

Rossland. Molybdenite has been observed in several of the mines and prospects of Rossland. It is usually of the amorphous variety, forming very thin layers along joint-planes.

Dr. Walker[1] mentions its occurrence in the Centre Star and War Eagle mines, and also on the Novelty and Deer Park claims. The latter deposit is stated to be highly auriferous. The best occurrences are in the Giant mine, a little to the northwest of Rossland. This mine, owned by the LeRoi No. 2 Company[2], was worked in 1900 chiefly for its copper-gold values. A considerable amount of tunnelling and open-cut work has been done; but none of the molybdenite appears to have been saved, although it is believed that the gold values are largely carried in this mineral.

The late Dr. Drysdale[3] mentions the presence of fine-grained molybdenite at the Velvet mine on Sheep creek, 10 miles west of Rossland, where it occurs in a lens, 2 feet by 3 inches. It is also a common mineral in the Coxey and Novelty claims on the west slope of Red mountain, where it is more massive. In the Novelty it is mainly associated with arsenopyrite, but in the Coxey arsenopyrite is almost absent, with chalcopyrite rather abundant.

Dr. Drysdale further states that in the Giant mine, it is associated with arsenopyrite, pyrrhotite, a little chalcopyrite, and magnetite. It forms along small fractures in the rock and at the crossing of such fractures often occurs as masses of pure amorphous molybdenite sometimes a foot in diameter. According to Mr. R. Marsh, samples from 3,000 tons of ore

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[1] Molybdenum Ores of Canada, 1911, p. 54. T. L. Walker.

[2] The Cal. Roi Mining Co., Ltd., was formed in Aug., 1921, and took over the Giant and California mineral claims.

[3] Geology and Ore Report of Rossland, B.C., Geol. Surv., Can., Mem. No. 77, 1915, p. 78. C. W. Drysdale.

shipped ran 3 per cent MoS_2. Dr. Walker mentions another sample that assayed 11·6 per cent MoS_2 and 3·39 ozs. of gold per ton. In the Jumbo mine, about half a mile north of the Giant, there is a rich body of molybdenite against the mass of alkali syenite. The chief ore in the mine is pyrrhotite. Bismuthinite is also present.

Coxey Mine. This mine is less than half a mile north of the Giant, on the eastern slope of Little Sheep Creek valley. The main work on the property was done about 1910, before the existence of molybdenite was suspected, and about 300 feet of tunnels were driven into the hillside. The ore ran about 7 per cent copper, and $10 to $60 in gold, the former being in the form of chalcopyrite.

During the war the mine was worked by two lessees, Messrs. S. L. Williams and John Ruffner. In 1918 they sent to the Mines Branch, Ottawa, 3,423 pounds carrying 10·54 per cent MoS_2 and 2,003 pounds carrying 21·58 per cent MoS_2.

It is interesting to note that 10 to 50 per cent of the gold values in these mines where molybdenite occurs, is in the free state, and is closely associated with dikes of alkali syenite. This metallic gold in the alkaline solutions may have been precipitated by the chalcopyrite and molybdenite.[1] This occurrence, with free gold, has been noted in the Kirkland Lake and other gold areas.

Now that the complex, amorphous molybdenite ores can be successfully concentrated and separated, it is probable that should the demand for the mineral increase some of the Rossland and other similar, British Columbia molybdenite deposits may be worked.

Trout Lake Mining Division

Trout Lake. Molybdenite occurs at an elevation of about 5,000 feet in several claims, 4 miles southwest of Trout Lake, on the northern slopes of the hill to the south of Trout creek. The claims are reached by water, up the lake to 10 miles northwest of Gerrard, and thence 4 miles by good wagon road.

Dr. Walker[2] states that molybdenite has been found associated with the silver-lead-zinc ores in the quartz veins of the Copper Chief, Ruffled Grouse, Willow Grouse, and Lucky Boy mineral claims. The country rock is a grey schist. In 1898, Mr. R. T. Davie staked a claim south of the Lucky Boy, called the Molybdenum. Very little or no work in connexion with the molybdenite appears to have been done on any of these claims. During 1917 molybdenite was found along a diorite dike cutting obliquely across the formation in the Copper Chief. Several open-cuts were made which showed a considerable quantity of the mineral.[3] Mr. S. S. Slipper reported in 1918 that this dike had been traced for 1,500 feet and that an analysis showed 11·4 per cent MoS_2.

Vancouver Island

Cowichan Lake. Specimens of molybdenite were brought in by Dr. W. F. Ferrier, from the Marguerite, Evangeline, and Josephine claims on the north side of Brittle mountain and about 5 miles north of Cowichan

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[1] Econ. Geology 1 (1906), p. 650. H. N. Stokes.
[2] Molybdenum Ores of Canada, 1911, p. 54. T. L. Walker.
[3] Ann. Rept. Min. of Mines, B.C., 1917, p. 191.

lake. It also occurs in the Jasper claim, which is also sparsely mineralized with pyrites and chalcopyrite.[1]

One of the most promising molybdenite deposits on the island occurs in the Allies group on Brittle mountain. Quartz-filled fissures in granite carry flakes and in places large lumps of the mineral.

It appears that molybdenite is of frequent occurrence on Vancouver island, but up to the present it has not been regarded as being of economic importance.

Vancouver Mining Division

Burrard Inlet, North Arm. Several molybdenite claims were staked about 1905, near Burrard inlet.[2] These claims are in the valley of a small stream, 2 miles above its outlet into the North arm. The molybdenite, which is of a fine granular type, occurs in a quartz vein 14 inches wide, in granite. No attempt has been made to mine the ore, though several samples have been sent to New York and Liverpool.

Dr. Walker states also that Mr. Gideon Bower, of Vancouver, was interested in molybdenite claims about 4 miles south of these. The occurrence is on a steep mountain side, 1½ miles from the shore opposite Croker island. Three samples from this locality assayed 0·86 per cent MoS_2 and 0·11 per cent copper.

Yale Mining Division

Cheam View. J. C. Gwillim,[3] reports an occurrence of molybdenite owned by Messrs. Knight, Dupres, and others of Sardis. The locality is on the south side of the Fraser river not far from Hope.

Lenses of quartz in granite carry pockets of fairly high-grade mineral, but the extent of the deposit appears to be small.

Skagit River. Samples of molybdenite were sent to the Mines Branch, Ottawa, by H. B. Brown of Rockport, Washington. The ore came from several localities near the International boundary about 22 miles south of Hope. At an elevation of 4,000 feet on the west of the Skagit river near Silver creek there is a copper-bearing dike about 40 feet wide which carries molybdenite in varying quantities up to 0·5 per cent MoS_2.

The best showing according to Mr. Brown is on the property belonging to W. H. Robinson on the Old Rainbow claim at Twenty-two Mile creek, the mineral being very free from copper. From here to the International boundary there are numerous deposits of molybdenite, some of which, at Tenmile creek, belong to Chas. Howlett, but they are mixed with complex ores.

Spuzzum Creek. Molybdenite occurs with free gold on the north fork of Spuzzum creek on the divide between that creek and Harrison lake which is about 10 miles northwest of Yale station. In 1913, J. A. Jamieson and associates did some assessment work.

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[1] Geol. Surv., Can., Ann. Rept. Vol. X, 1897, p. 122.
[2] Molybdenum Ores of Canada, 1911, p. 52. T. L. Walker.
[3] Mun. Res. Comm., Can., 1920, p. 126. J. C. Gwillim.

TABLE V

Molybdenite Deposits and Occurrences in British Columbia

	Mining Division	Name and Locality	Occurrence	Quantity of ore shipped	Classification	Remarks	References
1	Ainsworth	Kootenay lake, Grays creek	Quartz lead in granite	Nil.	C.	140-ft. tunnel; samples said to run 5·0% MoS_2	(5)
2	"	Duncan river	Quartz veins cutting grey mica schist	"	C.	Several tons 3·5% ore extracted; numerous open-cuts	(6)
3	Arrow Lake	Upper Arrow lake, near Nakusp, Bourne prospect	In quartz veins	"	P.	Three occurrences along lake, numerous open-cuts	Mining and Engineering Record June 15, 1917, p. 162
4	"	Lower Arrow lake near Tunnel station		"	C.	75-ft. tunnel, pits and stripping; 5 tons 3·5% MoS_2 ore extracted	(6)
5	Ashcroft	Gnawed mtn	Semi-amorphous in granite joint-planes; with copper ores	1 ton	C.	20-ft. shaft, pits and stripping; 50 tons 1% MoS_2 ore extracted	(6)
6	Atlin	Bennett lake	Quartz veins with free gold	Nil.	E.	Noted in mining for gold	(1) 1906, p. 55
7	"	Rainy Hollow dist	Some MoS_2 and galena in pyrrhotite		M.	Occurrence noted with other minerals	(1) 1907, p. 482; 1915, p. 64
8	Bella Coola	Near Ocean Falls		1 ton	C.	Ore runs 2% MoS_2; some prospecting	(2) p. 124
9	Clinton	Chilko lake	In gold claims	Nil.	C.	No development for MoS_2	(1) 1917, p. 232.
10	"	Lac la Hache, Timothy mtn.	In quartz fissures in diorite	1,000 pounds picked 350 pounds MoS_2 recovered	B.	Several tunnels, shafts and open-cuts; average ore about 1·5%	(6)
11	Fort Steele	St. Marys near Marysville	Semi-amorphous with chalcopyrite and bismuthinite	Nil.	C.	Little prospecting	(6)
12	Grand Forks	Franklin camp, Boundary dist.	In granodiorite shear zones with copper	"	F.	Several other occurrences; no development for MoS_2	Min. & Eng. Rec., June 15, 1917, p. 162
13	Greenwood	Carmi mine, Boundary dist.	Occurs with the copper ores	"	F.	In three localities; no development for MoS_2	(2) p. 127; (1) 1917 p. 201
14	"	Near Bridesville	Flake MoS_2 in quartz veins	10 pounds	C.	Shaft and assessment work; sample 11% MoS_2; high in molybdic ochre	(2) p. 127

TABLE V—*Continued*

Molybdenite Deposits and Occurrences in British Columbia—Continued

	Mining Division	Name and Locality	Occurrence	Quantity of ore shipped	Classification	Remarks	References
15	Kamloops..	Tp. 17, R. 14, Grand Prairie	In metamorphic siliceous limestone contact zone	Nil.	B.	Considerable prospecting; sample 3·6% MoS_2	(6)
16	"	Near Grace mtn. Seymour arm	MoS_2 vein carries silver.....	"	C.	Little prospecting; samples said to be rich	(1) 1907, p. 175
17	Lillooet.....	Index mine, Texas creek	In wide fracture in quartz; quartz-granite mass intrusive into schist and limestone	10 tons	B.	Several pits, trenches and tunnels; shipments 15% MoS_2	(6)
18	Nanaimo...	Cortes is. near Carrington bay	Finely disseminated through quartz vein	Nil..	E.	Assessment work............	(4) 1886, p. 23 B.
19	" ..	Knight inlet............	In narrow quartz vein.......	"	F.	Some prospecting; some ore hand-sorted	(2) p. 125
20	" ..	North passage, Fanny bay	In narrow quartz veins in granite stained with green copper carbonate	"	F.	Assessment work............	(4) Mem. 23, 1913, p. 141.
21	" ..	Powell lake............	Semi-amorphous in quartz..	"	M.	"	(5)
22	" ..	Northern Texada is., copper mines	Semi-amorphous in copper ores in marble and lime-silicates	500 pounds	C.D.	Found in several of the copper mines; at 1,000 ft. below sea-level; shipment 8·8% MoS_2	(6)
23	Nelson......	Molly mine, Lost creek.	In pegmatite dikes and in granite.	202 tons, 10 tons MoS_2 recovered	A.	Considerable surface and underground work; shipments 5·8% MoS_2	(6)
24	"	Nelson, Granite.........	In pegmatite quartz veins in hornblende biotite-granite.	Nil.	M.	No development.............	(3) p. 55.
25	"	Sheep creek............	Considerable yellow molybdite.	"	C.	Assessment work; several tons fair ore exposed.	(3) p. 55
26	"	Free Silver claim, Ymir.	In a fissure vein in monzonite	"	M.	Observed in mining for lead and silver.	(4) Mem. 94, 1917, p. 24.
27	New Westminster.	Chilliwack lake........	Occurs with yellow molybdite.	"	M.	....	(2) p. 126.
28	"	Empress group, Harrison lake	With copper ores on contacts of granite and limestone	"	E.	Extensive for copper only; no MoS_2 saved	(1) 1917, p. 286
29	"	Canon creek, near Pitt lake	Fine flakes in quartz network associated with pyrites	Few hundred pounds	B.	15 tons 8·0% ore sacked; 3 tunnels and 2 open-cuts	(6)

30	"	Stave lake, near Stump creek	In quartz-filled fissures in granite	Nil.	C.	Very little prospecting; ore about 1·0% MoS_2	(6)
31	Nicola	Copper King mine, Mamette lake	With copper in altered granite	"	C.	Some prospecting; abandoned owing to excess of copper	(1) 1915, p. 233
32	"	Duplex creek, Mamette lake	With copper in sheared granite	"	....	Several pits; abandoned owing to excess of copper	(1) 1915, p. 233
33	Omineca	Buckley river, I.X.L. group, Mud creek	....	"	E.	Some prospecting; 16 tons ore extracted	(1) 1914, p. 205
34	"	Telkwa trail, Kleanza creek	In quartz veins	"	P.	Little prospecting	(2) p. 125
35	"	Rocher Deboule mtn., New Hazelton Gold-Cobalt Mines, Ltd.	In complex sulphide vein with arsenopyrite in granodiorite.	27 tons, 430 lbs. MoS_2 recovered.	B.	Extensive tunnels, shafts and pits; shipments 2% MoS_2.	(6)
36	Osoyoos	Golconda mine, Ollala	Semi-amorphous with copper in decomposed pyroxenite.	2·2 tons cobbed, 690 lbs. MoS_2 recovered.	B.	Tunnels and stripping	(6)
37	"	Hedley, 21 Mile creek	Sparingly through quartz diorite, in ryholite and diorite.	Nil.	M.	Considerable float found	(4) Mem. 2, 1910, p. 141.
38	"	West Summerland	In quartz ledge contact of granite and schist.	246 lbs.	F.	Stripping and trenching; shipment 0·3% MoS_2.	(5)
39	Portland Canal	Molly B. Stewart	Very fine grains in contact metamorphic quartz vein in altered greenstone	Nil.	C.	Open-cuts and trenching; 15 tons of 5·0% ore extracted average grade 2·0% MoS_2	(6)
40	Similkameen	Granite creek, Tulameen river	....	"	P.	Assessment work	(2) p. 127
41	"	Independence camp, Coldwater river.	With copper in granite porphyry	"	E.	No development for MoS_2. Noted in mining for copper; MoS_2 not saved	(1) 1913, p. 237
42	"	Nickel Plate mine, Champion creek	With pyrite in quartz stringers cutting schists	"	C.D.	Some prospecting; 2·0% MoS_2 across 10-ft. vein	(6)
43	Skeena	Molybdenum Mining and Reduction Co., Alice Arm	Amorphous MoS_2 in irregular contact fissure veins cut by dikes	383 tons	A.	Extensive tunnels, raises, stopes; ore about 1·5% largest B.C. producer; small concentrator	(6)
44	"	Molybdenum group near Zimacord	Small quartz veinlets in diorite dikes	Nil.	M.F.	Little prospecting	(5)
45	"	Lime creek	Semi-amorphous in quartz stringers	"	F.	Several open-cuts	(1) 1916, p. 66; (2) p. 124
46	"	Fitzgerald Bros. property, Bear river	In long quartz ledge in granite	Several hundred pounds	C.	5 pits; samples 6·0% MoS_2	(6)
47	"	Mammoth mine, Observatory inlet	Amorphous, in quartz veins	Nil.	M.	Very little prospecting; no development	(1) 1907, p. 74
48	Slocan	Slocan lake, Rosebery	As rosettes in quartz matrix	"	M.	Assessment work	(2) p. 128

TABLE V—*Concluded*

Molybdenite Deposits and Occurrences in British Columbia—Concluded

	Mining Division	Name and Locality	Occurrence	Quantity of ore shipped	Classification	Remarks	References
49	Trail Creek.	Giant mine, Rossland camp	Amorphous, with copper as sulphides along fracture planes in granite and granodiorite	Nil.	C.B.	3,000 tons of copper ore, carried 3·0% MoS_2; none saved MoS_2 carries gold.	(6)
50	“	Rossland camp	“ “	27 tons	C.B.	300 feet tunnels; shipments 15·0% MoS_2; carries gold; MoS_2 found in many other of these mines	(6)
51	Trout Lake.	Near Trout lake	In silver-lead quartz vein in grey schist	Nil.	C.	Some prospecting; several occurrences	(6)
52	Vancouver..	Britannia Beach, Howe sound	On shear zone with copper ores	“	M.	No development for MoS_2; noted in Britannia copper ores	(4) 1908, p. 38, O. E. LeRoy
53	“ ..	Lynn creek, Vancouver.	With metallic sulphides in calcite	“	E.	Several tunnels; several other occurrences	Min. & Eng. Rec., June 30, 1917, p. 176
54	“ ..	North arm, Burrard inlet	Fine-grained, in quartz vein in granite	“	F.	Little prospecting	(6)
55	“ ..	Pleasant lake, Jervis inlet	Scattered in large flakes through quartz in granite	“	M.C.	Assessment work	(2) p. 125
56	“ ..	Clowhom lake, Sechelt inlet	In quartz	“	M.C.		(2) p. 125
57	Vancouver island	Cowichan lake, mount Brittle	With sulphides in quartz fissure in granite	“	M.C.		(6)
58	“ ..	Indian River dist.	With sulphides in wide dike in greenstone and granite	“	C.	Tunnel and stripping; several other occurrences	(6)
59	Vernon.	Armstrong camp, Aberdeen mtn.	Galena with quartz ledge in granite schist and slate	“	M.	No development for MoS_2; noted in mining for galena	(1) 1902, p. 188
60	Yale.	Cheam View, Hope.	Pockets of MoS_2 in quartz in granite	“	E.	Some prospecting	(2) p. 126
61	“	Skagit river, International boundary	In copper-bearing dike in granite	“	E.	Some prospecting; several occurrences	(6)
62	“	Spuzzum creek	With free gold in granite	“	P.	Assessment work	(5)

NOTE.—In addition to the above there are about 30 other known occurrences of minor importance.

In the above tabulation the following *tentative* classification has been adopted for grading purposes.
A. Economic conditions favourable and probably a considerable producer.
B. Probable producer.
C. Has possibilities and worthy of further investigation.
D. Has possibilities on a small scale, suitable for economic hand-cobbing.
E. Prospect not very encouraging.
F. Prospect not worthy of further investigation.
P. Prospect—no definite information.
M. Mineral occurrence only.

Key References—
(1) Annual Reports of the Minister of Mines, British Columbia.
(2) Munition Resources Commission, Canada, 1920. Reports by J. C. Gwillim.
(3) Mines Branch No. 93. Molybdenum Ores of Canada, 1911, by T. L. Walker.
(4) Geological Survey of Canada.
(5) Private information; Mines Branch, Ottawa.
(6) See description in Report.

MANITOBA

Lake of the Woods Region

Township 9, Range 16, Falcon Lake and Star Lake. The Falcon Lake Mining and Milling Company own several molybdenite claims on the northwest end of Falcon lake, eight miles west of the Ontario-Manitoba boundary. These deposits, which are on the western edge of those described about Shoal lake, Ontario, can be reached by canoe and trail from Ingolf on the Canadian Pacific railway.

The occurrence was originally discovered by Mr. William Gordon of Winnipeg in 1900, but it was not until 1917 that he and Mr. George B. Hall, also of Winnipeg, re-located the deposits and staked the claims. Two geologists, J. S. DeLury[1] and E. L. Bruce[2] made detailed reports on this area.

Precambrian rocks occupy the whole area for miles around. The oldest rocks, consisting mainly of volcanic schists and greenstones, are intruded by red and grey granite-gneisses, the later granites accompanied by pegmatite and aplite dikes. These acid phases of the granite are confined to a band of the Keewatin, about half a mile wide and two miles long, running parallel with, and adjacent to the Keewatin-granite contact on the north of Falcon lake; and it is along this zone that the molybdenite claims have been staked.

The molybdenite is found in several different phases of the rocks, namely: (1) as a constituent of typical pegmatite dikes; (2) in equigranular granitic dikes; and (3) in quartz veins.

In the first of these the molybdenite occurs as crystals from half an inch to two inches in diameter, and occasionally as aggregates weighing almost 20 pounds,[3] the larger crystals being found in the dikes close to the parent granite mass; but here the average molybdenite content is probably less than in the dikes farther from the intrusive. In the second type, the crystals are much smaller, but the deposits appear to be richer than either of the other two. In the third type, the mineral is found in veinlets traversing quartz, and appears to be too low grade to be of economic value.

The deposits have the advantage of being quite free from the usual, associated metallic minerals. DeLury reports the presence of beryl in places, but it does not appear to be abundant.

The cleanest and best ore occurs in pegmatite dikes on the Tomboy and Gull mineral claims, where the greater part of the work has been done. Mr. Hall informed the writer, that these clean cut and persistent dikes which are 2 feet to 9 feet in width, run parallel, across the claims in a southwesterly direction, one of them having been traced for at least 3,000 feet.

On the Tomboy the work done consists of a 7 by 9-foot shaft, 12 feet deep; a pit 9 feet deep; and 2 open-cuts, one of which is 69 feet long. In all, about 170 tons of rock has been extracted. On the Gull, where there are 2 small pits and 4 shallow open-cuts, the longest of which is 37 feet, about 60 tons of rock has been mined from all the workings. (Figure 7.)

J. S. DeLury estimated the average molybdenite content of the pegmatite dikes to be only about 0·2 per cent with a maximum of 1 per cent. Other engineers estimate the average as 0·5 per cent; but ordinary

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[1] Manitoba Pub. Serv. Bull., 1917, p. 8. Justin S. DeLury.
[2] Geol. Surv., Can., 1917. E. L. Bruce.
[3] Mineral Prospects in Southeastern Manitoba, 1920, p. 47. J. S. DeLury.

sampling is out of the question, and only by mining sufficient ore for a regular mill run, could even an approximate idea of the value be obtained. At present the grade of the ore does not warrant this. Possibilities of finding richer and perhaps larger bodies of ore exist, however, and the deposit warrants further prospecting in the vicinity of the granite contacts.

Mr. Hall was confident that 80 per cent of the molybdenite from these veins could be hand-picked to give a high-grade product. The ore mined consisting of about half a ton of hand-cobbed material is estimated to run about 10 per cent. About 200 pounds of pure flake molybdenite was distributed for sample purposes.

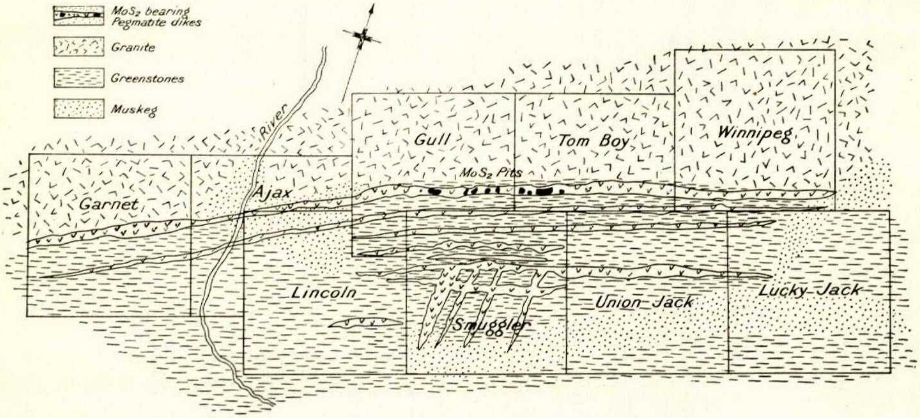

Figure 7. Manitoba molybdenite properties at Falcon lake, veins from 2 feet to 9 feet in width.

Northern Manitoba

Herb Lake. Good showings of molybdenite have been reported from the west bank of Grass river, immediately below Crowduck bay[1]; also on claims at the north end of this bay.

The molybdenite is found in quartz veins in the granite near its contact with Precambrian sedimentary rocks. The best showing is in the Grass River quartz vein, which is 3 feet wide, and carries coarse masses of molybdenite; but sufficient stripping had not been done to show its extent.

In 1919 some molybdenite claims were staked on the south shore of Copper lake. The vein is said to be 3½ feet wide, carrying molybdenite and pyrite.[2]

Northwestern Manitoba

Phantom Lake. A claim was staked for molybdenite in 1919, by Mr. Gus Rosen, on Phantom lake, about 5 miles south of the Flinflon camp. The samples brought down were stated to be very rich but no further details are available.

Hut Lake. Mr. Robert Kerr owns a molybdenite property at Hut lake, near The Pas. Mr. Kerr states that the ore can be sorted to run 5·0 per cent MoS_2 and that samples of the ore sent to Orillia assayed 2·25 per cent MoS_2. Samples sent to the Department of Mines, Ottawa, were reported by them to be of too low grade to warrant shipping to the Ottawa concentrator.

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[1] Manitoba Pub. Serv. Bull., June, 1917, p. 9. R. C. Wallace and J. S. DeLury.
[2] Op. cit. p. 3.

TABLE VI

Molybdenite Occurrences and Prospects in Manitoba

Region	Locality	Mode of occurrence	Quantity of ore shipped	Classification	Remarks	References
1 Lake of the Woods	Near Falcon lake, tp. 9, r. 16	In quartz veins and pegmatite dikes in Keewatin schist and gneiss	200 pounds flake	C.B.	One shaft, 10 pits and stripping. Half ton 10% ore from 250 tons mined	(1)
2 "	Near High lake.........	Quartz fissure veins in felsite in granite and schist	Nil.	D.	A few prospect pits. Some gold, copper, silver ore extracted but no molybdenite	Min. Prospect S.E. Manitoba, 1920
3 Northern Manitoba	Herb lake, Grass river.	Coarse masses in quartz veins near granite contact in sedimentaries	"	C.	Very little prospecting........	(1)
4 Lake Winnipeg	Tp. 25, r. 9 E, Wanipigow river	With chalcopyrite in quartz.	"	M.E.	No development work for MoS_2	Can. Min. Jour., Dec., 1917, p. 460
5 "	Tp. 23, r. 14 E., Gold lake	Associated with galena in quartz gold veins	"	M.	Noted in developing gold prospects	Can. Min. Jour., Aug. 1, 1916, p. 364
6 "	Tp. 58, r. 11 W., Little Playgreen lake	As aggregates in red pegmatite dike in granite	"	M.	....	G.S.C., 1898, p. 169
7 "	Little Playgreen lake, Echimamish river	Along contact of zone in gneiss and intruded igneous rocks	"	M.C.	....	G.S.C., 1905, p. 71
8 N.W. Manitoba	Phantom lake near Flinflon camp.	....	"	M.C.	....	(1)
9 "	Hut lake, Kerr prospect.	....	"	P.E.	Very little prospecting........	(1)

In addition to the above list three other occurrences have been noted about which no information is available.

In the above tabulation the following *tentative* classification has been adopted for grading purposes.

A. Economic conditions favourable, and probably a considerable producer.
B. Probable producer.
C. Has possibilities and worthy of further investigation.
D. Has possibilities on a small scale, suitable for economic hand-cobbing.
E. Prospect not very encouraging.
F. Prospect not worthy of further investigation.
P. Prospect of no definite information.
M. Mineral occurrence only.
Key References: (1) See description in Report.

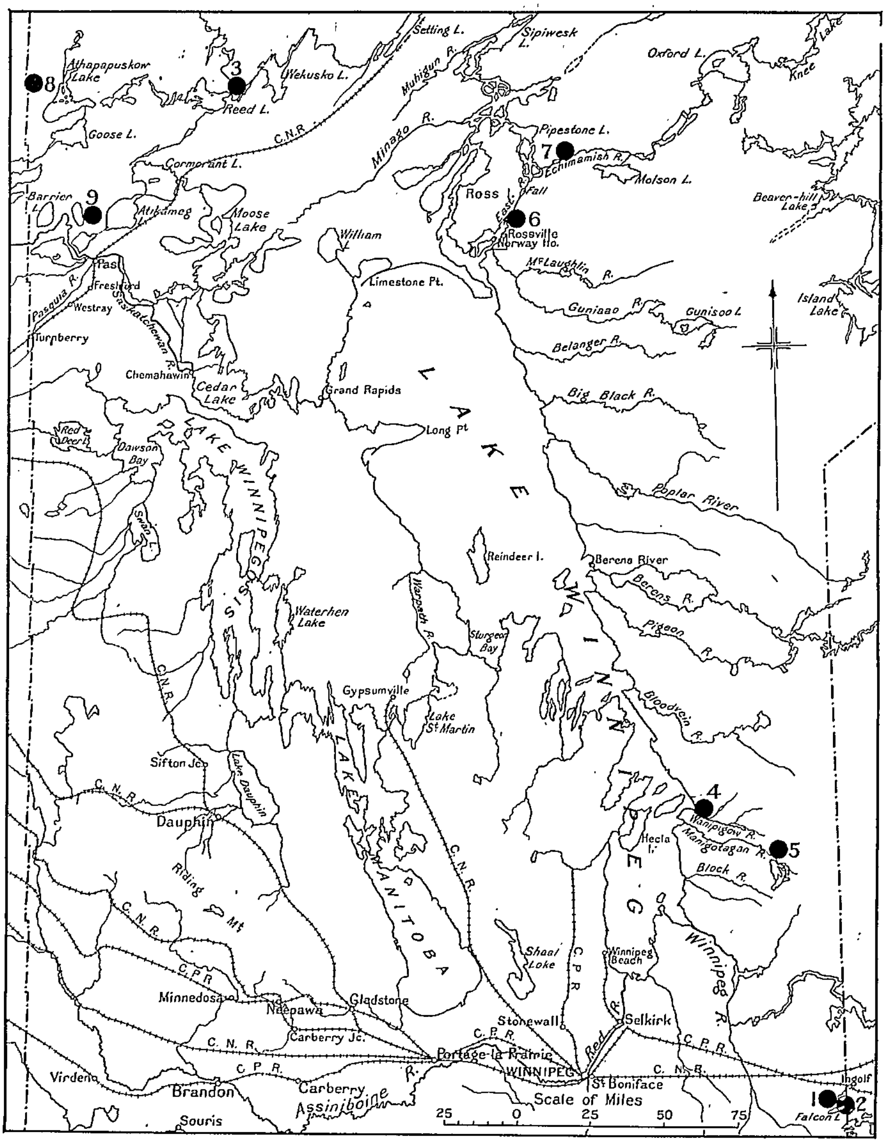

Figure 8. Molybdenite occurrences in Manitoba.

MARITIME PROVINCES

NOVA SCOTIA

Cape Breton County

Deep Cove, Gabarus Bay. This deposit, which occurs at Deep cove on the east coast, 20 miles south of Sydney, was worked in 1917 by Messrs. G. H. Crowdes of Louisburg, and James Stewart of New Glasgow

A. O. Hayes and J. C. Gwillim, who examined this property in 1917, reported that the molybdenite occurs in very thin quartz seams. The seams occur in thin pegmatite dikes that have intruded the granite and volcanic rocks exposed along the north shore of Gabarus bay for a distance of one mile east of Deep cove. The presence of molybdenite in this locality has been known for over 50 years.[1]

In June 1917, Mr. Stewart shipped to the Mines Branch, Ottawa, 3,474 pounds of ore picked from the sea shore, averaging 2·49 per cent MoS_2, from which 75 pounds of pure molybdenite was recovered. Experimental tests showed it to be a good ore for concentration. Another small sample sent to Ottawa assayed 2·3 per cent MoS_2.

No work appears to have been done other than a small amount of prospecting. Float molybdenite has also been reported on the coast near Louisburg 6 miles farther northeast.

Hants County

Leminster, Swinimer Prospect. This property is situated on the farm of Roy Swinimer, near the junction of Lunenburg, Halifax, and Hants counties, 17 miles south of the town of Windsor. The rocks are similar to those of the New Ross deposits, and the molybdenite occurs in a vein of quartz and calcite about 10 inches wide. James Dunright, of Whiteburn, Queens county, who has held an option since 1917, reports a small lead of bismuth on the foot-wall, and indications of silver values in a pit 8 by 12 feet, sunk in 1918. From this pit he sent to the Department of Mines concentrator, at Ottawa, 376 pounds of picked ore, assaying 1·08 per cent MoS_2. Owing to trouble with water and lack of capital no further work has been done on the property. As this deposit was never officially examined, nothing is known regarding its possibilities.

Lunenburg County

New Ross: Nova Scotia Molybdenum, Ltd. The property owned by this company is situated on the farm of Mr. Bennett Walker, on the south shore of Whalen lake, 3 miles northeast of New Ross.

The country rock is a coarse-grained, porphyritic, muscovite-granite. To the north of the property is biotite-granite and at the contact between the two is a narrow band of highly altered micaceous quartzite. Throughout this area there are dikes of coarse granite and pegmatite masses, cut by well-defined, banded quartz veins. These dikes carry a variety of minerals, including ores of tin, tungsten, and molybdenum.[2]

Mineralogy of Nova Scotia, 1868, p. 61. H. How. Geol. Surv. of Can., 1873-74, p. 379. Fletcher.
Geol. Surv., Can., Sum. Rept., 1917, p. 17 F. E. R. Faribault,

The vein material as exposed in the workings is chiefly a milky-white, brittle quartz, containing pink decomposed orthoclase feldspar. The molybdenite appears to be closely associated with this feldspar, in which it has been observed in float as well as in the workings.

The mineral has been known to occur in quartz boulders, on Mr. Walker's farm, for at least 50 years, and as early as 1868 its presence in this locality was reported by Henry How. No serious attempt was made to find the deposit till the spring of 1917, when Mr. H. C. Burchill, of Windsor, and associates, formed the Nova Scotia Molybdenum Company, and Mr. T. R. Hyland, the manager, did some prospecting, and sank a shaft 500 feet south of the Windsor road. In sinking this shaft, after removing about 12 feet of overburden, ore was struck on the contact of a pegmatite dike and muscovite-granite. The overburden contained loose boulders of molybdenite-bearing quartz. About one-fourth of a ton of ore assaying 1·66 per cent was sent to Ottawa.

At the time of closing operations in March, 1918, the shaft had reached a depth of 52 feet, at which point drifting was extended for 13 feet east and west. Ore was encountered in the greater part of the west drift, but none was found in the east drift. About 36 feet from the top of the shaft ore was again struck, dipping in a northwest direction, and a 38-foot crosscut driven in a northerly direction near the top of the shaft encountered this ore-body. According to Mr. Burchill, the thickness of the lower ore-body is 9 feet, and of the upper one, 6 feet. Trenching has been done on various places on the property, but the soil cover is very deep—20 feet in places—and the results from this prospecting work have not been encouraging.

During 1917 a shipment was made to Ottawa, by G. F. Murphy of the Nova Scotia Technical College, for the Maritime Optical Company. All shipments from this property went to the Department of Mines, Ottawa, and are as follows.

From the Maritime Optical Company, April, 1917, 675 pounds carrying 1·66 per cent MoS_2; from the Nova Scotia Molybdenum Company, August, 1917, 1,033 pounds carrying 1·03 per cent; and in April, 1918, 40,684 pounds carrying 0·49 per cent.

From the 21·2 tons of ore, which proved to be an ideal one for crushing and concentration, 155 pounds of molybdenite was recovered. There are still several tons of selected ore on the property and a large amount of float consisting of boulders of white quartz, with pink feldspar, in which molybdenite is scattered, is found on the shore of Whalen lake.[1]

The ore appears to be low grade but is capable of being hand-sorted, and surface indications show that the mineral is present over a considerable area. Although prospecting is expensive on account of the heavy overburden the deposit would seem to be the most promising one so far found in Nova Scotia.

There are several other occurrences of molybdenite in this region. Some prospecting work was done in 1890 by Messrs. C. Keddy and P. Lantz on a deposit 1½ miles southwest of New Ross where molybdenite occurs in grey muscovite-granite which is broken by vertical joints. A 10-foot pit sunk on one of these joints disclosed a very rich molybdenite-bearing vein, about 2 inches wide.

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[1] Mun. Res. Comm., Can., 1920, p. 108. J. C. Gwillim.

Dr. Walker[1] who visited the property in 1909, stated that the granite is impregnated with molybdenite scales for some distance from the main vein and resembles some of the most promising deposits of the state of Maine, as described by Frank L. Hess.[2] No trenching or other work was done, so that the extent of the mineralized area is not known.

These New Ross granites were analysed by Mr. R. A. A. Johnston, who recognized some 30 minerals, including ores of tin, tungsten, molybdenum, manganese, bismuth, lead, copper, and arsenic.

NEW BRUNSWICK

Charlotte County

Pennfield Parish. Molybdenite is found as scattered grains and scales in Trout brook, Pennfield parish, two miles north of the post office. The quantity is said to be considerable.[3]

York County

Stanley Parish: South West Miramichi; Arcadia Tungsten Mines, Ltd. The tungsten mines are situated at the mouth of Burnt Hill brook, a tributary of the South West Miramichi river, 20 miles northeast of Boiestown on the Canadian National railway. The deposit occurs near a contact of slate and granite areas.[4]

Mr. Mathew Lodge states that he found several small pockets of molybdenite associated with wolframite in the quartz veins but that the molybdenite does not occur in commercial quantities.

The Department of Mines, Ottawa, examined a considerable quantity of this tungsten ore, and obtained assays varying from 0·25 to 1·00 per cent MoS_2.

The work at the mine consists of a 160-foot shaft, with two levels with 200 feet of drifting on each. There is a 40-ton per day concentrator, using the ordinary gravity method for treating the wolframite. Very little attempt has been made to separate or save the molybdenite.

NEWFOUNDLAND

Although this island is not under the jurisdiction of the Dominion government, a short description of its molybdenite deposits is submitted. Several occurrences of the mineral are known but there is only one about which definite information is available.

Northeast Coast: Fleur de Lys Harbour. This property, consisting of about 640 acres, is owned by Mr. M. L. Parrell of St. Johns, Newfoundland, and is at tidewater in a landlocked harbour near Baie Verte on the northeast side of the island.

The ore-body occurs along the plane of a reverse fault in granite gneiss. Paralleling the enriched fault, eighty feet to the west, another somewhat similar fault occurs. The gangue and associated minerals consist of pyrrhotite, calcite, quartz-breccia, talc, and chlorite schists.

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[1] Molybdenum Ores of Canada, 1911, p. 19. T. L. Walker.
[2] U. S. Geol. Surv., Bull. No. 340, 1907, p. 231.
[3] Min. Res. of New Brunswick, Part M, Vol. X, p. 126, 1899.
[4] Molybdenum Ores of Canada, 1911, p. 22. T. L. Walker.

The molybdenite occurs as flakes and massive amorphous lumps on the slickensided surfaces and as minute disseminations in the altered rock fragments. The ore-body is lenticular and its greatest thickness is 45 feet. It has been traced for 300 feet along the strike. The work, which was done in 1915, consists of one shaft 55 feet deep, from which a 12-foot drift has been driven on the 20-foot level. Mr. Parrell states that ten channel samples across the ore zone averaged 1·5 per cent MoS_2. Eighteen tons of picked ore, averaging 10·0 per cent MoS_2, and about 100 tons of 1·5 per cent MoS_2, have been mined, all of which is still on the property. Samples of the above lots of ore were sent to the Mines Branch in June, 1918, the former assaying 10·32 per cent and the latter 1·25 per cent. The picked ore showed 0·30 per cent nickel and a trace of copper.

There is a deposit of copper close to the molybdenite occurrence, on which a 40-foot shaft has been sunk. Assays made by the Mines Branch showed 12·84 per cent copper, and 0·22 per cent MoS_2.

The writer has not visited the property, but from the description furnished it should be a profitable producer should the market re-open.

A large deposit of molybdenite is reported to have been found at Rencontre, Fortune bay, but no definite information about it is available.[1]

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[1] Mineral Industry, 1902, p. 477.

TABLE VII

Molybdenite Deposits and Occurrences in the Maritime Provinces

	County	Locality	Occurrence	Quantity of ore shipped	Classification	Remarks	References
			CAPE BRETON ISLAND				
1	Cape Breton	Near Glengarry valley, East bay	With pyrites on dike contacts in coarse pink granite	100 pounds cobbed	D.E.	A few pits......................	Private reports Mines Branch
2	"	Near Deep cove, Gabarus bay	In thin quartz seams cutting granite and volcanics	1·7 tons picked..	C.	Very little prospecting. Ore picked from sea shore; mineral distribution wide, but low grade	(1)
3	Victoria....	Near St. Ann, North river	....	Nil.	M.	No development work done....	G.S.C., 1892, p. 60
			NEW BRUNSWICK				
1	Charlotte ..	Trout brook, Pennfield parish	As scattered grains in quartz veins in granite	Nil.	M.C.	Found as float................	(1)
2	"	St. Stephen parish....	....	"	M.	No development work done.....	Min. Res., N.B., 1899, p. 126 M
3	"	Gaspereau, Clarendon parish	Quartz veins in granite....	"	M.	....	Private Reports Mines Branch
4	Gloucester..	Near Bathurst........	In quartz veins in granite.	"	M.	....	Min. Res., N.B., 1899, p. 126 M
5	York.......	Stanley parish, Burnt Hill brook, Arcadia Tungsten mines	With wolframite in quartz veins on contact of slate and granite	Several samples	C.	Wolfram ore carries 0·25 to 1% MoS_2, very little attempt to save MoS_2	(1)
			NOVA SCOTIA				
1	Halifax.....	Near Kearney lake...	In quartz boulders........	Nil.	M.	High-grade MoS_2 in float; never traced to source	Min. Res., N.S., 1885, p. 18
2	"	Near Musquodoboit harbour	In quartz boulders........	"	M.	High-grade MoS_2 in float; never traced to source; discovered 1862	Min. Res., N.S., 1885, p. 18

3	Hants......	Near Leminster, Windsor	In narrow quartz and calcite veins	376 pounds cobbed	E.	Some pits.....................	(1)
4	Shelburne...	Jordan Falls..........	In quartz pegmatite dikes in granite and staurolite schist	"	F.	Very little prospecting..........	G.S.C., 1896, p. 146 M
5	Lunenburg..	Nova Scotia Molybdenum, Ltd., New Ross	Associated with pink feldspar and quartz veins in coarse biotite-granite	21 tons, 155 pounds MoS_2 recovered	C.	50-foot shaft, drifts and crosscuts. Ore about 0·5%; overburden very heavy; probably best deposit in Nova Scotia	(1)
6	"	Keddy-Lantz prospect near New Ross	Impregnating granite joint-planes in grey muscovite granite	Nil.	E.	One pit........................	(1)
7	"	Near Lake Ramsay...	In irregular masses of coarse pegmatite	"	E.	Considerable prospecting........	(1)
8	Yarmouth..	Chegoggin point near Yarmouth	....	"	M.	....	G.S.C., 1893, p. 60

NEWFOUNDLAND

1	Northeast coast	Fleur de Lys, Parrell mine	As amorphous lumps on plane of reversed fault in granite gneiss	Samples only...	B.	55-foot shaft, 12-foot drift and pits. 100 tons of 1·5%; 18 tons 10% MoS_2 cobbed ore extracted.	(1)
2	Fortune bay Rencontre	....	....	Nil.	P.	Some prospecting..............	(1)

In addition to the above there are four or five other recorded occurrences about which no information is available.
In the above tabulation the following *tentative* classification has been adopted for grading purposes.
A. Economic conditions favourable, and probably a considerable producer.
B. Probable producer.
C. Has possibilities and worthy of further investigation.
D. Has possibilities on a small scale, suitable for economic hand-cobbing.
E. Prospect not very encouraging.
F. Prospect not worthy of further investigation.
P. Prospect—no definite information.
M. Mineral occurrence only.
Key references: (1) See description in Report.

ONTARIO

GENERAL

There are a greater number of known molybdenite occurrences and a larger number of producers in the province of Ontario than in any other province in the Dominion.

Almost the whole of the Ontario molybdenite production is confined to a belt about 150 miles in length, stretching from southeast Pontiac and the lower Gatineau in Quebec, and continuing in Ontario in a southwesterly direction through Renfrew, Calabogie, and Bancroft, and thence through south Haliburton county.

Outside the southeastern Ontario zone, there are many other occurrences north of lakes Huron and Superior. Although the eastern Canada types of deposit are usually met with in this region, true vein deposits associated with quartz and metallic sulphides are numerous, and somewhat resemble the types found in British Columbia. Very little work has been done in connexion with these occurrences. There has been almost no production and the deposits on the whole are not very encouraging. Reliable information is scarce, and their possibilities have been discounted through lack of transportation and inaccessibility. Among those of promise are the Kakabeka Falls and Loon Lake deposits in Thunder Bay district, and the Net Lake deposit in Nipissing district.

The first three recorded occurrences of molybdenite in Canada were from Ontario, when in 1852 the mineral was discovered at Terrace cove, lake Superior; Mud Turtle lake, Laxton township; also near Michipicoten harbour, lake Superior. The first Canadian shipment recorded was in 1902, by John Webber, and was probably from the old Mud Turtle Lake mine.

The following table shows the Ontario molybdenite production, the figures for which have been compiled from the annual reports of the Ontario Bureau of Mines:—

TABLE VIII

Ontario Molybdenite Production

Year	Employees	Wages	Concentrates	Value
	No.	$	Pounds	$
1902			900*	400
1903			2,500**	1,275
1914			20	15
1915	95	22,061	15,470	14,099
1916	169	94,082	24,562	26,393
1917	196	116,382	77,517	108,501
1918	92	69,907	47,614	59,067

* Estimated from 3¼ tons of picked ore and flake.
** Estimated from 85 tons of ore.

In the following pages will be found a general tabulation of about 120 occurrences and deposits in the province with descriptions of those of the most probable importance.

Frontenac County

Olden Township

Concession VI, S. 1/2 Lot 7, Macdonnell Property.[1] This property is situated 5 miles by motor road, southeast of Mountain Grove. A 5-foot pit 12 feet long has been dug in a small patch of limestone and pegmatite near a granite contact. The ore is associated with pink feldspar and pyroxene, very little pyrites and no mica being observed. In 1915, Mr. G. M. Macdonnell sent 238 pounds of 0·4 per cent MoS_2 ore to the Mines Branch testing laboratories, Ottawa. The occurrence is at present of no commercial value. Adjacent contacts might be prospected, but are not promising.

Concession VI, Lot 6, Smith Property. The adjoining lot to the south of the Macdonnell property was worked in 1917 by Ed. Smith, of Perth, who states that there is a wide granite-limestone contact vein half a mile long. According to J. C. Gwillim[2] this occurrence is in a patch of Grenville rocks in granite-gneiss. The pit, which is 20 by 4 feet and 8 feet deep, is in a hornblendic rock, granite occurring a few feet to the north and south of it.

In May, 1917, 1,000 pounds of 0·27 per cent ore, and in June, 150 pounds of 0·06 per cent ore were sent to the Mines Branch, Ottawa. The grade of these shipments, as well as the opinion of engineers, would indicate the improbability of obtaining good ore, in the immediate neighbourhood of where work has been done.

Miller Township

Northeast Range, Lot 5, Kring Prospect[3]. Dr. Walker states that molybdenite occurs in a pegmatite dike of 8 feet maximum width. Four pits were opened up about 1901 and although the mineral was found as an alteration product in all of them, the quantity does not appear to have been great. Specimens from this prospect were exhibited by the Ontario government at the Pan-American Exhibition. Three-quarters of a mile to the northeast, approximately along the strike of the gneiss, there is a narrow dike carrying some molybdenite and black tourmaline. Prior to 1900 a little work was done by Messrs. Elkington and Tooley.

On lot 5, southwest of the Frontenac road, three pits were sunk by Mr. G. C. Shannon of Kingston in a pegmatite dike cutting gneiss. Two of these pits are 30 feet long and 10 feet in depth at the deepest portion, and the other is 12 feet square; all are connected by surface trenches. A little molybdenite was found in the pits and a small amount of perhaps 1 per cent ore was laid aside on the dump.[4]

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[1] Mun. Res. Comm., Can., 1920, p. 116. J. C. Gwillim.
[2] Mun. Res. Comm., Can., 1920, p. 117. J. C. Gwillim.
[3] Molybdenum Ores of Canada, 1911, p. 44. T. L. Walker.
[4] Ontario Bureau of Mines, 1917, p, 305. A. L. Parsons

Haliburton County

Cardiff Township

Concession V, Lot 11, Orr-Kidd Prospect. This prospect is situated on one of Mr. Kidd's farms, one-half mile from the road, north of Paudash P.O. The deposit consists of two pegmatite dikes, 6 inches and 2 feet wide respectively, cutting gneiss. The pegmatite is impregnated with fine-grained iron pyrites and a small amount of molybdenite in large flakes. Mr. F. O. Orr, of Montreal, obtained a number of very large perfectly formed crystals from this deposit. An open-cut 55 feet long, 4 to 6 feet wide, with an average depth of 5 feet, has been made along the pegmatite zone. At the upper end of the cut which is here about 10 feet deep the best ore is found. (See sketch map of area, Figure 9.) At the south end of the cut, the pegmatite is crossed by a vein of biotite mica beyond which there is very little molybdenite. Mr. Kidd states that 50 pounds of pure flake was picked from this showing.[1]

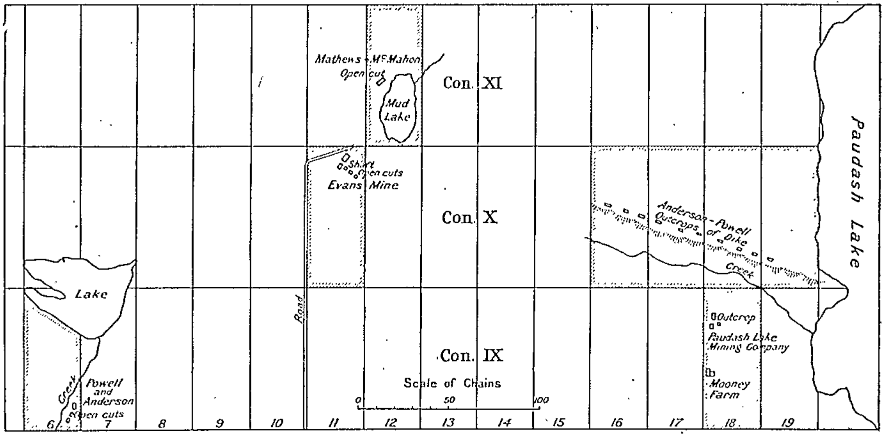

Figure 9. Molybdenite prospects in the Paudash Lake area, Cardiff township, Haliburton county, Ont.

The ore is low grade, but because of size of flake it would be easy to hand-pick, and on this account the property might be worth further prospecting.

Concession IX, N. 1/2 Lot 18, Paudash Lake Molybdenite Company. This property is located on the farm of Mr. John Mooney, one-half mile west of Paudash lake. There is an outcrop of coarse, grey pegmatite granite, in contact with, and lying on top of, banded gneiss. Within this granite there are one or more irregular quartz veins. The molybdenite occurs in large flakes sparsely disseminated in the pegmatite, and in the quartz; very little pyrites is present. The molybdenite is segregated in places, making it easy to cob.

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[1] Ontario Bureau of Mines, 1917, p. 294.

The work which was done in the fall of 1917 by Mr. W. E. Joiner, consists of three pits opening up the mineral zone. These pits are 75 by 15 feet and 7 feet deep; 50 by 30 feet and 10 feet deep; 15 by 15 feet and 7 feet deep. (Figure 10.)

The main pit is connected with an ore-sorting shed by 100 feet of tramway. Several tons of selected ore averaging between 3 and 4 per cent are stored in the shed; besides this, several hundred pounds of pure flake averaging over 90 per cent MoS_2, was sent to the United States.

Not enough development work has been done to determine the true character of the ore-body, but it would appear that it is only a surface deposit. There is plenty of timber and water a short distance from the workings. This property was bought by W. E. Joiner, of Toronto, who formed the Paudash Lake Molybdenite Company, with Mr. H. A. Soverhill as secretary-treasurer.

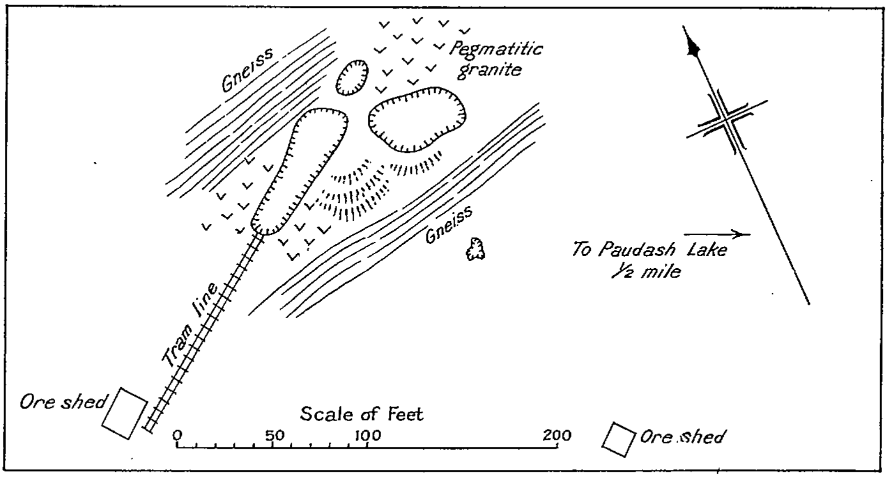

Figure 10. Paudash Lake Molybdenite Co., (Mooney prospect), Cardiff township, Haliburton county, Ont. (August, 1921.)

Concession IX, S.E. of Lot 6, Powell and Anderson Prospect.[1] This prospect occurs on another of Mr. Kidd's farms about 15 miles southeast of Wilberforce station on the Ottawa, Irondale and Bancroft railway. Within the gneiss there are two parallel pegmatite granite dikes, each about one foot wide. Small amounts of molybdenite have been found in several places along the dike. At one place in an open-cut there is a band of micaceous rock containing an appreciable amount of the mineral. Several chunks of molybdenite weighing over one pound have been found, and on the occasion of the writer's visit, a sack of pure flake, made up of crystals one inch in diameter, was shown by Mr. Kidd as coming from this prospect. There are three open-cuts, the largest being 40 feet by 8, and 10 feet at its deepest portion.

No shipments have been recorded. This claim might be considered worthy of further attention.

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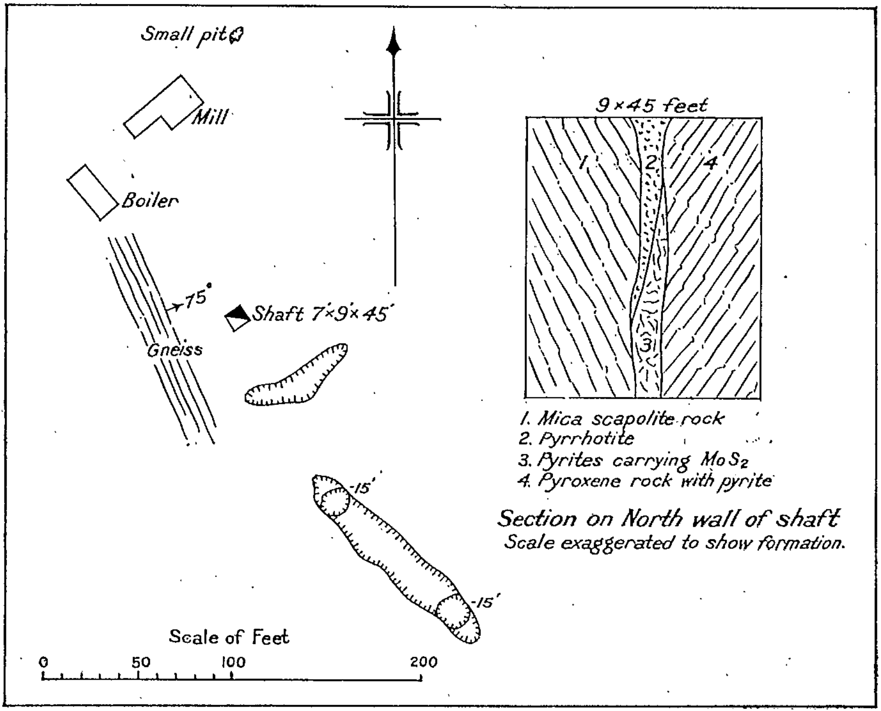
[1] Ontario Bureau of Mines, 1917, p. 294.

Concession XI, N.W. Corner Lot 12, Mathews-McMahon Prospect.[1] The property is situated on the west side of Mud lake, about 10 miles by road, southeast of Wilberforce station.

Large flakes of pure molybdenite weighing several pounds were taken from this property. The only work done consists of two small open-cuts on the contact of a pegmatite dike, 50 feet wide, cutting gneiss. More ore may be found along the pyroxene contact of the dike, and since where the latter is finer grained the mineral is likely to be more uniformly disseminated, this part of the dike is worthy of further prospecting.



Section on North wall of shaft
Scale exaggerated to show formation.

Figure 11. Evans mine (Treasure Hill), Cardiff township, Haliburton county, Ont. (August, 1921).

Concession X, Lots 11-15 and Concession XI, Lots 11-12, Evans mine. The main workings on these properties, sometimes also known as the O'Brien, or Treasure Hill mine, are on N. ½ lot 11, concession X, and are situated within 200 yards of the road, about 12 miles southeast of Wilberforce station.

The deposit occurs near the contact of granite and gneiss in which bands of crystalline limestone are prominent. In the main showings, pyroxenite, pyrites, pyrrhotite, and molybdenite occur on the contact between a reddish pegmatitic phase of the granite and the gneiss. These

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[1] Loc. cit.

contact bands are in places hidden by a capping of the gneiss. The molybdenite is either pockety, or very low grade when it occurs with the other sulphides.

The work done consists of a shaft 7 by 9 feet and 45 feet deep, started in 1907, and two open-cuts 50 by 120 feet long, excavated in 1910 and 1914. (Figure 11.)

In the open-cuts, massive bands of pyrrhotite carrying a little molybdenite are exposed. The shaft was full of water at the time of the writer's visit; but it is stated by Dr. Walker[1] that although the surface showing, consisting chiefly of pyrrhotite, was only one inch wide, at the shaft bottom it was 20 inches wide and carried molybdenite. This vein analysed 4·2 per cent MoS_2. In the open-cuts, it was observed that the molybdenite in many cases penetrated about one foot into the pegmatite. These pits are in almost solid iron sulphides and very little molybdenite is seen. There are other showings at the contacts between the granite and limestone. The deposit is in formations favourable for molybdenite and is worthy of more attention.

A small concentrating plant was erected, consisting of a Wettlaufer jaw-crusher, 12-inch rolls and screens, power being derived from a 40 h.p. loco-type boiler. The ore was all hand-sorted, crushed and rolled, and the products passed over a 10-mesh screen. The material remaining on the screen consisted of a rough concentration of molybdenite flakes and was sacked and shipped. About 150 tons of ore was treated, and the resulting ton of concentrates was shipped to Toronto.

The buildings have all fallen down, and the boiler is about the only piece of machinery left on the property. About 20 tons of crushed low-grade ore is in the old bin. Timber and water are abundant.

The property was staked about 20 years ago by Mr. Alex. Evans, who in 1910 shared it in partnership with several others, including Messrs. Elliott and Dwyer of Wilberforce. In 1913 an option was taken by M. J. O'Brien, who completed sinking the shaft and dug some pits.

The present owners are Messrs F. D. S. Robertson and A. H. Crichton, of Toronto, who discontinued work after the outbreak of the war.

Concessions XX and XXI, Lots 2 and 3, Joiner Property. This property, owned by W. E. Joiner, Toronto, is situated about two miles east of the American Molybdenite plant and three-fourths of a mile south of the railway at a point two miles northeast of Wilberforce station.

A portion of the above claims was staked and prospected by Mr. W. E. Joiner, in 1917. In 1919 the Cardiff Molybdenite Mines, Ltd., capitalized at $40,000 with Mr. Joiner as general manager, was formed with the object of defining the ownership. In January, 1922, a new company called the United Molybdenum Corporation, Limited, capitalized at $750,000, was formed, 300,000 shares of stock being issued to the Cardiff Molybdenite Mines, Ltd., for their properties, consisting of 400 acres. It is the intention of the new company to erect a mining and milling plant at a future date.

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[1] Molybdenum Ores of Canada, 1911, p. 42. T. L. Walker.

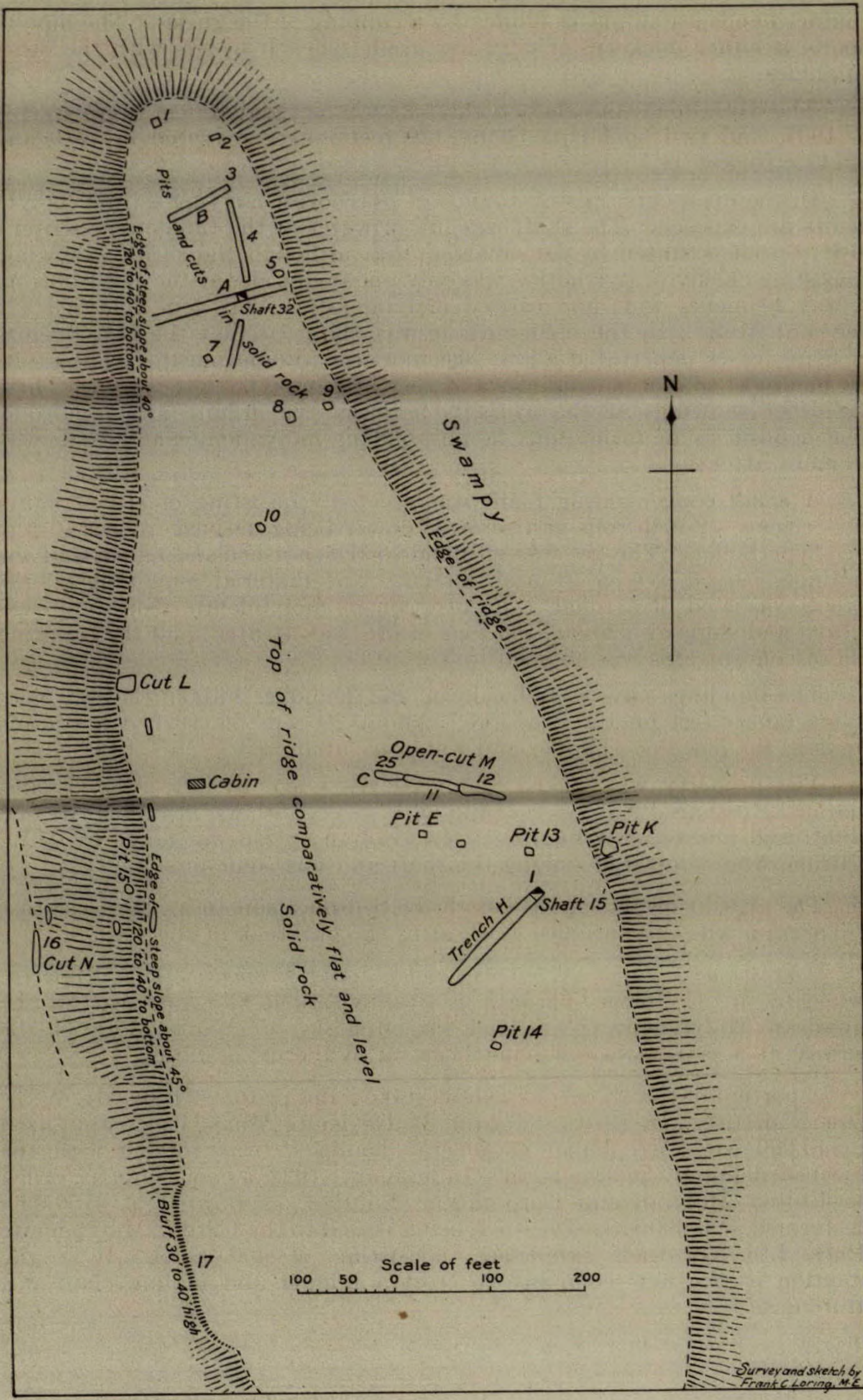

Figure 12. Sketch showing ridge carrying molybdenite, Joiner molybdenite property, Cardiff township, Haliburton county, Ont.

On the eastern side of a long, wide limestone ridge there is a steep bluff of hornblende-granite rock about 1,500 feet in length and 270 feet wide, striking parallel with the limestone. Flakes of molybdenite appear to be scattered throughout the whole of the granite ridge.

A large amount of development work has been done in prospecting the property. The workings which are on the top of the ridge, consist of two shafts 30 and 15 feet deep; 200 to 300 feet of deep wide trenching; open-cuts in various directions; and about 20 pits. (Figure 12.)

Rich ore is reported to have been taken from the bottom of the shaft at the north end of the ridge where most of the work has been done. The molybdenite here occurs as large flakes and is more pockety than at the south end, where in most places it is disseminated as minute crystals throughout the rock. Showings of molybdenite are stated to occur in other dikes in the vicinity.

On the exposed rocks on the surface of some parts of the ridge, hardly any traces of the mineral are to be seen, and its presence is revealed only after about a foot of rock has been removed. Evidences of surface decomposition were observed in which individual flakes were in the process of alteration to greyish white powder, samples of which were tested in Ottawa, and proved to be powellite (calcium molybdate). Representative samples taken from different parts of the ridge varied from 0·30 to 0·75 per cent MoS_2, and a 0·5 per cent mill feed might be obtained without much sorting.

It cannot be stated that the whole mass contains this percentage of molybdenite, but the nature of the ore encountered in the bottom of the shaft is encouraging, and almost every pit on the top of the ridge shows a fairly even distribution of the mineral. The property could be best proved by diamond drilling or by driving a tunnel into the side of the hill. From the work done, there is little doubt that there is a large tonnage of low-grade ore which could be economically mined, milled, and transported.

In 1920, 30 tons of 0·31 per cent ore, and in 1921, 600 pounds of 0·53 per cent ore, were sent to the Department of Mines at Ottawa for testing, and proved to be ideal for concentration. Although this deposit is of low grade, it is so well situated that it may well be considered worthy of further development with a view to operating on a large scale.

Harcourt Township

Concession I, Lots 3 and 4, Harcourt Mine. This property, owned by the Canadian Land and Immigration Company of Haliburton, Ltd., is situated on the southwest shore of Farquart lake, 3 miles north of Wilberforce station. The mineral occurs in two parallel zones, separated by a hard, light green pyroxenite rock. One zone contains pyrites and marcasite, with a little molybdenite in large flakes and many veins of pyrites that are free of molybdenite, and the other, pyrrhotite and chalcopyrite, with some molybdenite in stringers. There does not appear to be any dissemination of the molybdenite into the pyroxene or pegmatite.

Most of the mining was done in 1898 and 1901 under the management of S. Dillon Mills,[1] who wrote a concise description of the property. A pit

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[1] Ontario Bureau of Mines, 1902, p. 47.

12 feet deep was sunk at the south end without encountering much ore, and a shaft 7 by 8 feet and 15 feet deep was sunk in the northern portion, but the ore was of too low grade. (Figure 13.)

Most of the mineral was found on the east side of the bluff, where a cut 60 feet long and 6 feet wide, and in some places 15 to 20 feet deep showed four or five pyritic seams carrying molybdenite. A few hundred feet to the south promising looking ore was taken out.

About 2 tons of cobbed, high-grade material is still lying on the dump. No shipments have been made other than 50 pounds of flake taken out for experimental purposes by an English steel company in 1911. The Harcourt mine appears to be on a continuation along the strike of the Joiner ore-body, which is 3 miles to the south.[1]

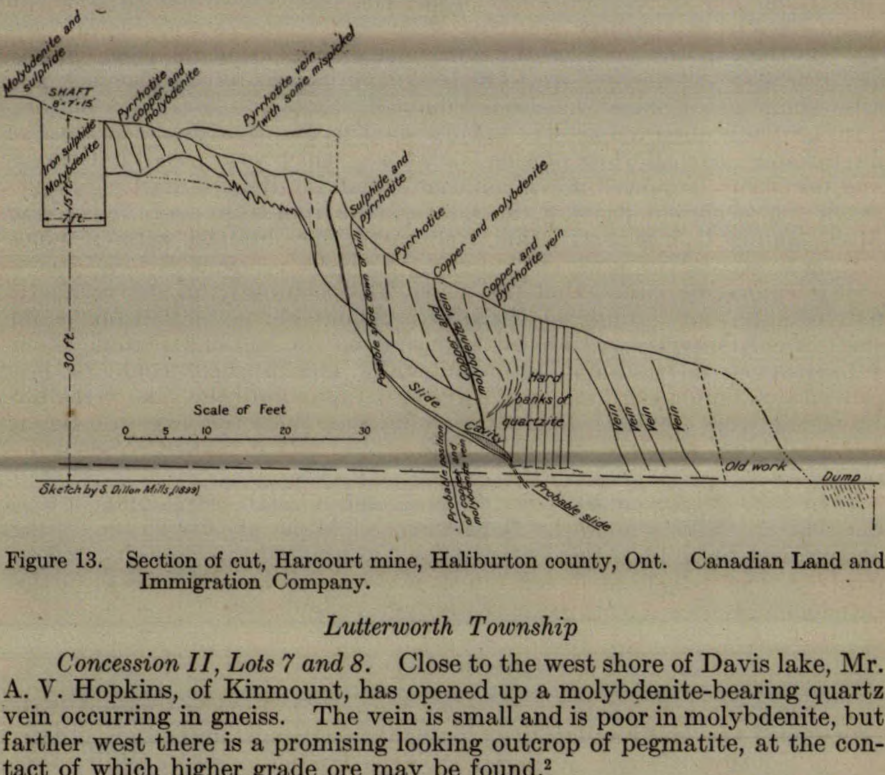

Figure 13. Section of cut, Harcourt mine, Haliburton county, Ont. Canadian Land and Immigration Company.

Lutterworth Township

Concession II, Lots 7 and 8. Close to the west shore of Davis lake, Mr. A. V. Hopkins, of Kinmount, has opened up a molybdenite-bearing quartz vein occurring in gneiss. The vein is small and is poor in molybdenite, but farther west there is a promising looking outcrop of pegmatite, at the contact of which higher grade ore may be found.[2]

Concession V, Lot 23, Hamilton Molybdenum Alloys Co., Ltd. This company's most northerly property is located on James Bryant's farm on the northwest shore of East Moore lake, 8 miles west of Kinmount station. Other properties are owned by this company on Mud Turtle lake, in Laxton township. (See Horscroft mine.)

A number of parallel dikes from 25 to 50 feet wide traverse the East Moore property, and where some of them merge to a point, fairly rich ore was found. In 1916 and 1917 a shaft 6 by 12 feet and 30 feet deep was

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[1] Ontario Bureau of Mines, 1917, p. 298. A. L. Parsons. Geol. Surv., Canada. Mem. 6, p. 350.
[2] Ont. Bur. of Mines, 1917, p. 302. A. L. Parsons.

sunk. Apparently very little ore was extracted and none was shipped. Mr. James Harris states that they are pleased with the prospects and will continue sinking as soon as the market justifies re-opening. This is known as the Hamilton mine No. 2.

Concessions IV and V, Lot 19. W. G. Miller in his report on Limestones of Ontario, in 1904[1], mentions the presence of molybdenite disseminated through impure crystalline limestone south of Miners bay. It is believed that this deposit was mistaken for silver by the old prospectors, since rumours of the existence of silver in this region have not been verified.

Monmouth Township

Concession XII, Lots 14 and 15, Lillico Mine. This deposit, locally known as the Burrows property, is owned by the Ontario Molybdenum Company and lies on top of a plateau near the road, 1½ miles northwest of Tory Hill station on the Canadian National railway.

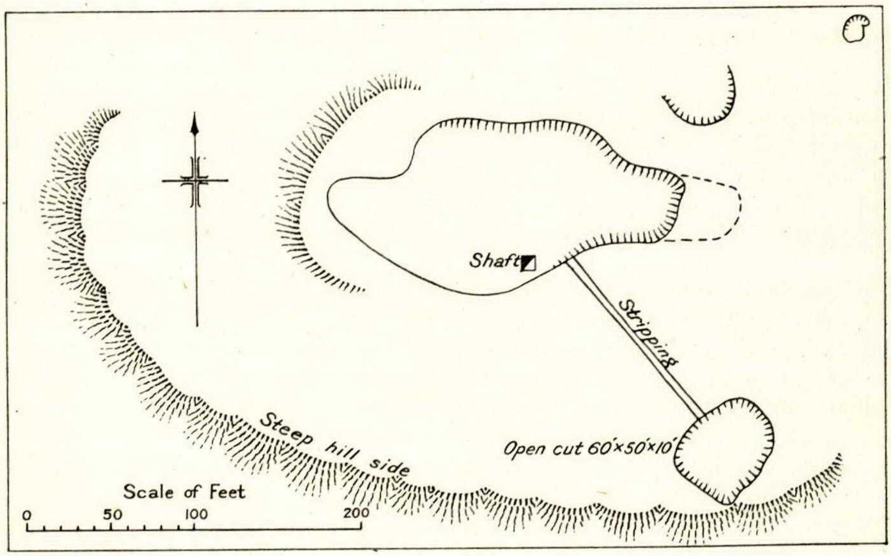

Figure 14. Ontario Molybdenite Co., (Lillico mine), Monmouth township, Haliburton county, Ont. (September, 1921.)

The rocks in this region consist of gneiss, reddish granite, and pegmatite dikes, and in places, very hard quartzite. The mineral zone occurs in flat-lying belts of heavy rusty sulphide ore, in which molybdenite, in large bright flakes, is associated with pyroxenite, pyrrhotite, and pyrites.

The workings, which are on the north half of lot 14, consist of large shallow open-cuts and pits. The most westerly cut, in which the richest ore was found, is some 200 feet long, 100 feet wide, and 8 feet deep at the face. Another pit is 60 by 50 feet and 10 feet deep, and there are several other smaller pits at various points in the mineralized area. A small shaft in the main quarry was full of water at the time of the writer's visit. (Figure 14.)

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[1] Ont. Bur. of Mines, 1904, p. 57 B.

Several diamond drill holes were put down by a Mr. Johnston. All records have been lost, but it was stated that some molybdenite was found in the cores.

During 1917 and 1918, 3,000 tons of rock and ore were mined and about 157 tons ranging from 0·27 to 5·20 per cent was sent to the Mines Branch concentrator at Ottawa. From these shipments 1,562 pounds of molybdenite was recovered. There is still a considerable quantity of low-grade ore on the dump.

It would appear that the best ore has already been extracted, but from the geological relation of the rocks it is quite possible that more ore-shoots may occur in this area.

The property belonged to Mr. A. Gibson, of Tory Hill, and was worked by Mr. R. J. Lillico, of Toronto, who is now president of the Ontario Molybdenum Company, incorporated in 1917, the present holders.

Concession XIII, Lot 13, Gibson Prospect.[1] This property also was at one time worked by the Ontario Molybdenum Company and is about one mile north of the Lillico mine. There is an outcrop of pyroxenite in granite, along the contact of which molybdenite occurs. This contact has been traced for a considerable distance. The work, which was done in 1916, consists of a quarry on the outcrop, 50 feet long with a face 10 feet high.

Thirteen hundred pounds of hand-picked ore, running 3·85 per cent, was sent to the Mines Branch, Ottawa, by Mr. George Padwell, who had an option. About 15 tons of ore, averaging a little over 1·0 per cent, is on the stock pile.

The deposit is very similar to the Lillico and there is a probability of finding more ore on the property.

Concession XIV, Lot 10. There is a showing of molybdenite owned by Mr. William Madill, of Essonville, which has only been slightly explored by a few shots. This may be a continuation of the Padwell deposit, which is about one-fourth of a mile to the northeast.

Concession XV, Lot 11, Padwell Property. The workings on this property are in an open field about 100 yards north of the road, 1½ miles west of Essonville.

On the contact of a white crystalline limestone and granite, there is a flat zone of weathered mineralized pyroxenite. The foot-wall is white limestone, and the hanging-wall, syenite gneiss. The mineralized zone consists of about two feet of pyrite and pyrrhotite, with a band of decomposed pyroxenite, and a band of pink calcite about 8 feet thick. The molybdenite is found in small scattered pockets within the pyroxenite and the sulphides, with a few flakes in the calcite. The ore, however, is too low grade for straight milling, but could be hand-picked to run 1½ to 2 per cent MoS_2.

An open-cut, on the outcrop, follows south along the dip of the ore-body, for a distance of about 70 feet, and is 30 feet wide, and at the south end of the face is about 15 feet deep, nearly the whole floor being in white limestone. The showing of the ore in the face looks as if the ore-body might continue, but the sides are decidedly lean.

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[1] Ont. Bur. of Mines, 1917, p. 307.

In November, 1916, 55½ tons of hand-picked ore, running 1·4 per cent MoS_2, was sent to the Mines Branch concentrator, Ottawa, from which 1,268 pounds of molybdenite was recovered. During 1917, 62 tons of 1·0 per cent MoS_2 ore was sent to the International Molybdenum Company's concentrator at Renfrew.

An option was held on this property by Mr. George Padwell, by whom the above shipments were made. Later it reverted to Messrs. Frederick Bradley, of Essonville, and Leonard Reel, of Tory Hill. At the present time Mr. C. W. Godfrey, of Wilberforce, is believed to have an option on the property.

The prospect of finding much more ore in the immediate vicinity of the pit is not very encouraging; on the other side of the road, however, where the hill slopes down, about 150 yards to the south of the pit, the geological conditions favour the finding of other ore-bodies.

Concession XV, Lot 32, and Concession XVI, Lot 32, American Molybdenites, Ltd. The property belonging to this company consists of about 100 acres along the railway, one-fourth of a mile south of Wilberforce station. The ore-bearing zone consists of a wide ridge or dike of massive white feldspathic rock, evenly spotted with green pyroxene crystals and sparsely sprinkled with large flakes of molybdenite. An examination of the six or seven workings and rock piles did not show any rich pockets of ore, and because of the disseminated nature of the flakes, it is doubtful if it would pay to hand-pick. The ore exposed at the time of the visit probably would run about 0·25 per cent. It was stated that some richer ore had been mined, but the showings where this came from were then buried under debris. Some diamond drilling had been done, but no satisfactory records of the results could be obtained.

The work done consists of two shafts, one 30 and the other 40 feet deep, two pits, and three fairly extensive strippings.

During 1918 a 125-ton concentrator using Callow oil flotation process, office buildings, etc., were erected.

The ore is hoisted in a 1¼-ton skip from the mine workings, up a 10-degree tramway to a 200-ton mill bin. It is crushed by jaw-crushers and a Marcy ball mill, classified and passed over Callow cells, and the concentrates dried in a brick oven. Previous to the erection of the concentrator about 900 tons were mined in 1917, from which 86 tons of ore were shipped as follows: to the Mines Branch, Ottawa, 58·6 tons of 0·21 per cent ore; and to Renfrew, 27·2 tons of 0·39 per cent ore. About 320 pounds of molybdenite was recovered. Besides this, some ore was treated in the mill, which ran only for a short time, but no information concerning results was obtained. During the summer and autumn of 1921 more stripping was done, and the concentrator ran for a short time, but so far as can be ascertained the results were not very satisfactory.

The originally named Dominion Molybdenites, Ltd., was incorporated in May, 1917, for $1,000,000. Messrs. J. J. Gray, W. J. L. Mackay and P. J. Dwyer,[1] of Toronto, were interested in the company. In August of the same year the name was changed to American Molybdenites, Ltd. In the summer of 1918 an option was given to the Molybdenum Products Company, which was incorporated in July, 1918, with Mr. O. D. Walters

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[1] Can. Min. Jour., July 15, 1917.

as president, and Mr. M. B. R. Gordon, managing director. This company did some development work and built the concentrator. The property has since reverted to the American Molybdenites, Ltd.

At present, the power plant on the property consists of one Jenkins 150 h.p. and one Goldie and McCulloch 180 h.p.; also one 135 h.p. Wheelock-Goldie and McCulloch compound engine, and one 50 h.p. Eric engine.

Concession XV, Lot 32, and Concession XIV, N. ¼ Lot 33, Wilberforce Molybdenite, Ltd. This property lies on the adjoining lots, south of the American Molybdenites, and the workings are on a bare knoll 100 yards to the west of the Wilberforce road.

The deposit is thought to be a continuation of the molybdenite-bearing ridge of the neighbouring property, but the ore-body is slightly different. It is a mineral zone, rich in mica, and carrying pyrites, pyrrhotite, and pyroxenite, with bands of gneiss. The molybdenite occurs as large crystals very sparsely disseminated throughout the mass. The whole zone is highly altered and weathered to a characteristic rusty appearance.

In the fall of 1918 four or five cuttings were made on the top of the knoll, the largest of which is 100 feet long and 10 feet deep. There is a fair amount of low-grade ore on the dump, but there are no records of shipments having been made.

The company, in which Messrs. Henry C. Secord and A. Burgess of Toronto are directors, was incorporated in June, 1918. Steps have been taken to merge this property with the American Molybdenites, Ltd., and the Dwyer prospect. All of these properties are within easy access of one another and appear to be in the same mineral zone, which, taken as a whole, is a pyroxene-quartz-albite formation. This zone is a contact between granite on the west and crystalline limestone on the east.

Concession XVII, Lot 32, Dwyer Prospect. This deposit, which is immediately to the north of the above, has some molybdenite showings in a similar rock. It is understood that this property was also under option to the Molybdenum Products, Ltd. Mr. P. J. Dwyer, of Wilberforce, who worked this property in 1921, states that the ore-body is wide and is a continuation of the Wilberforce Molybdenites and the American Molybdenites ore-bodies. The work done consists of an open-cut, 25 feet deep, on the hillside, and a few pits on surface outcrops. The small amount of ore extracted was not shipped.

Hastings County

Dungannon Township

Concession XVI, N. ½ Lot 5, Stoughton Prospect. This property, which is 8 miles northeast of Bancroft, was worked for short periods from 1917 to 1920, by Messrs. J. Waring of Madoc and A. A. Stoughton of Bessemer.

J. C. Gwillim, who examined the property in 1917, stated that a few shallow pits were sunk on the exposed main pegmatite ridges that intrude crystalline limestone and gneiss.

The present workings consist of two trenches, 30 and 20 feet long, and 2 to 3 feet deep. The ore-bodies so far opened up do not appear to have much commercial value. There are a few camp buildings on the property.

The Bancroft Mining Company took an option in 1917, and, early in 1918, 694 pounds of hand-picked ore, running 4·19 per cent, was sent to the Mines Branch plant, Ottawa, from which 28 pounds of molybdenite was recovered and sold.

The officers of the company are Messrs. C. DeWolf Reid, of Montreal, president, and P. C. Armstrong, vice-president. Lot 6 of the same range was staked by Mr. Stoughton for the Bancroft Mining Company, but no work was done.

Herschell Township

Concession IV, Lots 27 and 28, Williams Prospect. This showing occurs just north of the railway, 2 miles west of Baptiste station. No work has been done outside of putting a few shots into the outcrop and extracting 200 or 300 pounds of ore running high in molybdenite, which was sent to the Tivani ferro-molybdenum plant in 1918. Mr. J. W. Evans, the manager of the above plant, who visited the property, found much molybdenite float in the area. Because of the amount of overburden present considerable work would be required to prove the extent of this deposit.

Kenora District

Gull Lake

Molybdenite was discovered by Mr. C. Coates, of Dryden,[1] at a point one mile south of the end of Gull lake, a large lake about 15 miles northeast of Dryden station on the Canadian Pacific railway.

Pegmatite dikes, rich in quartz and feldspar, intrude a hornblende schist and follow along the general strike. In one of these dikes, which is 6 feet wide and 50 feet long, molybdenite occurs associated with mica. A small test pit 3 feet deep has been sunk on this dike and some molybdenite extracted, but none was shipped.

Dr. Walker states that samples, said to have been taken from this locality in 1910, were the most promising seen by him in the whole region.[2] Small occurrences of the mineral were also found in some of the other pegmatite dikes.

Manitou Lake Region

Pidgeon Prospect. This property is on the old mining claim A.D. 8, situated on a small lake west of Upper Manitou lake, about 25 miles due south of Dryden station, and was restaked in 1915, by Mr. E. D. G. Pidgeon, of Wabigoon.

In the Precambrian granite there is a quartzose-pegmatite dike, about 10 feet wide and 250 feet long, that carries chlorite, bismuthinite, mica, and molybdenite. The latter mineral occurs in intimate association with the chlorite. The chlorite which occurs in masses is probably altered country rock. In the immediate neighbourhood there is a dark basic hornblende rock.

Beyond a little assessment work which yielded about 200 pounds of high-grade samples no further development was done in 1920.

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[1] Ont. Bur. of Mines, 1917, p. 297.

[2] Molybdenum Ores of Canada, 1911, p. 49. T. L. Walker.

Lennox and Addington Counties

Sheffield Township

Concession XII, Lots 9 and 10, Calvert Prospect. In 1917, Mr. W. R. Kelly, of Tamworth, did some work for the Cameron Mining Company on a showing of molybdenite on Calvert's farm, 5 miles northeast of Tamworth station, and 3 miles west of the Chisholm molybdenite mine.

As a result of surface strippings, one ton of 0·91 per cent ore was sent to the Mines Branch, Ottawa, from which 13 pounds of pure molybdenite was extracted.

Concession XIII, Lot 12, Kellar Prospect. This deposit is about 5 miles northwest of the Chisholm mine. Work was done in 1916 by the O'Briens-Greenfield Company, of Superior, Wisconsin. There appears to be three series of deposits, one of which is on a contact between granite-gneiss and limestone. The molybdenite occurs in seams and fine cracks along this contact, but the mineral does not penetrate far into the rock. Another deposit is in a pegmatite dike within the gneiss, where the molybdenite is confined principally to quartz stringers, together with feldspar, pyrite, and calcite. The richest deposit is in the granite gneiss about 50 feet from the contact; it seems, however, to be only a local concentration. In 1916 about 160 pounds of pure flake molybdenite was taken out.

Concession XIV, Lot 5, Chisholm Mine. This mine, which now belongs to the Sheffield Molybdenite Company, Ltd., is on Timothy Dwyer's farm, 6 miles north of Enterprise station on the Bay of Quinte branch of the Canadian National Railway, and 4 miles west of Wilkinson on the Canadian Pacific. The company owns about 497 acres.

The ore-bearing zone occurs within Grenville limestone surrounded by red granite. The granite outcrops several hundred feet to the east of the property. The original outcrop, which was located in 1904, was almost entirely covered by a capping of crystalline limestone, the remnants of which are still clearly seen on the edges of the pits. The ore-body is broken by horses of limestone. The molybdenite is associated with a heavy sulphide ore, containing much iron pyrites and pyrrhotite, also pyroxenite. The flakes of molybdenite are large, and the ore is much heavier than that obtained from the average Renfrew mines.

During 1904 the late Mr. Chisholm did a considerable amount of work on the property and sunk a pit 50 feet in diameter and 10 feet deep. In 1915, when work was re-started, another pit was sunk on the ore-body, separated from the old pit by what was thought to be a 20-foot band of limestone. This proved to be only a capping and both pits are now joined, exposing a fairly continuous mineralized zone. The two main excavations are each about 80 feet in diameter and 15 to 20 feet deep. (Figure 15 also Plate II.) The bottom of No. 2 pit, which at the time of visit was filled with water,[1] has been reliably reported to be solid, clean sulphide and pyroxenite vein materials.

During 1904, Mr. Chisholm mined about 600 tons of rock, from which 85 tons of picked ore was sold in the United States, for $1,275. A sample of this ore assayed at the Mines Branch, Ottawa, contained 1·75 per cent

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[1] Mun. Res. Comm., Can., 1920, p. 117. J. C. Gwillim.

MoS_2. In 1915 he shipped 18 tons to the Ottawa testing plant. This shipment was divided into, run-of-mine, picked ore, and ore at pit bottom, and the whole averaged 1·4 per cent MoS_2.

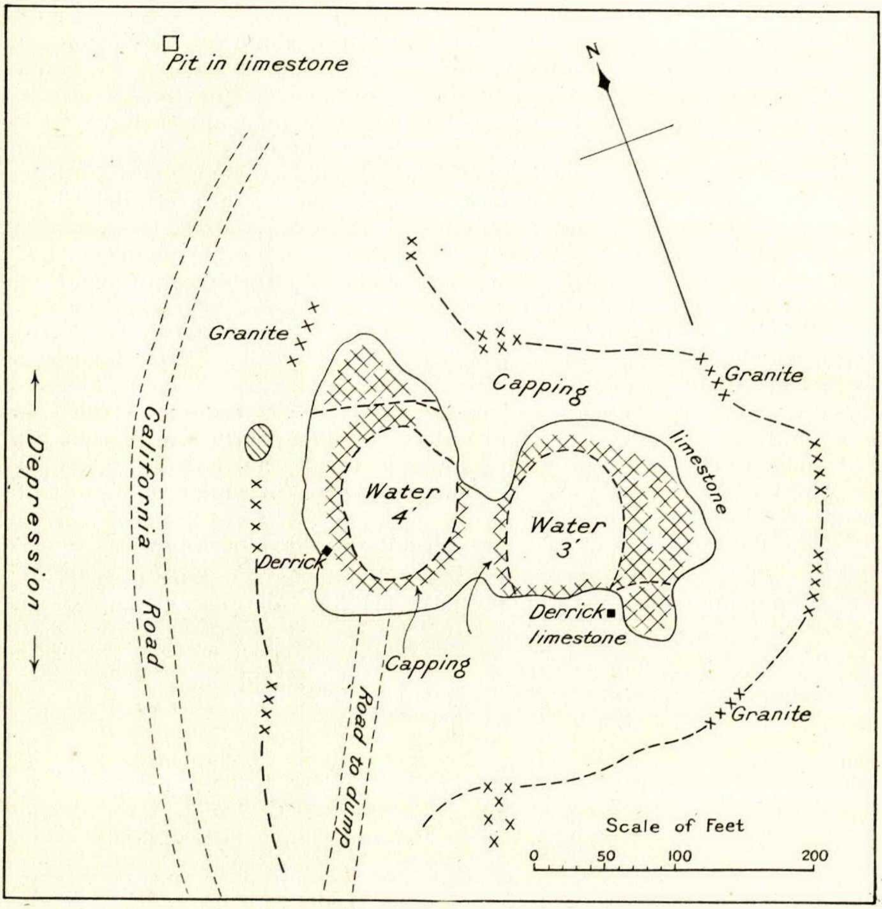

Figure 15. Chisholm pits, Sheffield township, Addington county, Ont.

During 1916 the International Molybdenum Company of Renfrew had an option on the property, and sent about 235 tons of ore to their concentrator at Renfrew. Not much actual mining was done, as the ore chiefly came from picking over the stock piles. In January, 1917, Messrs. Chisholm and Seybold continued working, and erected a small cobbing plant, having a capacity of 25 tons in 10 hours, and consisting of a jaw-crusher, two sets of rolls, and two one-eighth-inch screens. A sample tested by the Mines Branch showed a feed of 0·46 per cent from which a concentrate of only 1·5 per cent MoS_2 was made. Re-milling these concentrates brought the grade up to 13·30 per cent MoS_2, with a recovery of only 35 per cent of the original MoS_2 in the ore. Improvements were made to increase this recovery and the feed was enriched by rough hand-picking. After treating a considerable quantity of the ore in this manner the company, in July, 1917, sent about 5 tons of these crude concentrates, running 5·8 per cent, to the Mines Branch, Ottawa. The fine material that passed through the screen, contained only a trace of molybdenite, and was sold as a by-product because of its value in pyrites, about 80 tons being sent to Grasselli Chemical Company. After Mr. Chisholm's death, in March, 1917, very little mining was done, but a 40-ton concentrator was erected containing two 10 by 16-inch jaw-crushers, Sturtevant rolls, a Groch flotation machine, Wilfley tables, etc. No ore appears to have been concentrated, but some of the tailings from the old cobbing plant were put through. Mr. V. R. Aufhammer, who was in charge, left before any results were obtained, and no further work was done on the property. In January, 1919, the Sheffield Molybdenite Mining Company, Ltd., was incorporated, with Messrs. J. A. Seybold, of Ottawa, as president, and H. C. Bellew, of Montreal, director.

J. C. Gwillim in his examination in June, 1917, estimated the area of the Grenville limestone to be, roughly, 200 by 300 feet, and that further extensions might occur in both directions of the strike. There is, however, no certainty of the depth of the mineral zone, as the remnant of the limestone may be shallow, and granite may closely underlie the present pits, but there is still some promising looking ore at the bottom of the pits. In a previous report Mr. W. B. Timm expresses a similar opinion of the property.[1]

About 10,000 tons of rock was estimated to have been removed at that date.

Shipments from this property have been as follows:—

Year	Ore	Per cent MoS_2	Shipped to
	tons		
1904	85	1·76	United States
1916	18	1·40	Ottawa.
	235	1·00	Renfrew.
1917	5	5·8	Ottawa—concentrates from cobbing plant.

From this 343 tons shipped, about 8,000 pounds of pure molybdenite was recovered. The 80 tons of pyrites fine ran 64·0 per cent sulphur.[2]

There is a good camp on the property and the company is provided with mining, drilling, and pumping machinery.

Concession XV, Lot 8, Spratt Prospect. Mr. L. L. Cailloux, in 1916, did some work on a showing of molybdenite that occurs on the farm of Mathew Spratt, two miles north of the Chisholm mine. An open-cut 10 by 20 feet and 10 feet deep was made in an oxidized zone along the contact of gneiss and limestone, from which a ton or two of low-grade ore was extracted. Very little molybdenite was seen on the walls of the pit.[3]

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[1] Mines Branch Sum. Rept., 1915, p. 88.
[2] Molybdenum Ores of Canada, 1911, p. 43. T. L. Walker.
Ontario Bureau of Mines, 1904.
Mun. Res. Comm., Can., 1920, p. 117. J. C. Gwillim.
[3] Ont. Bur. of Mines, 1917, p. 311. A. L. Parsons.

On one of Timothy Dwyer's farms on the same lot, a pit 8 by 10 feet and 10 feet deep was opened in crystalline limestone in 1916, and a little molybdenite was found, associated with pyrite, quartz, and tourmaline.

Concession XVI, Lot 15, Wager Prospect. This property is situated near the boundary of Hinchbrooke and Sheffield townships, 6 miles north of the Chisholm mine.

On a contact of gneiss and crystalline limestone there is a narrow band of quartz and pyroxenite in which molybdenite in small flakes occurs. The band has been traced for a distance of about 1,500 feet.

In 1915, Mr. Wager's farm was purchased by Messrs. Robert Gamble and J. H. Cameron, of Ottawa, and in the fall of that year work consisting of trenching in about half a dozen places and three open-cuts, was done on the contact. No shipments were made, except 286 pounds of 0·89 per cent ore which was sent to the Mines Branch, Ottawa, for testing purposes.

Mr. Gamble, who has prospected all through this region, stated that there were many showings of molybdenite within 6 miles of the Chisholm mine, and he considered that the most promising were on concession XIII, lot 10, on Timothy Molony's farm, and on concession XV, lot 12, on which there is a big oxidized zone.

Nipissing District

Calvin Township

Concession IX, N. ½ Lot 27, Talon Chute. Molybdenite has been reported near Talon chute in the Algonquin Park reserve, 25 miles east of North Bay. This property was worked by the Mattawean River Development and Mining Company. W. B. Timm, who visited the mine in 1918, reported that the supposed molybdenite found in the main workings on lots 28 and 31 was graphite. On the Gauthier claim, lot 27, a pit 20 by 6 feet and 6 feet deep was sunk in a mineralized zone of pyrrhotite, pyrites, quartz, and pyroxenite. A little molybdenite was observed, but was of too low grade to be of economic value.

About one mile west, on lot 31, a small molybdenite deposit, owned by Mr. M. J. Galvin, of North Bay, was worked during 1917 by Pennsylvania capitalists. No shipments were recorded.

Strathy Township

Net Lake, Barton Property. A molybdenite prospect was opened up about 16 years ago at a locality one-fourth of a mile east of the railway at Stop 76½, near the shore of Net lake, about 4 miles north of Timagami station on the Timiskaming and Northern Ontario railway. The molybdenite occurs as radiating nodules in a quartz-breccia and is accompanied by chalcopyrite. Dr. Walker[1] states that there are three areas of the brecciated ore enclosing a triangle of barren rock of about 200 square feet. The main ore-body, which is about 50 feet wide, is on the southern outcrop, and consists of poorly-defined gash veins of quartz in greenstone carrying chalcopyrite and molybdenite, with traces of gold. In 1906 a

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[1] Molybdenum Ores of Canada, 1911, p. 48. T. L. Walker.

50-foot shaft was sunk on this ore-body,[1] and 200 tons of rock and ore were removed, which are still on the dump. It was observed that the molybdenite is well distributed in the quartz, but its richness is deceptive. A. L. Parsons estimated that about one-fifth of this dump consisted of quartz that would assay about 1·0 per cent MoS_2. There are two other openings on the property, in which the veins, although of higher grade, are not more than a foot wide. Close to the shaft there is stated to be a well-defined vein, in which a rich mass of gold quartz was discovered.

The property was owned by the Gold Reef Company, Ltd., who, prior to the war, leased it to Mr. J. W. Barton, of Toronto. Mr. Barton also staked the four adjoining claims.

During operations in 1916 a good camp was erected, which has since been burned down, but there still remains a boiler, hoist, pump, and a substantial head-frame. Mr. Barton, previous to dropping his option at the end of the war, did a little work in 1917 and 1918, as a result of which he shipped to the Mines Branch, Ottawa, 1,216 pounds of hand-cobbed ore assaying 8·42 per cent MoS_2, from which 94 pounds of pure molybdenite was recovered.

Although the ore appears to be too low grade for milling purposes, it is easy to concentrate, or to hand-sort, and the property is advantageously placed as far as transportation, water, and timber are concerned.

Renfrew County

Admaston Township

Concession IX, W. ½ Lot 9, Gorman Prospect. This prospect is situated on the farm of J. O. Gorman, one mile east of Shamrock village, 9 miles southwest of Renfrew. The nearest shipping point is Opeongo station, 5 miles to the northeast.

The main work consists of an irregular pit on the south edge of the road, about 80 feet long, 12 feet wide, and 6 feet deep, with a 30-foot cross trench at the west end. About 100 yards to the west and 50 feet south of the road there is another pit 30 by 6 feet and 3 feet deep, from which the richest ore was obtained. (Figure 16.) The whole exposure is very much weathered and most of the molybdenite has been washed away. A few pockets of high-grade ore were observed, but unless very carefully selected it is probable that it would average under 0·5 per cent MoS_2.

The deposit was discovered about 60 years ago, when the road was being made, and it was then thought that the mineral was silver or lead, its true nature not being ascertained until about 10 years ago. In 1917, Mr. J. O. Gorman gave an option to Mr. A. J. Gravelle, of Ottawa, who with several others formed the Opeongo Mining Syndicate, and under this name shipped to the Mines Branch, Ottawa, in November, 1917, 21·72 tons of 0·38 per cent ore, from which 117 pounds of pure molybdenite was recovered. From this shipment and from personal observation, it would appear that the occurrence is not likely to be of economic importance.

Concession XIII, E. ½ Lot 8, Kiley Prospect. Molybdenite occurs on Patrick Kiley's farm, about 2 miles due north of Mount St. Patrick village, 12 miles southwest of Renfrew.

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[1] Ont. Bur. of Mines, 1917, p. 308. A. L. Parsons.

The country rock consists of bands of gneiss and limestone that have been cut by pegmatite dikes, the surfaces of which are much exposed and worn by glacial action. On the contact of a pegmatite and limestone band, whose general strike is east and west, there is a vein of pyrites and pyrrhotite carrying molybdenite. The deposit was accidentally discovered when sinking a well over 20 years ago, but the nature of the mineral was not known. Some 10 years later the well went dry and was lowered 5 feet, and an appreciable quantity of heavy sulphide ore, with molybdenite, was brought to the surface. About 2 tons of good grade ore, which was removed from the well at a depth of 15 feet, is now used to make a farm wall.

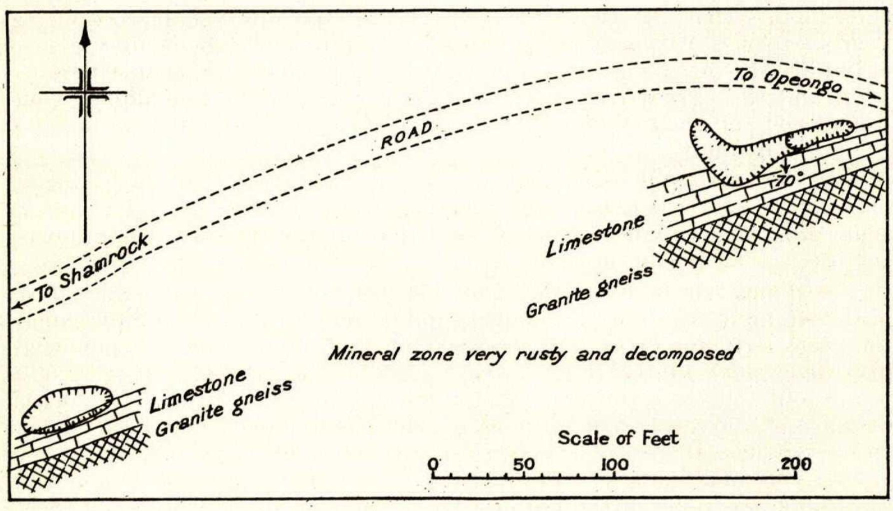

Figure 16. Gorman prospect, Admaston township, Renfrew county, Ont. (September, 1921.)

Bagot Township

Concession IV, W. ½ Lots 27 and 28, Phoenix Molybdenite Corporation, Ltd. Molybdenite occurs on the farms of William Warren about 4 miles northeast of Ashdad station.

On W. ½ lot 28, which was locally known as the Taylor mine, the country rock consists of a reddish granite, and bands of gneiss and limestone cut by irregular masses of pegmatite. Along the contacts of these bands there are numerous mineralized zones consisting of pyrites and pyroxenite, some of which contain molybdenite.

Messrs. Dietz and Keady, of Boston, who made a report on the property in the fall of 1914, state that nineteen of these contact veins have been discovered on lots 28 and 29, most of which are said to contain molybdenite.

Mr. Warren, who located the main outcrop consisting of one of these veins, sold the mining rights to Sir Henry Pellatt, in 1914. Work was done that summer and during 1915 and 1916 under the direction of Mr. M. J.

Paterson, of Toronto, who sunk a shaft and some test pits and did some stripping. From the ore mined, 2½ tons was hand-cobbed and shipped. During 1917 a considerable amount of work was done by Mr. A. W. Taylor, of Toronto. At present the property is owned by the Phoenix Molybdenite Company whose president is Mr. F. L. Stinson, of Toronto.

The main pit is about 90 feet long, 25 feet at the widest place, and 25 feet deep. At the south end of this pit a 10 by 10-foot shaft has been sunk to a depth of 28 feet. (See Figure 17.)

The ore-body when first worked consisted of stringers of molybdenite accompanied by pyrites and pyroxenite, the whole being much weathered and oxidized. Besides this, there were small pyritic stringers containing molybdenite, running at right angles to the general strike, and it was at these points that the richest ore was found, the intervening rock being nearly barren. A considerable quantity of yellow molybdic ochre was also encountered. At a depth of about 20 feet the character changed somewhat and the cross stringers were no longer observed, the oxidized zone was passed and the molybdenite was more evenly disseminated throughout the mineral zone.

In the north and south walls of the shaft itself there are two stringers of molybdenite, which converge together at the bottom and give rise to some promising looking ore. It is said that, at the time of closing down, the ore was increasing in richness.

Stripping has been continued for 150 feet both to the north and south of the main pit, exposing the oxidized and decomposed gneiss and pyroxene, the north stripping being on a gneiss-limestone contact which is somewhat distorted. (See Plate III.)

About 150 yards to the north a number of pits have been sunk along a distance of about 400 feet, in most of which molybdenite has been found. In one of these there is a transverse pyritic stringer containing about one inch of solid molybdenite, but nothing has been done to prove its value.

Work was done in the fall of 1917 by Mr. A. W. Taylor, when three car lots of ore was sent to the Mines Branch, Ottawa, for concentration, as follows: 21·3 tons of 3·4 per cent, 25 tons of 6·2 per cent, and 34·3 tons of 5·3 per cent MoS_2. From this 81 tons, of which 10 per cent only was hand-cobbed, about 7,800 pounds of pure molybdenite was recovered. In addition 472 pounds of flake running 65·0 per cent was shipped elsewhere.

The ore was extracted from the pits and shaft by means of a derrick, and a portable steam hoist, which still remain on the property.

From a brief investigation of this property it would seem that the possibilities of locating a fairly large tonnage of paying ore, both in the present workings and on some of the other leads referred to, are quite encouraging. Timber is plentiful, and water in limited quantities can be obtained from a creek about 200 yards to the south. The main workings are within 300 yards of Mr. Warren's farm.

On the W. ½ of lot 27, which is about half a mile north of the above workings, the rocks are somewhat similar to those on the adjoining property. A small amount of molybdenite occurs in a contact pyroxenite between gneiss and bands of limestone. A little work was done, consisting of a small irregular pit, 10 by 5 by 3 feet, sunk in the banded gneiss in the northeast limit, but very little molybdenite was found. A few

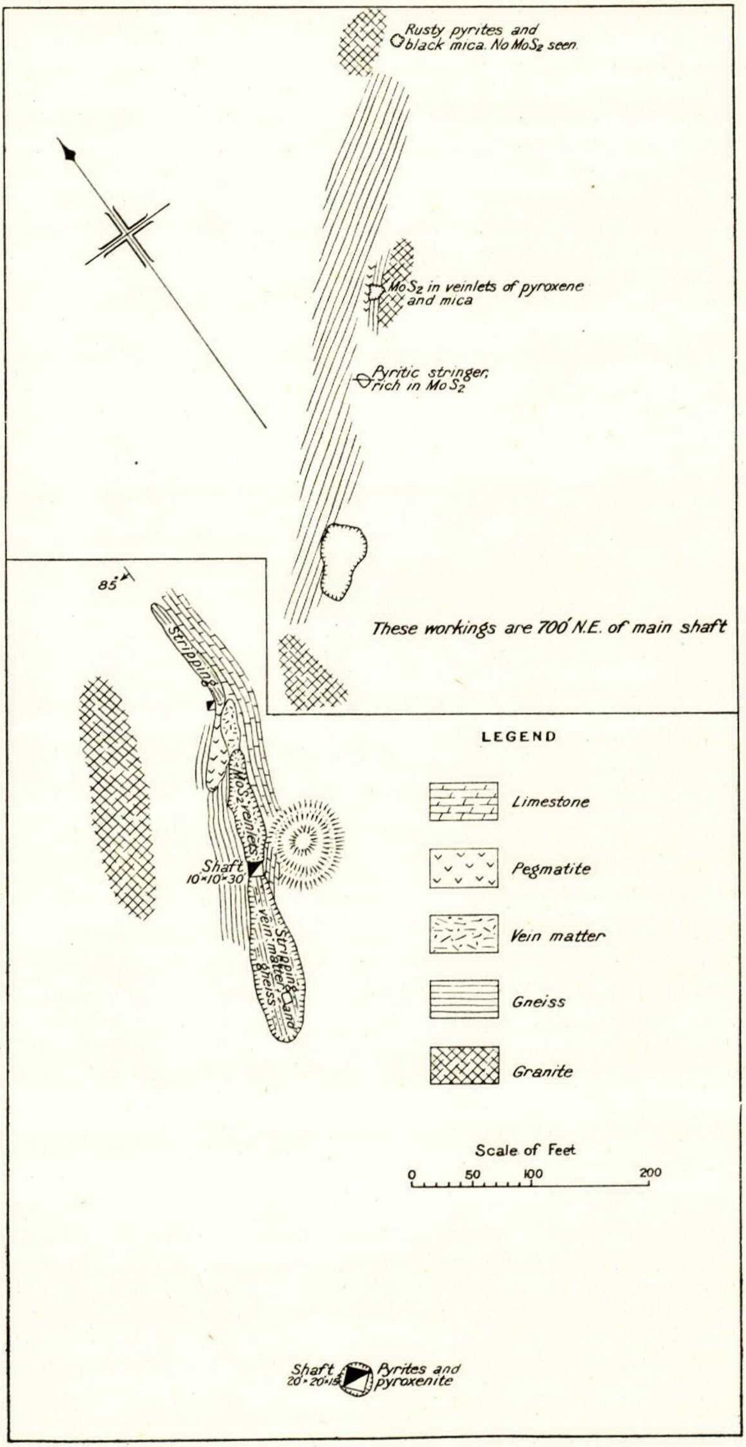

Figure 17. Phoenix Molybdenite Corporation (Taylor mine), Bagot township, Renfrew county, Ont. (September, 1921.)

hundred feet farther southwest, a 5 by 7-foot shaft was sunk to a depth of 18 feet on a narrow band of pure white crystalline limestone. A small quantity of ore was taken from the contact between the gneiss and limestone. A little to the south of the shaft there is a very narrow stripping for 100 feet, which exposes a small pyritic vein, but no molybdenite was seen. Along another 200 feet a number of small pits were sunk, at the east end of this zone some molybdenite was recovered from limestone-gneiss bands similar to those that were located in the shaft. The remaining pits are all in gneiss; they follow a fault-plane, and appear to be barren, except for a few transverse pyritic veinlets carrying traces of molybdenite. (Figure 18.)

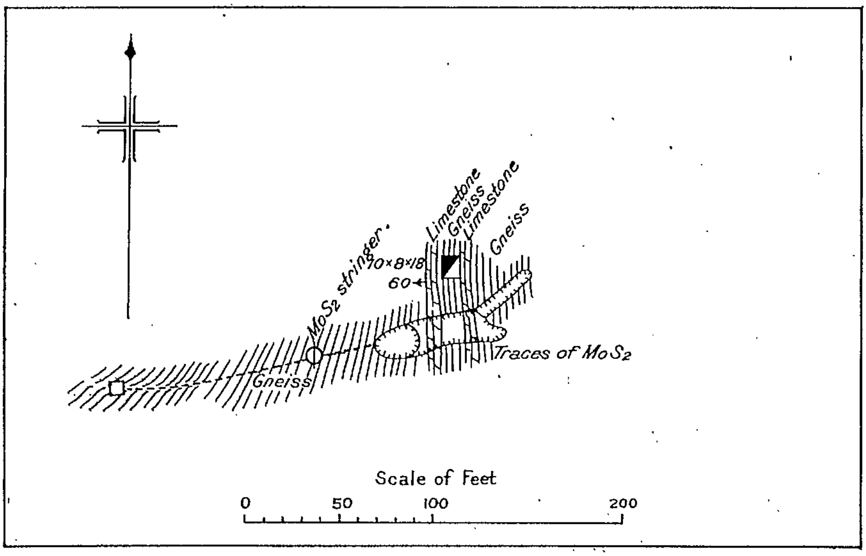

Figure 18. Phoenix Molybdenite Corporation (Canadian Molybdenite Co. prospect), Bagot township, Renfrew county, Ont. (September, 1921.)

Work was first started in 1914 by Mr. R. R. Gamey under direction of Mr. W. J. Urquhart, of Toronto, but no shipments were made at that time. Mr. Warren later sold the mining rights to the Canadian Molybdenite Co., Ltd., whose officers were Messrs. C. E. Holland and A. J. Edwards, of Toronto. Two sacks of hand-picked flake and 15 sacks of hand-cobbed ore were sent to the Mines Branch, Ottawa, in 1916 and 1917, as follows: 86 pounds of ore carrying 45·5 per cent MoS_2; and 1,435 pounds carrying 2·1 per cent. From the above shipments about 60 pounds of pure molybdenite was recovered. In 1919 the Eureka Molybdenite Corporation was formed, but no work was done by them, but early in 1923 the mining rights were sold to Mr. F. L. Stinson, who later formed the Phoenix Molybdenite Corporation, Ltd. This corporation bought the property on the west ½ of lot 28, in August, 1924, already described, and during the same year did a little work on the west ½ of lot 27.

Concession X, S. ½ Lot 15, Hunter Prospect. This property is situated on the farm of James Smith, one mile south of Calabogie station.

A little molybdenite occurs on the contact of limestone with a coarse-grained pegmatite dike containing pink feldspar, hornblende, pyroxene, and mica. There is also a small pyritic stringer that carries a little molybdenite. In the mineral zone, which is about one foot wide, were seen some large dark crystals of tourmaline. On the east contact there is a band of gneiss.

There are a few small pits, the largest of which is 300 yards west of the Calabogie road, and is 20 by 10 feet and 8 feet deep. A small pit on the east side of the road contained only a little graphite.

The above work was commenced 35 years ago by Mr. Samuel Hunter, who picked out about 100 pounds of pure flake. The occurrence does not appear to be of any commercial value, but is more of historical interest.

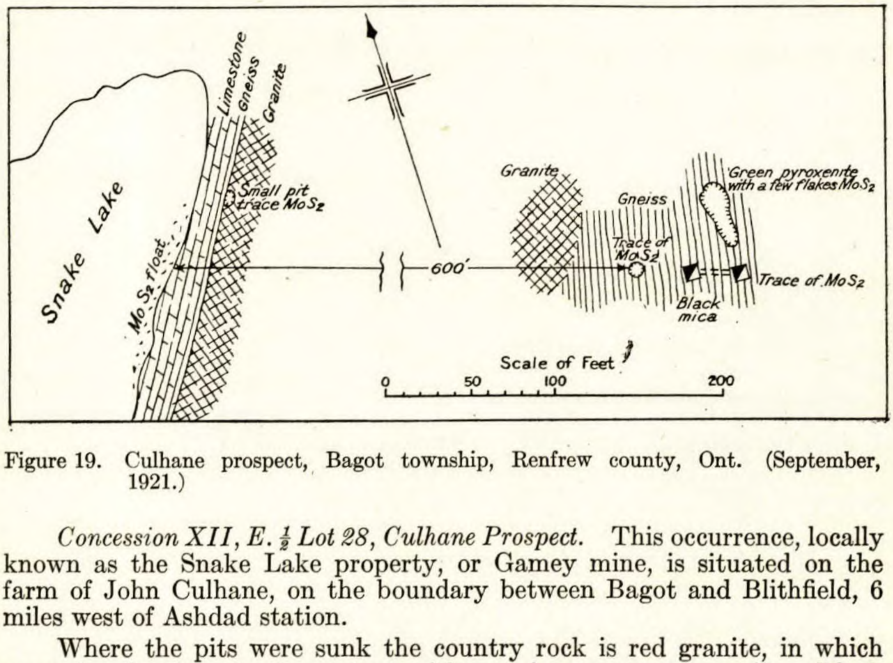

Figure 19. Culhane prospect, Bagot township, Renfrew county, Ont. (September, 1921.)

Concession XII, E. ½ Lot 28, Culhane Prospect. This occurrence, locally known as the Snake Lake property, or Gamey mine, is situated on the farm of John Culhane, on the boundary between Bagot and Blithfield, 6 miles west of Ashdad station.

Where the pits were sunk the country rock is red granite, in which occur bands of gneiss in contact with massive, green pyroxenite. Black mica is abundant, and molybdenite in fairly large flakes is very sparsely disseminated throughout the pyroxenite. Four pits have been sunk, the largest of which is 75 by 7 feet and 5 feet deep. Scarcely any molybdenite was observed in place, although it was stated that about 200 pounds of picked flake had been taken out in 1915, of which 35 pounds of 35 per cent ore was sent to the Mines Branch, Ottawa. There was about a half a ton of low-grade ore on the dump. (Figure 19.) Small pits sunk a few feet to the west of the main pit contained only mica, and no molybdenite was encountered, though it was in the same green pyroxene. This absence of molybdenite in the mica-bearing zones of the pyroxene has often been noticed.

The prospect at this locality does not seem worthy of further development.

About 200 yards to the west, on the east shore of Snake lake, an appreciable amount of molybdenite float was noticed. The mineral was also seen in some coarse white crystalline limestone boulders, in which were also some crystals of green pyroxene. There is a white limestone ridge paralleling the shore, and about 50 feet back, a granite ridge rises steeply. A small pit was dug near the shore but was not on the limestone contact. Owing to the encouraging nature of the float, it might be worth while locating the contact and doing some development work on it.

The actual work on these showings was done in 1915, by Mr. R. R. Gamey, of Toronto, under direction of Mr. W. J. Urquhart.

Blithfield Township

Concession I, W. ½ Lot 29, Quilty Prospect. This prospect is situated on the property of Thomas Quilty, 4 miles east of Ashdad.

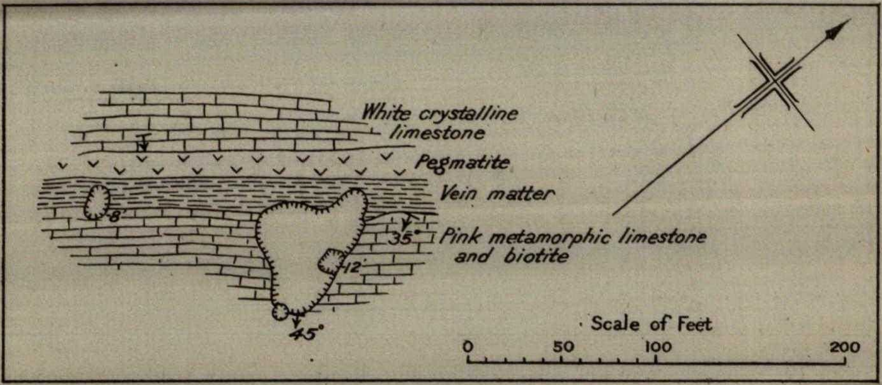

Figure 20. Quilty prospect, Blithfield township, Renfrew county, Ont. (September, 1921.)

The country rock consists of red granite and crystalline limestone. The ore-body occurs as a flat band of decomposed pyroxenite, which carries pyrites, pyrrhotite, and some molybdenite. On the foot-wall side of the deposit there is a bluff of pink pegmatitic granite and the hanging-wall is composed of pink and white calcite, carrying biotite mica.

The molybdenite, which is somewhat pockety, occurs in small veins with iron pyrites, pyrrhotite, and pyroxenite. The workings have the usual rusty appearance. There is evidence of much erosion and water action on the contact of the pink calcite and vein matter. The actual width of the vein at the main pit is about 12 feet.

In all, six pits have been sunk at various places along the strike, five being merely prospect pits. The main pit or quarry is 50 by 70 feet, and 10 to 12 feet deep. At the south end a small inclined pit has been sunk under the overhanging pink calcite which is very heavily mineralized with iron sulphides, and from which it was stated that a fair quantity of molybdenite was extracted, though none was observed in place at the time of the writer's visit. (Figure 20.)

In 1917, Mr. Quilty sold, through Mr. Christopher, of Pittsburgh, 500 acres of mining rights to the Schutz, Schreiner and Clyde Company of the same city. During the same year they shipped to the Mines Branch, Ottawa, 19 tons of 0·45 per cent ore, from which 120 pounds of pure molybdenite was recovered. There still remains a few tons of low-grade ore on the dump.

The prospect of finding other deposits along the contact is encouraging, but it is not likely that there will be a large quantity of milling ore over 0·5 per cent MoS_2.

Brougham Township

Concession XI, Lots 7, 8, 9, and Concession XII, Lot 8, Hunt Mine.—Renfrew Molybdenum Mines, Limited. This company's property, which is also sometimes known as the Belgian mine, is situated on Hunt's farm, on the southeastern slopes of mount St. Patrick, on the east shore of Condon lake, about 20 miles southwest of Renfrew. The nearest shipping point is Ashdad station, on the Canadian Pacific railway, about 12 miles to the east.

The ore-body was first discovered about 12 years ago by Hunt's son and was optioned to American capitalists, who, after shipping a small quantity of ore, allowed the option to drop. A sample sent to Ottawa, in 1909, showed 3·14 per cent MoS_2.[1]

In 1912 a second option was taken on the property by Mr. F. R. Aufhammer, who sold to a Belgian syndicate operating under the name of Algunican Development Company. After some diamond drilling and development work the company closed down due to the outbreak of war. About a year later, the present company, the Renfrew Molybdenum Mines, Ltd., was formed, and from then until they closed down in October, 1918, extensive operations were carried on, including considerable tunnelling, the erection of a concentrator, power line, and buildings.

The ore-body may be briefly described as a contact metamorphic type, occurring between massive, reddish pegmatitic granite and the older Grenville limestones and gneiss. The mineralized zone, which averages 6 feet wide, follows along this contact, and has been traced along the hillside by open-cuts and strippings for about 400 feet; and has been proved for a depth of 150 feet along its dip by shafts and tunnels. A concise description of the geology may be found in Dr. M. E. Wilson's report.[2]

The work done consists approximately of 1,800 to 2,000 feet of crosscuts and drifts on four levels between the depths of 40 and 150 feet, and they are connected by about 230 feet of shafts and raises. Besides this, about 400 feet of drifts have been widened out into stopes from 20 to 25 feet wide. (Figures 21-23.)

The first workings were to the east of the main body and an inclined adit was driven north into the hillside. Soon after entering the limestone, the tip of a tongue of pegmatite was encountered 80 feet from the entrance, on the north wall of which there was 12 feet of ore. Later this crosscut was continued for a total distance of 170 feet, when the main limestone-granite contact was reached, at which place some molybdenite-bearing pyrox-

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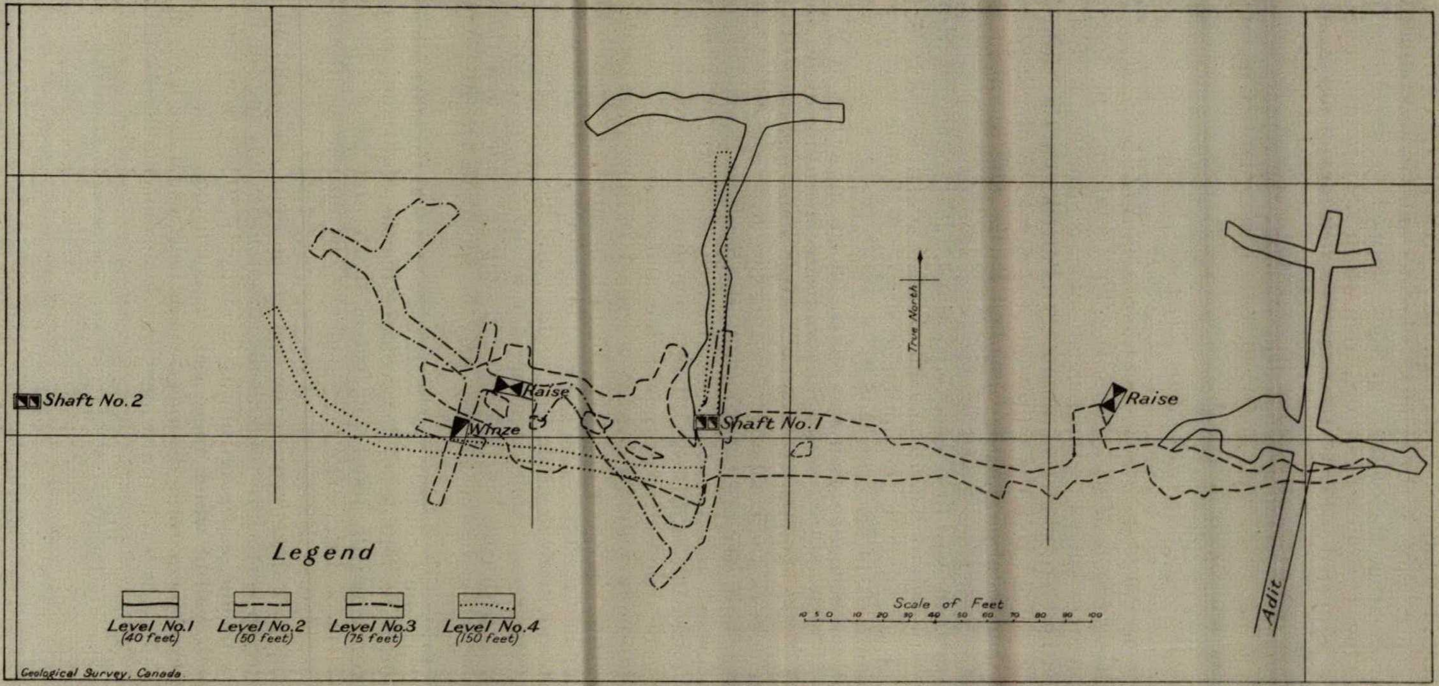
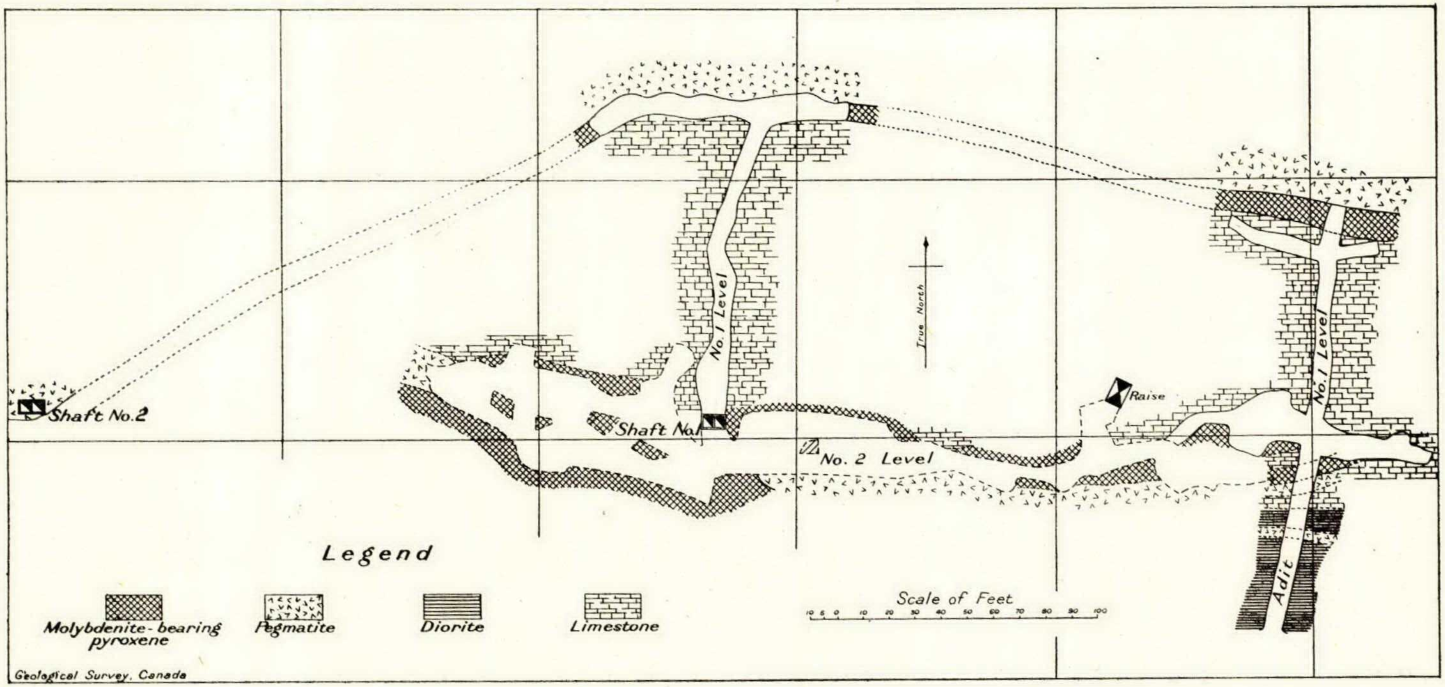
[1] Molybdenum Ores of Can., 1911, p. 47. T. L. Walker.

[2] Mineral Deposits in the Lower Ottawa Valley. Geol. Surv., Can., Summary Report, 1919, p. 37 E. M. E. Wilson.



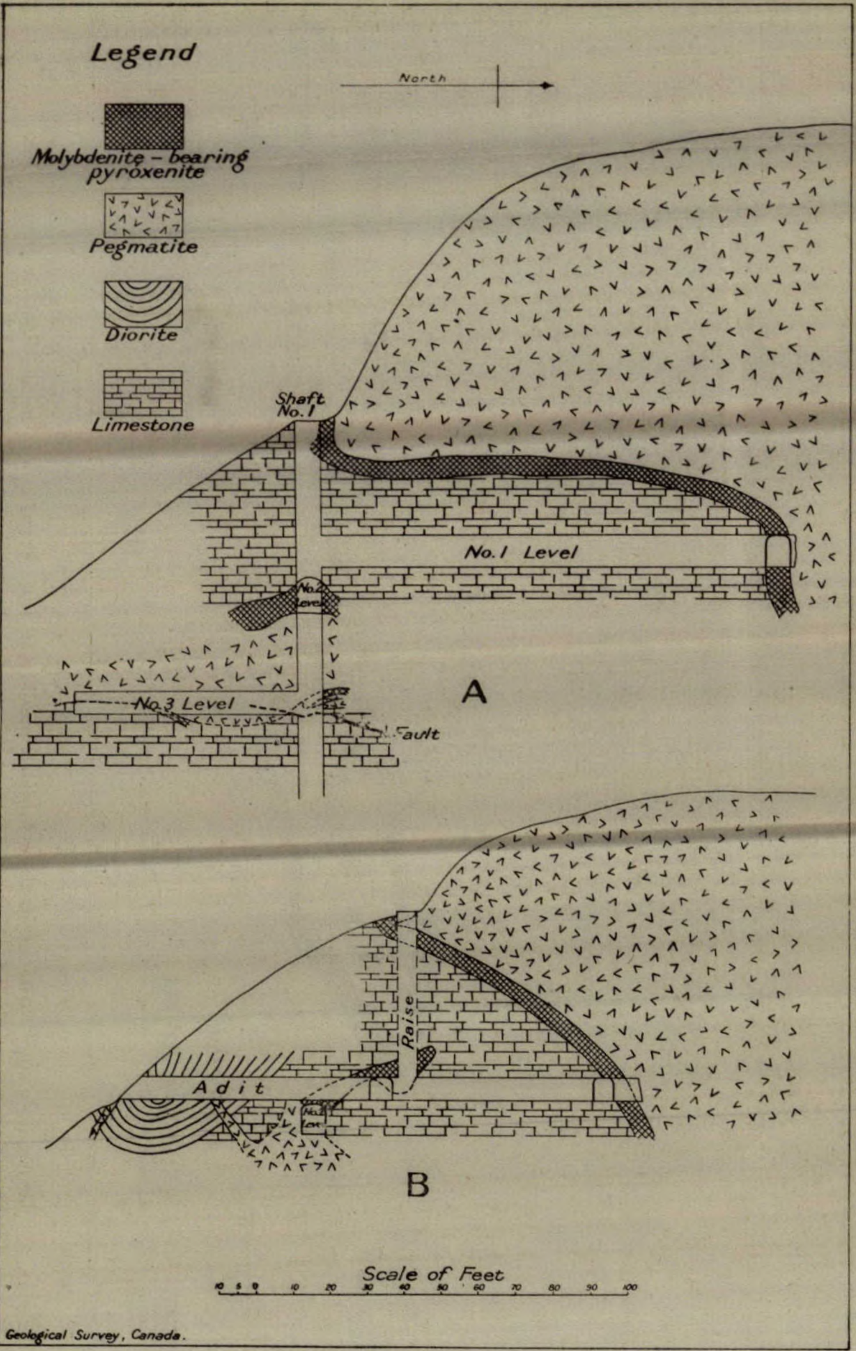
Plan by M. E. Wilson, Geological Survey, Canada.

Figure 21. Plan of underground workings, Renfrew Molybdenum Mines, Ltd., Brougham township, Renfrew county, Ont.



Plan by M. E. Wilson, Geological Survey, Canada.

Figure 22. Geological plan of workings, Renfrew Molybdenum Mines, Ltd., Brougham township, Renfrew county, Ont.



Plan by M. E. Wilson, Geological Survey, Canada.

Figure 23. Geological section of workings, Renfrew Molybdenum Mines, Ltd. Brougham township, Renfrew county, Ont.

ene was found. This contact has apparently not been followed, but the first ore-body was drifted on for a distance of 50 to 60 feet in either direction, and some stoping done. Later, a shaft was sunk on the limestone-granite contact about 200 feet to the west, to a depth of 80 feet, ore being struck at 50 feet and 75 feet, from which points a series of drifts and crosscuts was made. At a depth of 40 feet a northerly crosscut was driven to cut the main limestone-granite contact 130 feet in, and the ore on this contact was drifted on, for 100 feet; this is probably the same contact as that encountered at the north end of the adit. So far, the widest mineral zone found is at the shaft at the 40-foot, or No. 2 level, where it is 25 feet across.

J. C. Gwillim, who examined the mine in June, 1917, came to the conclusion that the ore-body is continuous for nearly 400 feet along its strike, and that at the No. 2 level it turns—at least in one place—under the granite for a distance of 130 feet northwards over the crosscut, and returns back beneath the same crosscut to a point in the shaft below No. 2 level. At this point, it is again met dipping southwest in the southerly crosscut at the 75-foot level, where it is cut off by the underlying granite. It is possible that this is merely a fault-plane, the lower side of which has moved northwards, carrying with it the continuation of the ore-body, in which case it may be encountered again when the shaft is continued down.

Dr. M. E. Wilson shows this faulting in No. 3 level at the shaft, where it is accompanied by massive pyrites (Figure 23), and he further points out that the limestone bends around the included masses of pegmatite, indicating folding; consequently, the contacts, along which the ore occurs, have also been subject to folding. Naturally, such convolutions greatly increase the area of the ore-body within a short distance of the surface.

On the 75-foot level there is about 500 feet of crosscuts and drifts, and here some ore was encountered and stoped out at the extreme west end. About 100 feet west of the shaft, a raise was put up to the 50-foot level, and a winze sunk for 75 feet on the contact, and at that depth (150-foot level) ore was followed for 200 feet, and a crosscut was also driven for 130 feet to the north.

The molybdenite appears to be most abundant where pyrite and pyrrhotite occur, and only sparsely present where these minerals are absent; pyroxene is nearly always present.

It will be observed from the plans that there are two molybdenite-bearing zones, one on the contact with the granite mass above, and the other with the second mass included with the limestone below. The best paying ore has been found in the lower mass. There are many surface workings on the top and sides of the hill above the shafts, in nearly all of which molybdenite was found. According to the statements of the caretaker, some good ore was being mined when operations ceased, and it had been intended to continue the shaft downwards to prospect the doubtful ground, also to continue sinking the new shaft which had already been started a few hundred feet to the west of the present workings.

Although the information concerning the ore encountered in the lower levels is meagre, it would seem that it was not so wide or rich as that occurring in the upper workings. It would appear, however, that there is plenty of room for further lateral development along the line of strike.

The following shows the approximate output for the last three years, when the main operations were being carried on by the Renfrew Molybdenum Mines, Ltd.:—

Year	Ore mined	Ore milled	MoS_2
	Tons	Tons	per cent
1916	1,200	100·0	1·29
1917	4,500	3,656·0	0·75 (approximate)
1918	3,449	3,155·0	0·50 (calculated from mill recovery figures.

The total concentrates produced, including hand-picked pure flake, amounted to 96,990 pounds, 85 per cent of which averaged about 95 per cent MoS_2. All the above ore, except 55 tons sent to Ottawa, was treated in the company's concentrator, and all the high-grade concentrates were sent to Paul Girod, of the Societie Electrometallurgie, Ugine, France, who specified a 95 per cent product.

In February, 1917, a concentrator of 30 tons daily capacity was erected, in which an Elmore vacuum oil flotation unit was installed, and later managed by Charles Spearman. A description and flow-sheet will be found under the chapter on Concentration. In 1918, a 12-mile electrical transmission line was built to connect the mine and mill with the power plant of the M. J. O'Brien Company on the Madawaska river at Calabogie.

The plant to-day consists of two 60 h.p. boilers, one 50 h.p. Corliss engine, one 600-foot capacity Ingersoll-Rand compressor, electrical equipment and installation of 500 h.p. capacity, all necessary mine equipment, 12 miles of transmission line, complete concentrator, and the usual bunk houses, offices, stables, etc.

From 60 to 70 men were employed at a time, of which about one-third were underground, during the periods of operation. The mining costs were roughly estimated at $6 per ton.[1] The mine is well placed for power, water, timber, etc. The officers of the company are Messrs. Jean Vanophen, A. R. Goyette, P. C. Neault, and others.[2]

A claim was staked on a showing along the road, opposite the Hunt mine, and a company called the Mount St. Patrick Molybdenum Company was formed in 1916, but no development work was done.

Concession XI, W. ½ Lot 16 and N. ½ Lot 17, Ross Property. This property adjoins, and is to the southeast of the International Molybdenum Company's claim on the top of mount St. Patrick. It was part of the land purchased by Dr. B. G. Connolly from Mr. Austin Morin. About 1914, Dr. Connolly sold the mining rights to Mr. C. G. Ross of the Aldfield Mineral Syndicate. This syndicate, after doing some prospecting work, gave an option to a Belgian syndicate, who are said to have shipped a little ore. During the war the Aldfield syndicate sold out to Molybdenum Limited, who later gave an option to Mr. F. G. Todd, of Montreal. In 1917 the property was leased to the International Molybdenum Company, Ltd., for six months. These transactions are somewhat involved and no separate records of shipments appear to have been kept. Some of the

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[1] Private correspondence.

[2] Summary Report, Mines Branch, 1915, p. 114. W. B. Timm.

ore shipped, which amounted to several carloads, was, however, apparently sent with that of the International Molybdenum Company to the Renfrew concentrator, or to the Mines Branch, Ottawa, and is, therefore, included in the shipments tabulated from the O'Brien properties.

The deposit is somewhat similar to that of the O'Brien claim, the country rock being mainly a banded granite-syenite gneiss. Between the bands, and at varying intervals, mineral veins of pyrites, pyrrhotites, quartz, decomposed pyroxenite, and some molybdenite occur. The molybdenite is unevenly dispersed throughout the vein matter, which in some places shows rich pockets, but in others it is barren. The veins are usually not more than 2 inches wide, but in places mineralization was noticed to a depth of about a foot along the contacts.

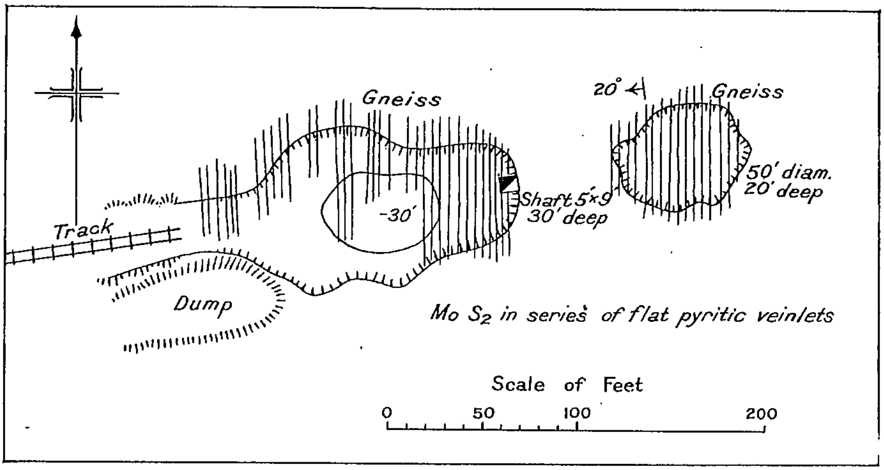

Figure 24. Aldfield Mineral Syndicate, (Ross mine), Brougham township, Renfrew county, Ont. (September, 1921.)

The work done consists of two large pits or quarries on the side of a hill, the slope of which appears to be in conformity with the dip of the rocks. The top, or easterly pit, is about 50 feet in diameter and 20 feet deep; the westerly quarry is about 120 feet long and 30 feet deep in the centre. Between the two, there is a 5 by 9-foot shaft, that has been sunk to a depth of 30 feet. (Figure 24.)

A portable steam boiler was used to drive a rock crusher and to run steam drills and jack hammers. The crushed ore was passed over screens, and the coarser material, which contained the greater part of the large flake molybdenite, was sacked and sent to Renfrew, or to the Mines Branch, Ottawa.

The deposit on this claim appeared to be considerably more promising than that on the O'Brien, and by careful selection it is probable that a large tonnage of ore can still be obtained from the present workings. The steep haulage up the hill and the lack of water are, however, disadvantages.

The following shipments are understood to have been made from the Ross property:—

TABLE IX

Shipments from Ross Mine, Mt. St. Patrick

Date	Shipper	Ore mined tons	Ore shipped pounds	Destination	MoS_2 per cent	Remarks
1913	C. G. Ross	70	195	Ottawa	5·02	
			2,000	London, Eng.		Hand-cobbed ore.
1914	C. G. Ross	100	1,000	London, Eng.		"
1915	C. G. Ross		20,100	Ottawa	0·60	Experimental.
1916 1917	F. G. Todd and International Molybdenum Company.	4,000	1,400,000	Renfrew and Ottawa.	1·00	Screened and crude ore.[1]

[1] A large portion of this was hand-cobbed and screened before being shipped to Renfrew. The screened ore averaged 4·0 per cent MoS_2, and run-of-mine about 1 per cent MoS_2. Approximately 7 tons of MoS_2 concentrates were recovered from the original 700 tons of ore.

Approximately 720 tons of ore was apparently shipped from this property.

The International Molybdenum Company, controlled by M. J. O'Brien, was formed to mine, purchase, concentrate, and refine ores of molybdenum.

In May, 1915, the Canadian Smelting and Refining Company at Orillia went into liquidation, and their plant was taken over by the Orillia Molybdenum Company. Part of this plant was utilized for experimental work and a process of concentration was evolved. By the end of the year the company had converted it into a 20-ton per day concentrator. Early in 1915, the company acquired the Jamieson molybdenite mine in Lyndoch township, and worked it throughout the year. About 80 tons of 2 per cent MoS_2 ore are said to have been shipped to the Orillia concentrator. The O'Brien claim on mount St. Patrick, Renfrew, was also worked and from it about 200 tons of ore was extracted. In 1916 the O'Brien and Orillia Molybdenum Company's interests were merged, forming the International Molybdenum Company. During the summer, the concentrating machinery at Orillia was removed to the new concentrator at Renfrew, Ont. The process employed was a modification of the water-film flotation type, in which they treated outside ores as well as their own.

A brief account of the concentrator at Renfrew, with a summary of the ores treated, will be found under the heading of Concentration.

Besides the Jamieson and O'Brien mines, options were taken on several other molybdenite properties, including the Chisholm mine in Sheffield township, the Morin prospects adjoining the O'Brien, Chabot mine in Huddersfield township, Quebec, and the Molly mine, Nelson, B.C. Before the end of 1916 the Chisholm and Jamieson properties reverted to their original owners, the O'Brien mine was worked until the end of the year, after which all work was done on the Morin mine. Detailed descriptions of these properties will be found elsewhere under their own names.

In 1917 three additional flotation machines were installed in the Renfrew concentrator, increasing the capacity 30 per cent. The only claims worked by the company during the year were the Morin mine and the Molly mine, B.C. By the end of the year the remaining options were given up and the Renfrew concentrator closed down. The concentrator has since been burned. An account of the refinery and production of ferro-molybdenum will be found elsewhere.

Concession XI, Lot 17, O'Brien and Morin Claims.—International Molybdenum Company. This company owned molybdenite properties on the top of mount St. Patrick, 18 miles southwest of Renfrew and 12 miles west of Ashdad station.

The Mount St. Patrick molybdenite occurrences were discovered by Joseph Charron, a prospector. The deposits are situated on the property once owned by Mr. Austin Morin, which consisted of several hundred acres. About 1908 Morin sold 100 acres to Dr. Connolly, of Ottawa, and the remainder to Mr. M. J. O'Brien, of Renfrew, who in the fall of 1915 worked the O'Brien claim under his own name, with Mr. J. C. Murray in charge. In 1916, Mr. O'Brien financed the International Molybdenum Company, Limited.

Although the company operated various deposits, most of the ore came from the Mount St. Patrick claims, from which about 17 cars of ore were shipped.

In general, the various workings on the O'Brien and Morin claims are on the contact of intrusive granite-gneiss with the Grenville gneiss and crystalline limestone. This contact is patchy and ill-defined, and the mineralization is sparsely diffused over a large area. Several small fairly high-grade pockets, or segregations, appear in places where pegmatite dikes have cut the older gneiss and crystalline limestone. Some of the narrow molybdenite-bearing seams are rich in pyrites.

These claims have been fairly well prospected by many open-cuts and shafts scattered over a considerable area, in all of which small ore-shoots have been found. (Figure 25.) The best looking ore was found on the eastern part of the workings, where a 32-foot shaft was sunk at the bottom of an open pit. The ore-body, composed of heavy pyrites and molybdenite, appears, however, to dip flatly away from the shaft. About 100 feet to the southeast on the slope of the hill a timbered shaft, 7 by 9 feet, was sunk to a depth of 40 feet. The rock on the dump is a dull grey, closely banded gneiss, and no ore or vein matter was observed. The writer was informed that this shaft was sunk with the object of striking the lead from the 32-foot shaft referred to above, but as the vein appeared to dip in conformity with the slope of the hill, it is possible that the shaft was started a little too far down. About 400 feet to the north of the main workings a 50-foot shaft was sunk on a promising looking outcrop at the contact of pegmatite and crystalline limestone. At the bottom, limestone carrying some flake graphite was found. By picking over the dump from this shaft, a few tons of fairly high-grade molybdenite ore might be collected. Small piles of low-grade ore are scattered about the workings.

The original work was done on the O'Brien claim and, later, when it was found that the ore did not continue in depth, work was transferred to the Morin claim. During 1917, the Morin was the only claim, outside British Columbia, that was worked by the company.

Before the Renfrew concentrator was built the first few shipments of ore were sent to the plant at Orillia. This ore was hand-selected and assayed from 3 to 6 per cent MoS_2, but there appears to be no definite record as to the amount treated. A few shipments were sent, at intervals, to the Mines Branch, Ottawa, and the remainder was treated in the Renfrew plant.

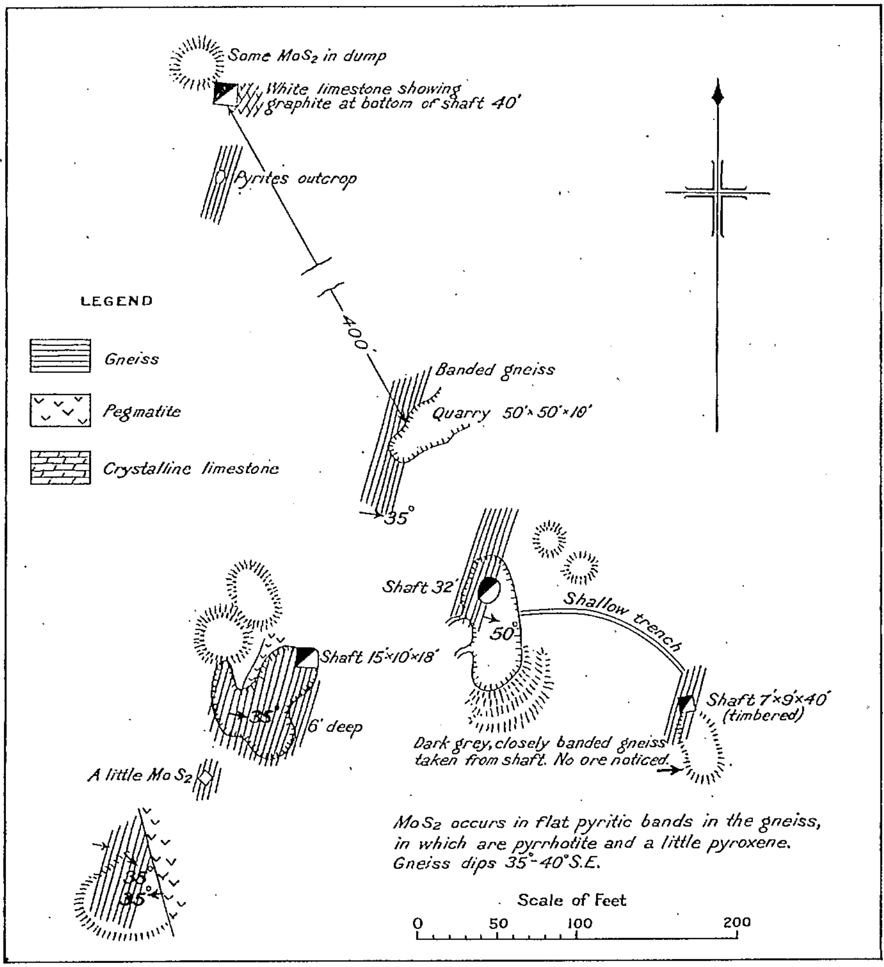

Figure 25. International Molybdenum Co. (O'Brien mine), Brougham township, Renfrew county, Ont. (September, 1921.)

In 1918 the Renfrew plant was burned down, together with all the company's records and, consequently, no definite figures are available as to the work done, shipments, etc. The following figures have been collected from various sources and are approximately correct, though it is possible that some small outside shipments may be included. In these are also included shipments from the Ross property adjoining, previous to its being worked by the International company.

TABLE X

Shipments from the O'Brien, Morin, and Ross properties, Mount St. Patrick

Date	Where sent	Tons of ore	MoS_2 per cent	Remarks
1916	Department of Mines, Ottawa.	25·2	1·45	O'Brien claim, selected ore.
	Orillia....................	126·5	....	O'Brien claim, selected ore.
		10·4	7·00	
		110·3	2·00	
1917	Renfrew..................	285·9	0·91	150 tons from the Ross claim; remainder from Morin.
	Department of Mines, Ottawa.	26·2	1·96	Morin and Ross.
		24·6	1·81	Crushed fines from the Ross property.
		27·5	1·57	
		44·7	1·84	

Of the above shipments, the only definite records of recovery are from those sent to the Mines Branch, which totalled 4,385 pounds of pure molybdenite. Averaging the run of the shipments and a recovery of 80 per cent shows a total recovery from these claims of approximately 8 tons of pure molybdenite.

From a brief examination of the property, it would seem that the extraction of the ore on the International Molybdenum Company's claims will always be a costly matter, owing to the scattered and low-grade character of the deposit, the lack of water, and difficulty of transportation.

Concession XIII, Lot 13, and Concession XIV, Lot 14, Maloney Prospect. Molybdenite has been found both as float and in place, on the farms of Pat Maloney on top of mount St. Patrick. Three or four small test pits were sunk on the various outcrops, but the ore is lean and occurs in a similar manner to that found on the O'Brien property.

There are a very large number of other showings of molybdenite on top of mount St. Patrick, amongst which may be mentioned concession X, lots 15 to 19. Most of these are owned by Dr. Connolly, of Ottawa, and other showings have been located on the O'Brien property.

In general, the many molybdenite occurrences in the Mount St. Patrick region are very similar, and the description of the deposit occurring on the International Molybdenum Company's claims can be applied to all. The granite-limestone contacts are molybdenite bearers, but are patchy and ill-defined, the mineralization is diffused over a large area, and on many small contacts, none of which are likely to produce an ore-body of sufficient magnitude and grade to justify development.

Owing to the high elevation, difficulties of obtaining water-power and haulage would have to be carefully considered, although if extensive mining were undertaken use could be made of the electric power line at the Renfrew Molybdenum Company's property nearby.

Concession XIV, Lots 35 and 36, Sunset Mine. This property, owned by Legree Bros., of Renfrew, was in 1916 purchased by the Steel Alloys Corporation, who worked it in conjunction with their Spain mine in

Griffith township, one mile to the west. The ore-body consists of a micaceous pyroxenite and pyrite in hornblende-gneiss, which at the main working is distorted and folded.

About the centre of the main pit, which is 70 by 30 feet and 6 feet deep, there is a vertical shaft 70 feet deep. On the west wall of the pit the folding is clearly seen until it disappears into the shaft, dipping at about 45 degrees to the south. (Figure 26.) The shaft, which was apparently started in ore, but soon lost it, was continued vertically for about 50 feet in barren gneissic rock. Owing to the shaft being full of water at time of visit an examination of it could not be made. About 400 yards to the east of the shaft, more work has been done in an outcrop of similarly folded rocks. Apparently very little ore was extracted. Only a very small quantity of molybdenite was observed in the east end of the cutting, which is about 100 feet long and 6 feet wide, with a pit 10 feet deep in the centre.

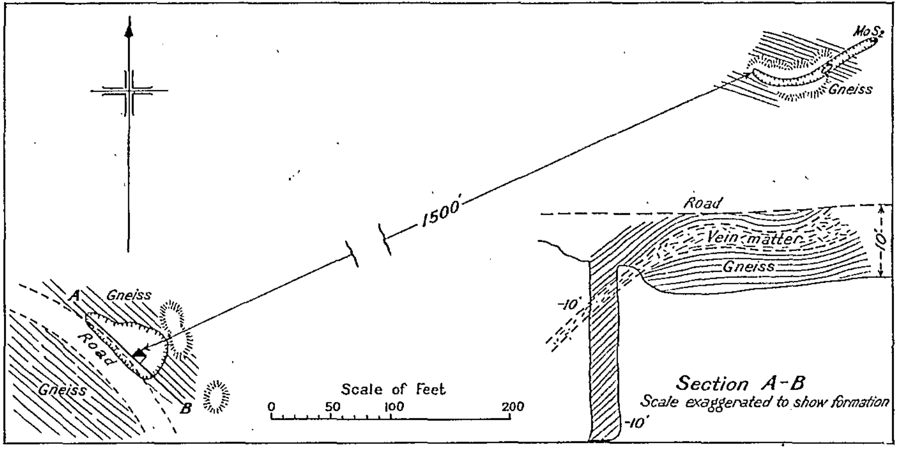

Figure 26. Sunset mine, Brougham township, Renfrew county, Ont. (August, 1921.)

In a general examination of the main pit and shaft, very little ore was seen in place, though it was stated that some high-grade material had been extracted. A. L. Parsons[1] states that there were about 8 tons of 3·0 per cent ore on the stock pile in 1917 and about 300 pounds of pure flake.

In 1918 about 20 tons of ore, ranging from 5·47 to 0·65 per cent MoS_2, was sent to the Mines Branch, Ottawa, from which 936 pounds of pure molybdenite was recovered. Between three and four hundred tons of low-grade ore is scattered about the property, and there is a few tons of cobbed ore in the ore shed.

The plant at the mine consists of a 100 h.p. boiler set in concrete, an air-drill compressor, 3-compartment ore house, bunk and cook houses, office, stables, etc.

Both the Spain and Sunset mines, now controlled by the Steel Alloys Corporation, are well provided with water supply, fuel, plant, and buildings. Haulage to the railway is about 20 miles by a good road.

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[1] Ont. Bur. of Mines, 1917, p. 291. A. L. Parsons.

Griffith Township

Concession V, Lots 31 to 34, Concession IV, Lots 31 and 32, Spain Mine. This property lies southwest of the Mount St. Patrick range, near the southeast corner of Griffith township, and extends to the boundary of Brougham township. It is 29 miles southwest of Renfrew, and 19 miles south of Caldwell station by road.

The mine, which is on concession IV, lot 31, was opened in 1912, by Mr. Joseph Legree, of Renfrew, and sold to Mr. William J. Spain, of New York, in 1915. It was taken over early in 1918 by the Steel Alloys Corporation.[1] Mr. J. Howard, of Wheeling, Va., is vice-president.

The country rock is gneiss overlain by Grenville limestones containing much mica and pyroxene. The ore-body outcrops on top of a gneiss ridge, and consists of a series of pegmatite dikes, some of which are 100 feet wide, cutting a metamorphosed zone of gneiss and limestone, the latter being converted into pyroxenite. The mass is described by Dr. M. E. Wilson[2] as being a hornblende-pyroxene-monzonite-gneiss cut by numerous pegmatite and aplite dikes.

The molybdenite is almost wholly confined to the pyroxenite and pegmatite. It does not occur throughout the latter, but only along the seams and joint-planes.

Pyrite and pyrrhotite are also found, but little or no mica is present. The molybdenite crystals are very large, averaging about 2 inches, and some are from 6 to 12 inches across. Aggregates of the pure mineral weighing several pounds are not uncommon. (See Frontispiece, Plate I.)

The work, which was nearly all done by Mr. Spain in 1915-16, consists of a large open-cut, a shaft, and about half a dozen small pits. The shaft, which is 6 by 9 feet, has been sunk to a depth of 50 feet. It was started on two or three small molybdenite stringers, and is in gneiss for almost its entire depth.

Almost the whole output has been obtained from the main pit, which is a large, irregular excavation about 75 feet long, 120 feet wide and from 10 to 25 feet deep. (Figure 27.) In this pit, the various pegmatite dikes and veins run approximately parallel to the strike of the rocks, their direction varying between 40 and 50 degrees east of the north as shown. In the southwest face of the pit the limestone is banded and undulating, with a tendency to dip flatly to the southeast. A considerable amount of molybdenite was noticed as splashes on the northwest wall of the pit.

As the ore-bearing zone consists of thin and irregular seams of molybdenite separated by almost barren rock, the whole mass has to be extracted, so that it would not be expected to produce a milling ore of over 1 per cent. At the time operations ceased in December, 1919, a wide pocket of high-grade and more concentrated ore was encountered at the bottom of the southwest face. This new ore-body, which has been merely tapped, is said to contain large flakes of molybdenite and to be richer than any ore that has yet been extracted from the open-cut. Investigation of this, however, could not be carried out owing to the depth of water in the pit at the time of the writer's visit.

Along the strike of the ore-body, to the southwest, the dike formation has been cut in several places by trenches from 3 to 6 feet deep, most of

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[1] Recently incorporated the Consolidated Molybdenum Steel Corporation.

[2] Geol. Surv., Can., Sum. Rep., Part E, p. 42, 1919. M. E. Wilson.

which show molybdenite. These dikes are traced for several hundred feet on both sides of the open-cuts.

A 50-ton concentrator using a Hooper pneumatic machine was built by Mr. Spain in 1916. A few months later, a Wood water-film flotation unit was introduced, and the mill was run intermittently for about 2½ months. In 1919, the Steel Alloys Corporation discarded the Wood machine and installed the Callow oil flotation system. (For description see chapter on Concentration.)

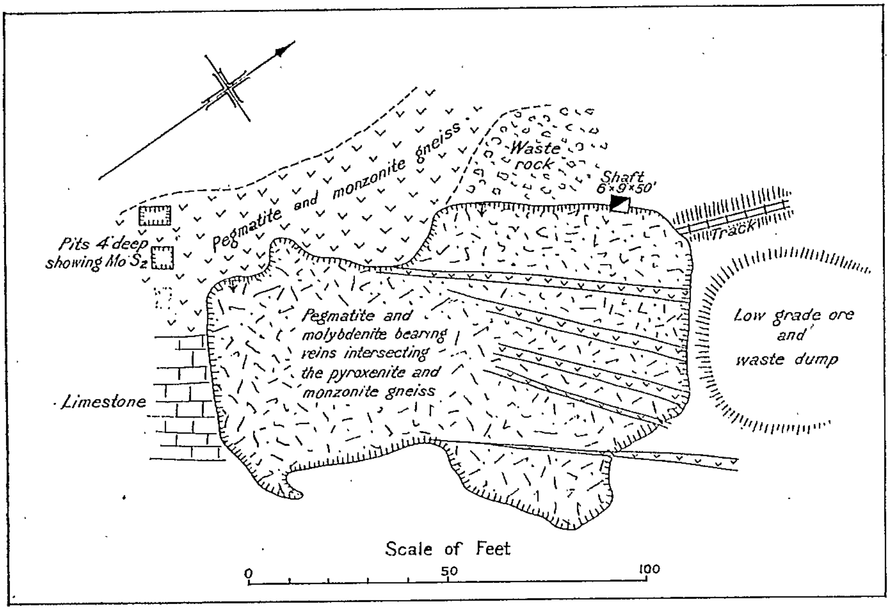

Figure 27. Main pit of Spain mine, Dacre, Ont.

There is probably no deposit in Canada from which hand-picked pure flake can be more economically obtained, and Mr. J. E. Cole, the mine superintendent, reported that up to November, 1915, about 5 tons of very high-grade picked flake—approximately 90 per cent MoS_2—was sent to buyers in the United States. Besides this, at that date there were on the dumps approximately 850 tons of 2 per cent ore; 38 tons of 12 per cent ore; and 2 tons 90 per cent flake. This would give about 29 tons of pure MoS_2 extracted from the open-cuts.[1] Later, the following shipments were sent to the Mines Branch, Ottawa.

Year	Pounds of ore	MoS_2 per cent	
1916	61,198	1·09	
	1,638	11·13	
	7,151	84·20	(Hand-picked flake not treated.)
1918	66,390	2·10	

From this 64·6 tons of ore, 6,854 pounds of pure molybdenite was extracted and sold to the Imperial Munitions Board, and 1,213 pounds

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[1] Mines Branch, Sum. Rept., 1915, p. 117.

to United States buyers. In addition to this, about 40 tons of ore was treated in the mill in 1919, yielding 600 pounds of concentrates which were sent to the Tivani Steel Works. Besides the above shipments, there are between three and four thousand tons of mixed low-grade ore and waste on the dumps.

The plant consists of 50-ton mill 60 by 100 feet, completely equipped with concentration plant, 100 h.p. Ames engine using wood fuel, a boiler house, 25 by 40 feet, containing two 60 h.p. Nagle type boilers, and the usual mine equipment such as drills, pumps, derricks, etc.

The mine buildings consist of bunk house for 50 men, large staff house, cook house, office, stables, ore bins, etc. Water is supplied by a 3-inch gravity pipeline from a lake one mile distant, to two tanks of 17,000 and 14,000-gallon capacity.

As will be seen from the shipments, by far the greatest values were obtained by hand-picking the flake for which this ore is particularly well suited. Deposits are often spectacular but only local; however, the Spain mine is undoubtedly the largest molybdenite property in this respect so far opened up in Canada.

Although there is molybdenite in the other prospect pits and showings, surface indications are not so good as are those of the main pit.

Concession IV, Lots 33 and 34, Legree Prospect. This property, which is owned by Mr. Joseph Legree, lies between the Spain and Sunset mines. In 1915 two prospect pits about 5 feet wide and 3 feet deep were dug on a pegmatite ridge striking east and west. From these pits about 2 tons of milling ore was extracted and is still on the dump. The occurrence is similar to that of the Sunset mine in Brougham township.

Lyndoch Township

Concession II, Lot 34, McCoy Prospect. This property, owned by Mr. W. C. McCoy, of Wensley, Frontenac county, is in the southwest corner of Lyndoch township, about 8 miles southwest of the Jamieson mine, and 30 miles south of Wilno station.

During 1916, a 4-foot pit was sunk, and further prospecting work and trenching in 1917 resulted in the following shipments: In the first year, one ton of 0·4 per cent ore and 8 tons of 93 per cent picked flake were sent to Ottawa, and in 1917, one ton of 0·89 per cent ore was sent to Renfrew.

The property has indications of containing some molybdenite, but the distance from a railway is a disadvantage.

Concession VIII, Lots 5 and 6, Jamieson Mine. This property is about 6 miles east of the Madawaska river and 6 miles north of Griffith. It is 45 miles southwest of Renfrew, and its nearest shipping point is Eganville, on the Canadian National railway about 25 miles to the northeast.

The country rocks are various kinds of gneisses, interbanded with crystalline limestone. The gneisses are cut in many places by intrusive granites and pegmatites, the molybdenite deposits occurring near their contacts with the limestones. The ore-body, which has been exposed for a length of 220 feet along its strike and consists of pyroxene and pegmatite, outcrops on a ridge of gneiss. Molybdenite in large flakes is intimately associated with pyrite and pyrrhotite, of which there is a considerable quantity. The three minerals rarely occur in the gneiss or limestone, but are found on the contacts of these rocks or distributed throughout the pegmatite dikes.

Work was first done on the property, in 1907, by the late Mr. R. A. Jamieson, of Renfrew, and later on, in 1915-16, was worked on lease by the International Molybdenum Company, Ltd. Two 20-foot pits, which have been connected by an open trench, were sunk in the gneiss-limestone contact. Between these pits there is an inclined shaft. The ore-body at the surface dips at about 45 degrees southeast. (See Plate IV.)

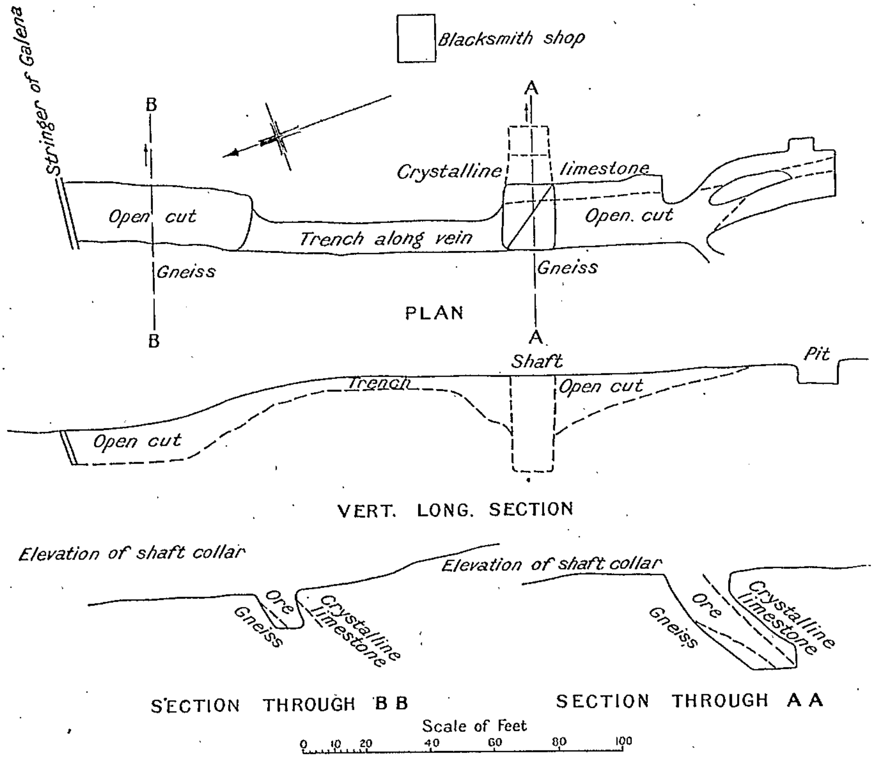

Figure 28. Sketch of Jamieson mine workings.

An examination of the workings by G. C. Mackenzie and W. B. Timm in 1915[1] showed that at 20 feet down the vein material flattened to about 30 degrees. The hanging-wall, along which there is a band of pink calcite, is crystalline limestone and the foot-wall is gneiss. In the southern pit, which is 45 by 25 feet, the vein was 6 feet wide at the surface, but decreased to 2 feet in the shaft. However, it appeared to be increasing again slightly near the bottom, which is about 40 feet down on the incline. In the north pit, 60 by 20 feet, the exposed vein material was also 6 feet wide. It is possible that the vein is faulted here, since test pits to the northeast along the strike failed to show the ore-body and the trenching between the two pits shows very little molybdenite. (Figure 28.)

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[1] Mines Branch Sum. Rept., 1915, p. 82.

A. L. Parsons,[1] who visited the property in 1917, says that the ore on the dump has been disintegrated considerably by the weathering of the pyroxene, with the formation of some yellow molybdite. The pyrrhotite also has undergone some change, taking a purplish tarnish, which is probably due to a thin film of ilsemannite, or possibly some unidentified compound of iron and molybdenum. Parsons also noticed this peculiar tarnish of the pyrrhotite in several other molybdenite deposits, and believes that it may serve as an indication of the presence of the latter mineral.

There are no records of the ore extracted by Mr. Jamieson in the early days, but Dr. Walker[2] believes that at least one ton of very high-grade cobbed ore was obtained. During the latter part of 1915 about 80 tons of hand-cobbed ore was sent direct to Orillia. The greatest part of this was cobbed to 20 or 30 per cent MoS_2, and 1½ tons was pure flake. In 1916 recorded shipments to Renfrew and Orillia amounted to 73 tons of 3 per cent ore, and 12·5 tons of hand-cobbed ore assaying 18 per cent MoS_2. It is stated that in all, 285 tons of ore, containing approximately 12,760 pounds of pure molybdenite was taken from this mine,[3] but by whom and when the balance of this ore was shipped is not recorded. Besides this there is approximately 200 tons of 1 per cent ore on the dump.

The ore was hoisted from the pits and shaft by a derrick, dropped on a sorting floor, graded, and the waste delivered by tram to the waste dump. Drilling was done by hand.

The buildings, which are in the valley to the northeast of the mine, consist of a well-built bunk house for 30 men, cook house, office, storehouse, and stable, and at the mine there is a blacksmith shop and powder house.

A little over half a mile to the southwest of the shaft, and along the strike of the vein, the company has staked another claim, called the Lyndoch. Surface indications are said to be very promising.

Matawatchan Township

Concession VI, Lot 3, Wilson Property. This property is situated on the farm of James Wilson on the south side of Aird lake, about 25 miles west of Calabogie station.

The outcrop consists of a mass of pyroxenite on the margin of a ridge of pegmatite from 40 to 50 feet wide. The molybdenite, which has been exposed by a few shots, occurs in small flakes scattered throughout the pyroxenite. Mr. Wilson said that two or three pounds of molybdenite had been taken out. The ore probably runs about 0·5 per cent.[4]

It is probable that by further prospecting a fair tonnage of low-grade material might be found, particularly near the pegmatite contact.

Raglan Township

Concessions IX and X, Lot 27, Windle-Liedke Prospects. These two prospects, owned by Messrs. John Windle and Herman Liedke, are about 5 miles east of the Madawaska river, at Schutt P.O. The nearest shipping point is Bancroft station, on the Wallace branch of the Canadian National railway, about 30 miles to the southwest.

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[1] Ont. Bur. of Mines, 1917, p. 303. A. L. Parsons.
[2] Molybdenum Ores of Canada, 1911, p. 45. T. L. Walker.
[3] Mines Branch Sum. Rept., 1915, p. 82.
[4] Ont. Bur. of Mines, 1917, p. 305. A. L. Parsons.

The ore occurs in a pegmatite dike 4 feet wide traversing crystalline limestone. The best showing is on the line between the two properties, where 30 to 40 tons of rock have been taken from a pit; of this amount about one ton, of possibly 2 per cent ore, has been laid aside. Two pits were sunk on Mr. Windle's property on concession IX. A little ore was observed on the dump, but none in the walls of the pit.[1]

Ross Township

Concession II, Lot 22, Haley Prospect. This prospect is located on the farm of John Ross half a mile west of Haley station, on the Canadian Pacific railway. Irregular bands of coarse-grained quartzose pegmatite occur in a country rock of biotite-gneiss. Small quantities of molybdenite, in thin flakes, occur in a pegmatite band about 3 feet in width, which cuts the gneiss at an angle of about 45 degrees. The mineral usually occurs with the quartz and is accompanied by a little pyrites.[2]

Work was done on this deposit many years ago, and it has changed hands several times. An irregular pit 50 feet long, 2 to 8 feet wide, and about 6 feet deep, and a shaft 40 feet deep, have been sunk. Assay samples taken from the mine showed that in the earlier operations, the ore ran from 1·5 to 2·0 per cent MoS_2. Dr. Walker says that 250 pounds of 1·0 per cent ore was sent to McGill University for experimental purposes.

The late Dr. J. A. Grant, of Ottawa, and Mr. T. E. Richardson, of Portage du Fort, had an option on the property, and in the summer of 1917 the Maple Leaf Exploration Company, of Toronto, continued sinking the shaft. In the fall of that year, Mr. M. L. Foley sent about 6 tons to Ottawa.

It is said that 10 tons of 3·64 per cent ore was shipped in 1916,[3] of which 6·6 tons was sent to the International Molybdenum Company's concentrator at Renfrew, Ont.

The following are the shipments made to the Mines Branch, Ottawa: M. L. Foley, hand-picked, 6·2 tons, 2·19 per cent MoS_2; per Maple Leaf (J. F. Day), hand-picked, 1·3 tons, 1·08 per cent MoS_2. From the above shipments 316 pounds of pure molybdenite was recovered. Altogether, about 18 tons of ore must have been shipped from the property.

Sudbury District

Roberts Township

Mataris Prospect. This property, which was staked by John Mataris in 1915, is about a quarter of a mile west of the Canadian National railway, two miles south of Raphoe station.

Three small quartz veins, from 1 inch to 6 inches wide, cut through the country rock of granite. The principal vein is about 25 feet in length, and pinches out at either end, as well as in depth, and contains only scattered grains of molybdenite.

The work done consists of a pit 8 feet deep, and strippings have been made over an area of a few hundred square feet. The main vein, as shown in the pit, narrows down to one inch at a depth of 4 feet. A number of joints in the granite are filled with molybdenite but the total quantity of the mineral is small, and the prospect of there being more is poor.

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[1] Ont. Bur. of Mines, 1917, p. 309. A. L. Parsons.
[2] Molybdenum Ores of Canada, 1911, p. 46. T. L. Walker.
[3] Ont. Bur. of Mines, 1917, p. 310. A. L. Parsons.

Thunder Bay District

Conmee Township

Concession II, Lot 3, Kakabeka. This property is situated 2 miles north of Kakabeka Falls station, 20 miles west of Port Arthur.

A large dike of basic granodiorite intrudes the metamorphic Keewatin schists of the district. Within this dike there is a quartz vein, 16 feet wide, which for the first 15 feet in depth dips 80 degrees south, then takes a twist, dipping 80 degrees to the north, and at 50 feet appears to take a 45 degree turn to the northeast.

Mr. F. Hille, who made an examination in 1916, says that:—

> This irregularity of the vein is no damaging feature, the principal thing is that the ore-body goes down, and as the origin of this class of mineral is exactly the same as the rock in which it occurs, namely volcanic, and since the granite broke through the Laurentian and Keewatin rocks, which are both of immense thickness, then the depth of this granite must be the same, and consequently the vein with its contents must be likewise considerable.

The vein itself is composed of a quartz gangue in which molybdenite, in very fine flakes, or semi-amorphous form, is as a rule evenly disseminated, but in some places it occurs in vertical streaks of larger flakes. Iron pyrites is also scattered throughout and small quantities of chalcopyrite and calcite were noticed.

Mr. Robert Gamble, of Ottawa, who now holds an option, believes that the vein has been faulted. Mr. Hille estimated the ore to be not less than 5 per cent MoS_2, but two samples sent to Ottawa ran 2·5 per cent and 1·3 per cent.

The principal work done consists of a well-timbered shaft 7 by 4 feet and 50 feet deep, sunk in the supposed foot-wall where it outcrops near the roadway. At the bottom of the shaft an 18-foot crosscut is driven southwards. Extensive trenching work has been done, and pits have been sunk at both ends of the vein, from some of which rich ore is said to have been extracted. The deposit was discovered in the summer of 1914, and worked for a period during the following year by Messrs. Younge and Walsh. During 1917 an option was taken by Messrs. Gamble and McBeety.

Transportation may be made by rail to Port Arthur, or Fort William, and thence by the Great Lakes. Fuel and timber are available on or near the property, water is available from two creeks running through the east end of the property, and power could be obtained from the Kaministikwia Power Company at Kakabeka Falls, about 3½ miles to the south.

Burrows Lake.

Molybdenite occurs on the Chubish mining claim, on the west shore of Burrows lake, 15 miles northwest of Longlac, which is 70 miles east of lake Nipigon.

The mineral is disseminated throughout a part of the granite. Samples from this deposit were of friable biotite-gneiss, carrying small disseminated scales of molybdenite, the whole being about 3 per cent ore. A considerable amount of ore is said to be exposed, and if this is so the Chubish claim may be regarded as the most promising prospect in the district.[1]

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[1] Geol. Surv., Can., Sum. Rept., 1918, p. 3 E. T. L. Tanton.

Lake Superior Region

Jackfish-Pritchard Prospect. This property, consisting of about 30 acres, owned by Capt. W. Pritchard and Mr. George Galbreath, of Fort William, is situated on the southwest side of Owl lake, about 11 miles north of Jackfish bay, near Schreiber.

The mineralized zone, which is stated to be about 80 feet wide, lies on a contact between a greenstone trap and slate. The work, which was done in 1920 and 1921, consists of a shaft 8 feet deep, and various pits and strippings. A small amount of ore that was mined is still on the property. Eight samples taken by Capt. Pritchard, and analysed by the Duluth Testing Laboratories, varied from 2·15 to 20·0 per cent MoS_2. It was not stated how these samples were taken, but if any are representative samples of the wider portion of the lead the prospect might be worthy of further development.

McTavish Township. Concession VII, N.E. $\frac{1}{4}$ Lot 5, Loon Lake. This property, consisting of four 40-acre claims, owned by Messrs. J. A. Johnson and D. Kelly of Fort William, is 3 miles northeast of Loon Lake station on the Canadian Pacific railway, 25 miles northeast of Port Arthur.

A series of pegmatite dikes cut alternating belts of granite and greywacke. These dikes are very conspicuous, as the intruded rocks have weathered out, leaving exposed ridges running in a southeast direction. Molybdenite occurs as fracture fillings within the pegmatites, and along the contacts. The occurrence is quite free from foreign sulphides, mica, etc. There is a considerable amount of yellow molybdic ochre on the weathered surfaces. The gangue is pink orthoclase feldspar and quartz.

Work was done in 1918, on two of these dikes which vary in width from 25 to 50 feet; the most westerly has been stripped for a distance of about 1,000 feet, over which length scattered showings of molybdenite occur. The easterly dike has been opened up by surface workings to a depth of 2 feet, over a length of 230 feet; the mineral in it is mostly confined to the westerly contact wall.

In June 1918 Mr. Johnson shipped 502 pounds of 2·14 per cent ore to the Mines Branch testing plant at Ottawa, from which an 85·7 per cent MoS_2 concentrate was made, with a 92 per cent recovery.

Captain H. E. Knoble, who made an examination in September, 1918, reported favourably on the property and estimated that a 2·0 per cent ore could be cheaply quarried, and electric power could be obtained from the Nipigon plant, 30 miles to the northeast. The country has been burned over and no wood would be available for fuel.

Terrace Cove. This occurrence of molybdenite is of historical interest as the first recorded in Canada.[1]

The locality is on the west side of Terrace cove on concession V of Homer township, north of the west end of Michipicoten island, in the southeast corner of Thunder Bay district.

Sir W. E. Logan[2] describing the deposit states that red feldspathic gneiss is traversed by large dikes of black trap and intersected by two sets of veins, one running south and west along the shore and parallel

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[1] Geol. Surv., Can., 1853-56, p. 40.
[2] Geol. Surv., Can., 1863, p. 705.

to the trap; the other set, running north and south, is cut by the trap dikes. The latter veins are 3 or 4 inches wide and carry in a quartz gangue considerable quantities of yellow and vitreous copper ore and molybdenite. One of these veins, bearing a considerable amount of both these minerals, is 8 inches wide and was traced for one and a half miles.

Although no work appears to have been done, it would seem from the above description that although the veins are small it might be possible to work the deposit on a small scale and ship by water.

Lake Nipigon Region

Tamarack Lake. P. E. Hopkins, in 1918,[1] reports the presence of molybdenite northwest of lake Nipigon, on the portage at the north end of Tamarack lake. The mineral was observed in flakes up to one-fourth of an inch diameter, in a dike of pink pegmatitic granite 20 feet wide that intrudes biotite-granite gneiss.

Hopkins also mentions several deposits of molybdenite between Armstrong and Collins. Two miles south of the railway on an island in Tunnel lake, 10 miles west of Armstrong, the mineral occurs as patches in the granite; also, float containing molybdenite is said to have been found at Trout lake and at Collins, 8 miles farther west.

Although molybdenite is found over a wide area in the Nipigon region, no development work has been done, and the occurrences so far discovered do not appear to be of economic value.

Harvey. Molybdenite occurs near Harvey station on the Canadian National railway, about 50 miles west of the Tamarack Lake deposits. In August 1919 Mr. J. H. Teare, of Sault Ste. Marie, Ontario, sent about 1,000 pounds of 0·4 per cent MoS_2 ore to the Mines Branch for testing purposes.[2] The ore shows fairly small flakes disseminated through a quartz and green hornblende gangue, associated with small amounts of pyrite, mica, and white feldspar. No information concerning the property is available.

Timiskaming District

Teck Township

Kirkland Lake Region, Tough-Oakes Mine. The occurrence of molybdenite is mentioned in reports of A. G. Burrows and P. E. Hopkins[3] in the Kirkland Lake and Swastika gold-areas.

Kirkland Lake is about 3 miles north of Swastika station on the Cochrane-Cobalt branch of the Timiskaming and Northern Ontario railway.

The mineral was found in 1910 in the Lucky Cross gold mine half a mile northeast of Swastika; at Tough-Oakes mine on the Teck-Lebel boundary line 2 miles northeast of the Lucky Cross; and in the Teck-Hughes mine on L. 1238.

Quartz veins occurring in conglomerate and greywacke carry pyrite, chalcopyrite, galena, zinc blende, calcite, dolomite, etc., and some molybdenite.

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[1] Ont. Bur. of Mines, 1918, p. 191.
[2] Mines Branch Sum. Rept.; 1919, p. 89.
[3] Ont. Bur. of Mines, 1914, Vol. XXIII, Part II p. 21.

Hopkins[1] states that:—

> Molybdenite has been deposited abundantly in fractures, usually as a thin film. Gold bearing solutions have circulated along these planes and the veins have been enriched by the deposition of gold in these later fractures, later movements have often slickensided these planes, while the gold, altaite, (telluride of lead) and other minerals may be polished. In some cases the gold must have been deposited after the slickensides were formed, since the veinlets of the metal were observed on the 200-foot level of the Tough-Oakes mine cutting across the smooth planes of the molybdenite.

It is of interest to note that W. K. McNeill, the provincial assayer, showed that both the molybdenite and altaite will precipitate gold from chloride solutions, the latter forming tellurides. An association of gold in contact with molybdenite was noticed in the Raty gold mine, Rickard township, Abitibi region.

A paper was read by J. B. Tyrrell[2] before the Canadian Mining Institute, in which he illustrated the bands of slickensided gold and molybdenite resulting from the faulting of quartz veins. He also mentions that the mineral was known for some time by miners and prospectors and was thought to be graphite.

In the Teck-Hughes mine the vein consists of molybdenite, pyrite, and visible gold, and occurs in conglomerate.

No shipments of molybdenite have been recorded from the region nor has there apparently been any attempt to save the mineral when mining for gold and copper, etc.

P. E. Hopkins[3] reports the presence of molybdenite in three adjoining townships near Dane station on the Timiskaming and Northern Ontario railway. These occurrences are a few miles south of the Kirkland Lake region.

Boston Township—on the Authier claim (L. 4737); and east of Dane station.

McElroy Township—in granite on the Charest claim (L. 5505), about 10 miles east of Dane station.

Skead Township—on the following mining claims: Wisconsin-Skead; Sampson; Crawford-Skead; and Skead-Gold. These claims are about 15 miles southeast of Dane.

Victoria County

Laxton Township

Concession XI, Centre of Lot No. 5, Horscroft Mine. This property is located on the west side of Mud Turtle lake, half way between Gull and Balsam lakes, and is near Norland post office, about 6 miles north of Coboconk.

This occurrence is of historical interest as the second recorded discovery of molybdenite in Canada. Alexander Murray,[4] in 1852, stated that the white crystalline limestones in this region were intersected by large veins of white quartz, in which were small masses of molybdenite associated with greenish pyroxene, scapolite, and iron pyrites.

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[1] Ont. Bur. of Mines, 1914, Vol. XXIII, Pt. II, p. 21.
[2] Trans. of Min. and Metall., 1913-14, Vol. XXIII, p. 157.
[3] Ont. Bur. of Mines, 1921, Vol. XXX, Pt. II.
[4] Geol. Surv., Can., 1852-53, p. 144.

It is of interest also to note that it was from this deposit that molybdenite was first recorded in the Ontario mineral production statistics, in 1902, when Mr. John Webber of Toronto shipped 3¼ tons of ore valued at $400.[1]

In 1916 two lessees worked on different claims within a few feet of each other. One of these is on the farm of Wm. Adair and was operated by Mr. T. Horscroft, but the ore-body apparently dips into the neighbouring property worked by Messrs. Ponton and Russell. On the former claim, an open trench or quarry 70 by 20 feet and 10 feet deep was excavated in the soil and decomposed pyroxenite in which near the surface an abundance of yellow molybdite was noticed. The ore would probably average 0·5 per cent MoS_2.[2] The ore is associated with pyrite and is concentrated along the contact of the limestone and pyroxenite.

During the fall of 1916 Mr. Horscroft shipped over 31 tons of partly selected ore, averaging 1·62 per cent, to the Mines Branch, Ottawa, from which 816 pounds of molybdenite was recovered. Mr. James Harris, of the Hamilton Molybdenum Alloys Company, states that his company has a one-third interest in the Adair property and that the other two-thirds are held by Mr. Webber of Toronto and associates. The mine is now known as Adair Mine No. 1.

The company's plant consists of a 45 h.p. steam boiler, double-hoist engine, steam drill, and air compressor, all of which are at the Bryant Mine No. 2.

Ponton-Russell Mine. Within a few yards of the Horscroft mine and in the same ore-body which dips under the lake, Messrs. Douglas Ponton and A. J. Russell sunk a 7 by 9-foot shaft to a depth of 50 feet, on the shore of Mud Turtle lake. Although this shaft was full of water at the time of the visit of the writer, it appears, from an examination of several tons of ore on the dump and in the store house, that the deposit consists principally of a micaceous pyroxenite, probably averaging one per cent MoS_2, but some of the ore is of much higher grade.

The plant consists of a boiler house, Cornish pump, and hand-derrick.

Because the ore-body dips under the lake there is always likely to be trouble with water. It appears doubtful if the property could be economically worked from the present shaft site, but the grade of ore warrants further development a little farther inland with the object of sinking and connecting up the different deposits.

Concession A., Lot 3, Adair Prospect. On another of Wm. Adair's farms, near the boundary of Laxton and Somerville townships, and about 2 miles north of the Horscroft mine, molybdenite was found associated with pyrite on a contact between crystalline limestone and thin-bedded quartzose mica-schists. Several pits were dug by Mr. Horscroft on this contact and in close proximity to a massive granite.

There are several other known occurrences of molybdenite in this region in the limestone belt: on small islands in Mud Turtle lake; at Elliotts falls; and along Gull river to Gull lake, apparently a continuation of the deposits already described in Lutterworth township. This belt appears to be particularly favourable for the occurrence of molybdenite, but the only economical method of production would be for one company to work all or most of these prospects.

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[1] Ont. Bur. of Mines, 1903, p. 25.

[2] Ont. Bur. of Mines, 1917, p. 299. A. L. Parsons.

TABLE XI

Molybdenite Deposits and Occurrences in Ontario

	Region or township	Locality and name	Mode of occurrence	Quantity of ore shipped	Classification	Remarks	References
			ALGOMA DISTRICT				
1	Lake Superior	Molybdenite lake near Michipicoten harbour	In pegmatite dike in coarse quartzose pegmatite	Nil.	F.	Third mention in Canada, 1853; little prospecting.	(5)
2	" ..	Oba river............	Quartz veins in volcanic complex	"	M.	Four different occurrences.....	(1) 1918, p. 3 E
			CARLETON COUNTY				
3	March........	Con. II, lot 6.........	In pegmatite dikes in crystalline limestone	Nil.	F.	One small pit................	(3)
4	Olden.........	Con. VI, lot 7, Macdonnell	Pyroxene and pink feldspar in limestone	238 lbs........	E.	Ore 0·4%; one pit............	(5)
5	"	Con. VI, lot 6, Smith	Granite-limestone contact...	1,150 lbs.......	E.	One pit......................	(5)
6	"	Cons. VIII to X, lots 23-27, Avery	" " ..	Nil.	E.	Four outcrops, possibilities elsewhere; one pit	(4)
7	"	Long lake............	In limestone with serpentine	"	M.	No development.............	(5)
8	Miller.........	N.E. range, lot 5, Kring	Pegmatite dike in gneiss....	Exhibition specimens	E.	Four pits....................	(5)
9	"	Elkington-Tooley.....	With tourmaline in pegmatite dike in gneiss	Nil.	E.	Little prospecting............	(5)
10	"	S. lot 5, T. Armstrong.	....	"	E.	Three pits and trenching; some 1% ore on dump	(5)
			HALIBURTON COUNTY				
11	Cardiff.......	Con. V, lot 11, Orr-Kidd.	Large flakes associated with pyrites in pegmatite dike in gneiss.	100 lbs. flake....	C.	Open-cut......................	(5)
12	"	Con. IX, lot 6, Powell and Anderson	Large flakes in coarse pegmatite dike in gneiss	100 lbs. flake....	C.	Three open-cuts..............	(5)
13	"	Con. IX, lot 18, Paudash Lake Molybdenum Co.	Large flakes in coarse quartz-feldspar pegmatite dikes in gneiss	300 lbs. flake....	D.B.	Several tons 4% ore in shed; 3 medium pits.	(5)

14	"	Con. X, lots 16-19, Powell and Anderson	Scattered sparsely through pegmatite dike in gneiss	Nil.	E.	A few test pits...............	(4)
15	"	Con. XI, lot 12, Mathews-McMahon	Large flakes associated with sulphide in a contact pyroxene zone	Individual lumps	C.	2 small open-cuts.............	(5)
16	"	Con. X and XI, lots 11-12, Evans mine	Heavy pyritic contact zone between limestone and granite complex	150 tons treated.	C.	45-foot shaft and several trenches and pits; very little MoS_2 seen; small crushing plant produced one ton concentrates	(5)
17	"	Con. XX, lots 2 and 3, Joiner	Widely disseminated through a hornblende-granite ridge near limestone	30 tons.........	A.	300 · ft. trenching; 20 pits; 2 shafts; extensive low-grade deposit; several hundred tons 0·5% ore on dump	(5)
18	Glamorgan...	Con. IV, lot 31, Armitage	....	Nil.	M.	No prospecting...............	(4)
19	" ..	Con. V, lot 32, British Molybdenum Co.	....	"	F.	Stripping and a few pits.......	(4)
20	" ..	Con. XIII, lot 34, Tory Hill Mica Co.	Associated with mica.......	"	E.	Assessment work; 60 tons low-grade ore extracted	(4)
21	Harcourt.....	Con. I, lots 3 and 4, Harcourt mine	Sulphide and pyroxene stringers in gneiss and limestone	50 lbs.........	C.B.	Several pits, shafts and trenches; 2 tons cobbed ore on dump	(5)
22	Lutterworth..	Con. II, lots 7 and 8, Hopkins (1)	Quartz vein in gneiss near contact of gneiss and pegmatite	Nil.	C.	A little prospecting...........	(5)
23	"	Con. V, lot 23........	On pegmatite contacts with limestone	"	C.	30-foot shaft and trenching; ore in shaft	(5)
24	"	Con. X, lot 7, Hopkins (2)	Quartz veins in hornblende gneiss	"	E.	Very little prospecting; several other occurrences but all appear too small	(3) p. 40
25	"	Con. IV and V, lot 19, Miners bay	Throughout crystalline limestone	"	M.	No prospecting...............	(5)
26	"	Con. X, lot 15, Hunter	In limestone...............	"	P.	Some prospecting............	(4)
27	Monmouth....	Con. XI, lot 12, Anderson	A silver-gold ore...........	"	E.	30-foot shaft and test pits; shipments for Au and Ag; MoS_2 thrown out on dump	(4)
28	"	Con. XIII, lot 13, Gibson	Contact pyroxene and sulphides in granite and gneiss	6½ tons.........	C.	15 tons 1% ore on dump; some quarrying	(5)
29	"	Con. XIII, lots 14 and 15, Lillico mine	Heavy flat pyritic seam in red granite and gneiss	157 tons; 1,500 lbs. pure MoS_2 produced	C.B.	Several large pits and quarries; some D.D. holes; 3,000 tons mined	(5)
30	"	Con. XIV, lot 10, Madill property	Associated with sulphides and contact pyroxenite in granite and gneiss contact	Nil.	P.C.	A few shots; probably continuation of Padwell (below)	(5)

TABLE XI—*Continued*

Molybdenite Deposits and Occurrences in Ontario—Continued

	Region or township	Locality and name	Mode of occurrence	Quantity of ore shipped	Classification	Remarks	References
			HALIBURTON COUNTY—*Concluded*				
31	Monmouth....	Con. XV, lot 11, Padwell property	With sulphides in flat contact pyroxenite zone between pure white crystalline limestone and granite	117 tons cobbed 2,100 lbs. MoS_2 produced	C.	One quarry..................	(5)
32	“	Con. XV, lots 10 and 12, Affenby and Henery	“ “	Nil.	D.	Two occurrences on the Padwell zone..................	(4)
33	“	Con. XV, lot 17, Johnston	Associated with sulphides in limestone	“	D.	One pit; 2 tons fair grade ore extracted	(5)
34	“	Cons. XV and XVI, lot 32, American Molybdenites, Ltd.	Sparsely disseminated throughout feldspathic pyroxenite and granite	86 tons..........	C.	7 pits, trenching and shaft; some D.D. holes; very low grade over wide area. Shipments 0·25% MoS_2; 125-ton concentrator	(5)
35	“	Con. XV, lots 32 and 33, Wilberforce Molybdenum Co.	Flat sulphide pyroxene zone in granite-gneiss and limestone	Nil.	E.	5 cuttings; several tons low-grade ore extracted	(5)
36	“	Con. XVII, lot 32, Dwyer	Pyroxene-quartz-albite vein in gneiss and limestone	“	D.	Some open-cuts and pits; continuation of American Molybdenum, Ltd., deposit	(5)
37	Dungannon...	Cons. XIII and XIV, lot 25, Bancroft	....	“	F.	Little prospecting............	(1) Mem. 57, p. 116; (2) 1917, p. 295
38	“	Con. XVI, lot 5, Stoughton	On pegmatite contacts in limestone and gneiss	694 lbs. cobbed	E.	Two trenches..................	(5)
39	Herschell.....	Con. IV, lots 27 and 28, Williams	....	300 lbs. flake....	C.	Trenching; much MoS_2 float but heavy overburden	(5)
40	“	Con. V, lot 31, Spencer	....	Nil.	C.	One pit; half ton closely cobbed ore on dump	(5)
41	Monteagle....	Con. I, lot 6, York r.	Quartz seam in fibrous hornblende	“	F.	A few shots..................	(1) Mem. 6, p. 351
42	“	Con. VI, lots 26 and 27, Spencer	Pegmatite contact in biotite gneiss	“	F.	A few pits. Mica mine	(3) p. 43; (2) 1917, p. 307

43	“	Con. XIII, lot 25, National Graphite Co.	In pyroxenite on contact near edge of graphite zone in limestone and granite	“	E.	No development for MoS_2. Graphite mine, no MoS_2 saved	(2) 1917, p. 307

KENORA DISTRICT

44	Gull lake.....	Dryden near Coates..	Quartz-feldspar pegmatite dike in hornblende schist	Nil.	C.	Some test pits................	(5)
45	Manitou lake.	Claim A.D. 8, Pidgeon	Quartz pegmatite in Laurentian granite	200 lbs. flake (samples)	C.	Assessment work; associated with chlorite and some bismuthinite	(5)
46	“ ..	Claim 148, S. V. Smooth Rock lake	On contact of gneiss and granite with pyrite in altered trap	Nil.	E.	No development.............	(2) 1911, p. 188
47	Wabigoon lake	Claim K. 645, Contact bay	Contact quartz vein with iron and copper in granite and diorite	“	F.	No development for MoS_2. Observed in mining for copper	(2) 1913, p. 313
48	Township 22..	Ignace, McClure......	Clean flakes in granite......	“	C.	One pit......................	(2) 1917, p. 299
49	English river.	Lac Seul..............	In coarse red and grey porphyritic gneiss	“	M.E.	No development.............	(2) 1895, p. 61
50	Lake of the Woods	Mikado Gold mine; and claim D. 149	Quartz vein in altered trap in granite quartz	“	F.	No development for MoS_2....	(2) 1911, p. 164
51	“ ..	Quarry island near Kenora	In quartz veinlets traversing gneiss	“	M.	No development for MoS_2. In ores of Sultana gold mine	(2) 1911, p. 176
52	“ ..	N.W. Angles inlet, Shoal lake	Dike in quartzite...........	“	M.	No development.............	Brit. N. Amer. Bond. Com., 1875, p. 36

LEEDS COUNTY

53	N. Crosby....	Con. V, lot 14, Merkley	Associated with dark green pyroxene in crystalline limestone and syenite granite	Nil.	F.	Two pits......................	(3) p. 45

LENNOX AND ADDINGTON COUNTIES

54	Sheffield......	Con. XII, lots 9 and 10 Calvert	....	One ton.........	D.	Ore 1% MoS_2; surface stripping	(5)
55	“	Con. XIII, lot 11, Oberkerk	Oxidized contact zone between gneiss and limestone	Nil.	E.	Very little prospecting........	(4)
56	“	Con. XIII, lot 12, Kellar	Contacts between granite gneiss and limestone	160 lbs. flake....	C.	Pits and trenching; three different deposits	(5)
57	“	Con. XIV, lot 5, Chisholm mine	Associated with sulphides and pyroxene between limestone and granite	343 tons.........	B.	Two large pits; 4 tons pure MoS_2 produced; 1,000 tons ore mined; 40-ton Groch concentrator	(5)

TABLE XI—*Continued*

Molybdenite Deposits and Occurrences in Ontario—Continued

	Region or township	Locality and name	Mode of occurrence	Quantity of ore shipped	Classification	Remarks	References
			LENNOX AND ADDINGTON COUNTIES—*Concluded*				
58	Sheffield.....	Con. XV, lot 4, Burns	Sulphide zone between limestone and granite	Nil.	P.C.	Adjoins Chisholm mine. Little prospecting	(2) 1916, p. 135
59	"	Con. XV, lot 8, Spratt	Oxidized contact zone between gneiss and limestone	"	C.	One open-cut. Two tons low-grade ore extracted	(5)
60	"	Con. XVI, lot 15, Wager	Quartz and pyroxenite contact in gneiss and limestone	286 lbs........	C.	Six trenches, three open-cuts. Traced for 1,500 ft.	(5)
61	"	Cons. XV and XIII, lots 12 and 10, Molony	Large oxidized zones at contact of gneiss and limestone	Nil.	P.C.	Little prospecting............	(5)
			MUSKOKA DISTRICT				
62	Muskoka......	Con. VII, lot 11, Howell	In pegmatite dike in banded granite-gneiss	Nil.	M.E.	No development.............	(4)
63	Monk.........	Con. VIII, lot 12, Stead	In gneiss formation..........	"	E.	Two small pits...............	(2) 1917, p. 305
			NIPISSING DISTRICT				
64	Airy..........	Con. VIII, lot 4, Jodouin	....	Nil.	P.	Very little prospecting.......	(4)
65	Calvin........	Con. IX, lot 27, Talon chute	Sulphide-pyroxene zone......	"	F.	One pit. Mostly graphite, traces of MoS_2	(5)
66	Garrow.......	Con. III, lot 10, Shephard	....	Half ton ore and flake	....	Little prospecting. Information unreliable	(2) 1917, p. 295
67	Rickard......	Con. IV, lot 7, Raty.	With copper pyrites in a carbonate schist	Nil.	F.	Developed for gold only......	(2) 1918, p. 214
68	Strathy.......	Net lake, Barton.....	Radiating nodules in brecciated quartz	1,216 lbs. cobbed	C.B.	One shaft and strippings. 200 tons ore extracted	(5)
			NORTH WEST TERRITORIES				
69	Patricia......	Cross lake...........	In pegmatite dikes in granite	Nil.	M.	No development	(1) 1902, p. 207 A

PARRY SOUND DISTRICT

70	Cowper......	Con. IV, lot 10, Wilcox mine	In copper ores..............	Nil.	E.	Development for copper only.	(2) 1899, p. 167
71	"	Con. V, lots 32 and 33 Foley	"	"	E.	" " ..	"
72	Ryerson......	Cons. V, VI, lots 29 and 30, Brown	Quartz ledges in limestone..	"	F.	Shaft and trenching. Mainly worked for gold and copper	(4)

RAINY RIVER DISTRICT

73	Bad Vermilion lake	Mine Centre..........	With pyrite and sericite in conglomerate	Nil.	M.E.	No development for MoS_2.....	(2) 1918, p. 178
74	Rainy lake...	Bear passage..........	Quartz vein at contact of Laurentian and Couchiching schists	"	F.	No development.............	(1) 1887, p. 180 F.

PETERBOROUGH COUNTY

75	Anstruther....	Con. XIV, lot 24, Jones	Near contact of limestone and gneiss.	Nil.	F.	No development.............	(2) 1917, p. 287

RENFREW COUNTY

76	Admaston....	Con. IX, lot 9, Gorman	Sulphide, pyroxene contact zone of limestone and gneiss	21½ tons......... 117 pounds MoS_2 recovered	E.	Ore low grade; some trenching	(5)
77	"	Con. XIII, lot 8, Kiley	Heavy sulphide contact zone of bands of limestone and gneiss	Nil.	C.	Some trenching. Ore in old well, several tons extracted	(5)
78	Bagot.........	Con. IV, lot 28, Phoenix Molybdenite Corpn. (Taylor)	Pyritic pyroxene stringers in gneiss, red granite and bands of limestone	84 tons.......... 4 tons MoS_2	B.	Shafts, quarry, and trenching. Ore high grade	(5)
79	"	Con. IV, lot 27, Phoenix Molybdenite Corpn. (Canadian Molybdenite Co.)	Limestone-gneiss contact....	1,520 lbs. cobbed; 60 lbs. MoS_2 recovered	E.	Shaft and trenching..........	(5)
80	"	Con. X, lot 15, Hunter	Limestone-pegmatite contact and gneiss	100 lbs. flake....	F.	Trenching and one pit.........	(5)
81	"	Con. XII, lot 28, Culhane	Massive pyroxene on greenstone contact in red granite	35 lbs. picked..	C.	Four pits. Possibilities at Snake lake	(5)
82	Blithfield.....	Con. I, lot 29, Quilty..	Heavy flat sulphide contact pyroxene zone between red granite and limestone	19 tons; 120 lbs. MoS_2 recovered	C.	One quarry and five pits. Ore low grade	(5)
83	Bromley......	Con. V, lot 24, Cole...	Pyroxene mass.............	1½ tons.........	E.	Several small pits............	(4)

TABLE XI—*Continued*

Molybdenite Deposits and Occurrences in Ontario—Continued

RENFREW COUNTY—*Concluded*

	Region or township	Locality and name	Mode of occurrence	Quantity of ore shipped	Classification	Remarks	References
84	Brougham....	Con. I, lot 17, Box....	Flakes in pegmatite in gneiss	½ ton..........	F.	Ore 0·5% MoS_2. A few shafts and one pit	
85	"	Cons. XI, XII, lots 7-9, Hunt mine	Metamorphic pyroxene contact in pegmatite granite and limestone	7,000 tons; 50 tons MoS_2 produced	A.	Extensive tunnels and shafts; 10,000 tons mined; 30-ton mill and plant; ore still in sight	(5)
86	"	Con. XI, lot 16, Ross.	Flat sulphide bands in gneiss	720 tons, about 7 tons MoS_2 recovered	B.	Two large quarries and shaft. Ore 1% MoS_2. Ore still in sight	(5)
87	"	Con. XI, lot 17, O'Brien (International)	Ill-defined gneiss-limestone contacts	500 tons........	C.E.	Extensive shafts, pits, trenches. Ore low grade, and very scattered. Extensive buildings.	(5)
88	"	Con. XII, lot 18, O'Brien farm	Pegmatite-gneiss-limestone contacts	Nil.	F.	Two pits....................	(4)
89	"	Con. XIII, lot 13, Maloney	Ill-defined gneiss-limestone contacts	Nil.	E.	Few small pits. Many small, low-grade occurrences	(5)
90	"	Con. XIV, lots 35-36, Sunset	Sulphide contact pyroxene in hornblende gneiss	20 tons cobbed, 936 lbs. of MoS_2 recovered	C.E.	70-foot shaft, pits and trenches; about 400 tons low-grade ore extracted	(5)
91	Griffith.......	Con. IV and V, lots 31-32, Spain mine	Metamorphosed pyroxene pegmatite zone in hornblende pyroxene-monzonite gneiss	100 tons, 3½ tons MoS_2 recovered	A.	One large pit, shaft and stripping; about 1,000 tons low-grade ore extracted; large masses of MoS_2 found; 50-ton mill, ore still in sight	(5)
92	"	Con. IV, lots 33-34, Legree	Sulphide contact pyroxene in hornblende gneiss	Nil.	C.	Two small pits. Two tons milling ore extracted	(5)
93	Lyndoch.....	Con. II, lot 34, McCoy	....	Two tons......	C.	Pits and trenches. Ore about 0·75%	(5)
94	"	Con. VIII, lots 5-6, Jamieson mine	On gneiss-limestone contact with much pyrite	280 tons, about 6 tons MoS_2 recovered	B.	Two large pits, shaft and trenches; 200 tons 1% ore on dump	(5) (5)

95	“	Con. VIII, lot 9, Legree	On pegmatite contact in gneiss and limestone	150 lbs. cobbed.	C.	Three pits and strippings; 5 tons milling ore extracted, continuation of Jamieson vein	(4)
96	Matawatchan.	Con. VI, lot 3, Wilson	Wide pyroxene-pegmatite contact in gneiss	Nil.	C.	A few shots. Possible large low-grade deposit	(5)
97	Raglan.......	Cons. IX, X, lot 27, Windle-Liedke	In pegmatite dike in limestone	“	E.	A few pits. One ton 2% ore cobbed	(5)
98	“	Con. XVIII, Craigmount Corundum	In fine seams in corundum-bearing syenite	“	E.	No development for MoS$_2$	(3) p. 46; (1) 1910, p. 374
99	Ross..........	Con. II, lot 22, Haley.	In quartz-pegmatite band in biotite-gneiss	18 tons cobbed. About 700 lbs. MoS$_2$ recovered	D.	40-foot shaft and large pit; apparently all ore now extracted	(5)
100	“	Con. IX, lot 7, Elliott	With pyrites in limestone...	Nil.	F.	Some pits	(3)
101	Sebastopol....	Range C, lots 36-38, Ziebath	Pegmatite between gneiss and limestone	“	F.	Two small pits...............	(2) 1917, p. 310

SUDBURY DISTRICT

102	Drury........	Worthington mine.....	Occasional seams in pyrrhotite in greenstone	Nil.	F.	No development for MoS$_2$.....	(2) 1905, pt. III, p. 161
103	Roberts......	Raphoe, Mataris......	Small quartz veins in granite	“	E.	One pit and strippings.........	(5)

THUNDER BAY DISTRICT

104	Conmee......	Con. II, lot 3, Kakabeka Falls	Wide quartz vein in granodiorite dike	400 lbs........	B.	50-foot shaft, tunnels and extensive trenching. Several tons good ore extracted	(5)
105	Canadian Northern railway	Burrows lake.........	Disseminated through granite gneiss	Nil.	C.	Some prospecting............	(5)
106	“ ..	Longlac, Hayne.......	With chalcopyrite in pegmatite	“	M.	No development............	(1) 1918, p. 3 E
107	Lake Nipigon.	Poplar point near lake Nipigon	With iron and copper sulphides in coarse-grained granite	“	M.	“	(2) 1907, p. 129 A.
108	“ ..	Tamarack lake.......	In a wide pegmatite dike in biotite-granite gneiss	“	M.C.	“	(5)
109	Harvey.......	Harvey station.......	Fine flakes in quartz hornblende gneiss	1,000 lbs........	E.	Little prospecting; ore 0·4%...	(5)
110	Lake Superior	Big Duck near lake Superior	With other sulphides on quartz-schist contact	Nil.	M.E.	No development.............	(2) 1914, pt. I, p. 11
111	“ ..	Schreiber.............	In gold quartz veins in granite	“	M.	No development. Three or four occurrences	(4)

TABLE XI—*Concluded*

Molybdenite Deposits and Occurrences in Ontario—Concluded

	Region or township	Locality and name	Mode of occurrence	Quantity of ore shipped	Classification	Remarks	References
THUNDER BAY DISTRICT—*Concluded*							
112	Lake Superior	Jackfish bay, Pritchard	In greenstone trap and slate in granite	Nil.	C.	Small shaft and pits. Samples high grade	(5)
113	McTavish....	Con. VII, lot 5, Loon lake	In wide pegmatite dikes cutting granite in alternating belts of granite and greywacke	500 lbs.......	C.B.	Extensive stripping, pits. Ore estimated 2·00% MoS_2.	(5)
114	Homer.......	Con. V, Terrace cove.	In cupriferous quartz veins in gneiss	Nil.	D.	No development. First recorded Canadian occurrence	(5)
TIMISKAMING DISTRICT							
115	Beatty.......	Con. I, lot 4, Abate..	In a rusty quartz vein in greywacke schist	Nil.	E.	Pits and trenching...........	(2) 1914, p. 182
116	Deloro........	Timmins.............	With pyrite in secondary quartz in jaspilite	"	E.	Very little prospecting........	Min. & Sci. Press, Dec. 18, 1915, p. 937
117	Teck.........	Kirkland lake, Tough-Oakes mine	With metallic sulphides in conglomerate	"	E.	Associated with gold; no attempt to retain MoS_2 when mining for Au and Cu. About six other occurrences in Kirkland Lake region	(5)
VICTORIA COUNTY							
118	Digby........	Con. VII, lot 16, Gull river	Small stringer in gneiss......	Nil.	M.F.	No development..............	(1) 1892, p. 7 J
119	Laxton........	Con. II, lot 5, Raven lake	In quartz vein in limestone	"	M.	"	Min Res. of Can. 1904, p. 10
120	"	Con. XI, lot 5, Horscroft	White quartz and micaceous pyroxene with pyrite in limestone	35 tons selected; about 1,000 lbs. MoS_2 recovered	C.	Quarry and shaft. Second mention of MoS_2 in Canada; first recorded shipper in Canada	(5)

121	“	Con. XI, lot 5, Ponton-Russell	White quartz and micaceous pyroxene with pyrite in limestone	No record......	C.	50-foot shaft and trenching. Continuation of Horscroft but under the lake; both now worked by Hamilton Molybdenum Alloys Co.	(5)
122	“	Con. A, lot 3, Adair..	With pyrite on limestone-schist contact	Nil.	C.	Several pits. Several other occurrences	(5)

In addition to the above list there are about 35 other known occurrences of minor importance in Ontario.

In the above tabulation the following *tentative* classification has been adopted for grading purposes.

A. Economic conditions favourable, and probably a considerable producer.
B. Probable producer.
C. Has possibilities and worthy of further investigation.
D. Has possibilities on a small scale, suitable for economic hand-cobbing.
E. Prospect not very encouraging.
F. Prospect not worthy of further investigation.
P. Prospect—no definite information.
M. Mineral occurrence only.

Key references—

(1) Geological Survey of Canada.
(2) Ontario Bureau of Mines Annual Reports.
(3) Mines Branch No. 93, Molybdenum Ores of Canada, 1911, T. L. Walker.
(4) Private information Mines Branch, Ottawa, Ont.
(5) See description in Report.

QUEBEC

GENERAL

The province of Quebec has furnished the largest output of molybdenite in Canada, although both Ontario and British Columbia have a greater number of known deposits.

The production was mainly from the Moss mine at Quyon, Onslow township, owned by the Dominion Molybdenite Company. This mine produced about 80 per cent of the total Canadian output, and was at one time the world's leading producer.

Geologically, most of the known types of Canadian molybdenite deposits are represented in the province. Molybdenite occurs disseminated throughout masses of granite or syenite in conjunction with segregations of pyrite, pyrrhotite, fluorite, quartz, and feldspar; the Moss mine deposit is representative of this type. A common type is that in which molybdenite is distributed in fairly large crystals throughout a green pyroxene, which intrudes crystalline limestone, or gneiss. The latter deposits are probably of contact metamorphic type, and, outside the Moss mine, are represented by almost all the southeastern Pontiac deposits, as well as some in the north Gatineau region. Another type of deposit which is common, is one in which molybdenite is intimately associated with other metallic sulphides. Such deposits are usually narrow, but in some places contain rich pockets. They are generally found on the contact of pegmatite dikes, and are much weathered and decomposed. Typical examples of deposits of molybdenite associated with metallic sulphides are found in the Aldfield and Masham deposits; also in some near Maniwaki, Egan township. Molybdenite occurs in quartz fissure veins in the granites of the Kewagama Lake area, Abitibi district. This appears to be an entirely different type from those mentioned above, and although little prospecting has yet been done, the indications are that this type of deposit may yield large tonnages of molybdenite. These deposits are fully discussed under the heading of Abitibi district.

Besides the Moss mine and Abitibi deposits, the Masham deposits, are likely to produce considerable quantities of molybdenite. Other occurrences that will probably yield a supply of the mineral are the Welsh deposits in Clarendon; the National Molybdenite Company's prospects in Eardley; and, possibly, the Farrel, Moodie, Giroux, and other properties in the vicinity of Otter lake, in southeast Pontiac. The Saguenay coast occurrences on the gulf of St. Lawrence have not been prospected, but from the old descriptions given, it is probable that molybdenite ore may, some day, be won from them.

The last named occurrences are of historic interest, as they are amongst the earliest recorded, having been discovered in 1863. Another molybdenite discovery of about the same date was at the Harvey Hill copper mine, Leeds township, Megantic district.

The following table compiled from the Annual Reports on the "Mining Operations in the Province of Quebec," shows the Quebec molybdenite production:—

TABLE XII

Quebec Molybdenite Production

Year	Employees	Wages	Concentrates	Value
		$	Pounds	$
1916	156	61,961	129,275	129,267
1917	289	144,637	226,739	238,096
1918	237	197,617	342,296	383,252
1919	195	60,164	83,002	69,203

Previous to 1916, a few hundred pounds of picked flake was shipped from the Ross property, in Aldfield township; about 100 pounds from the LaFleur prospect, in Egan township; and about two tons of ore from the gulf of St. Lawrence, for experiments in concentration.

In the following pages will be found a detailed account of some of the individual molybdenite deposits in the province, followed by a general tabulated list of all the known occurrences.

Abitibi District

LaCorne Township

Benjamin Claims: Eureka Mine. Consists of three claims totalling about 400 acres, located at the junction of the townships of Varsan, Malartic, La Motte, and LaCorne.

The property may be reached by launch from Amos, up the Harricanaw river and La Motte lake, a total distance of 35 miles, or by the new colonization road, which is ten miles shorter. Both routes are shown on the accompanying map. (Figure 31.)

The prevailing rock is a quartzose biotite-granite which has invaded the Keewatin rocks and in many places displays pegmatitic structure. The mineralization forming lenticular masses is mainly in sericite schist. The quartz and feldspar of the pegmatite are also well impregnated with molybdenite. The mineral disseminated throughout the sericite, is fine-grained, whereas in the pegmatite it occurs as pockets of large crystals. Wherever these mineral stringers cut black mica schist they contain no sericite, but only quartz and feldspar; where they cut granite, the sericite is very abundant with molybdenite disseminated throughout it.[1]

This property was first staked by Hugh Gilligan, of Cobalt, and has been in the hands of the present owner, Mr. L. N. Benjamin, of Montreal, for some years. In November, 1921, the Molybdenite Reduction Co., Ltd., was formed for the purpose of operating the claims.

The main work is on range I, lots 1 and 2, of LaCorne township. About thirty veins are exposed, forming a series of almost parallel echelons. The combined proven length of these veins is about 4,000 feet upon which there are about 1,000 feet of trenching and stripping, 12 to 15 pits each about 5 feet deep, and one shaft 7 by 8 feet that at the time of writing, was 45 feet deep. At the bottom of the shaft the ore is stated

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[1] Mining Operations in Quebec, 1919, p. 40. A. Mailhiot.

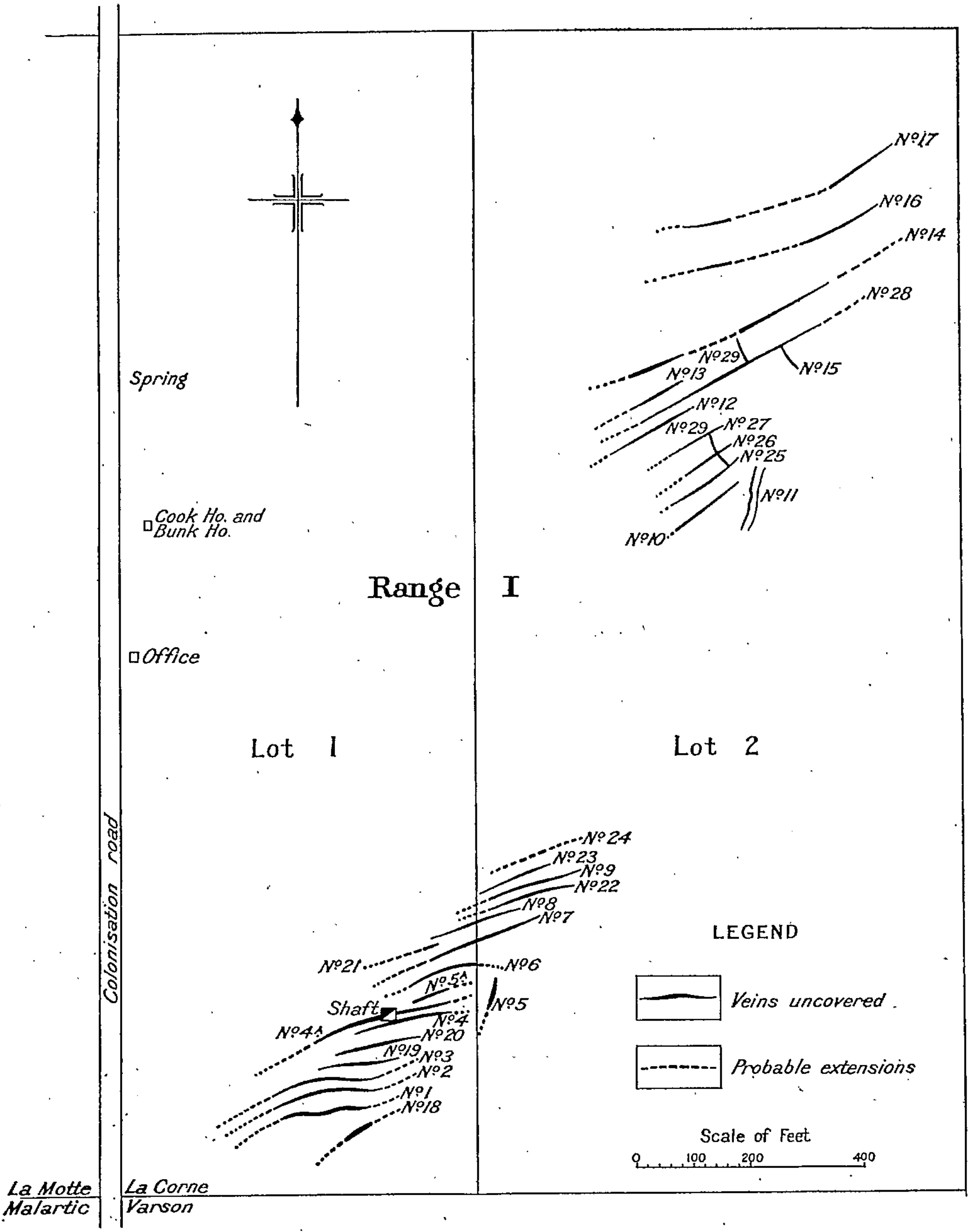
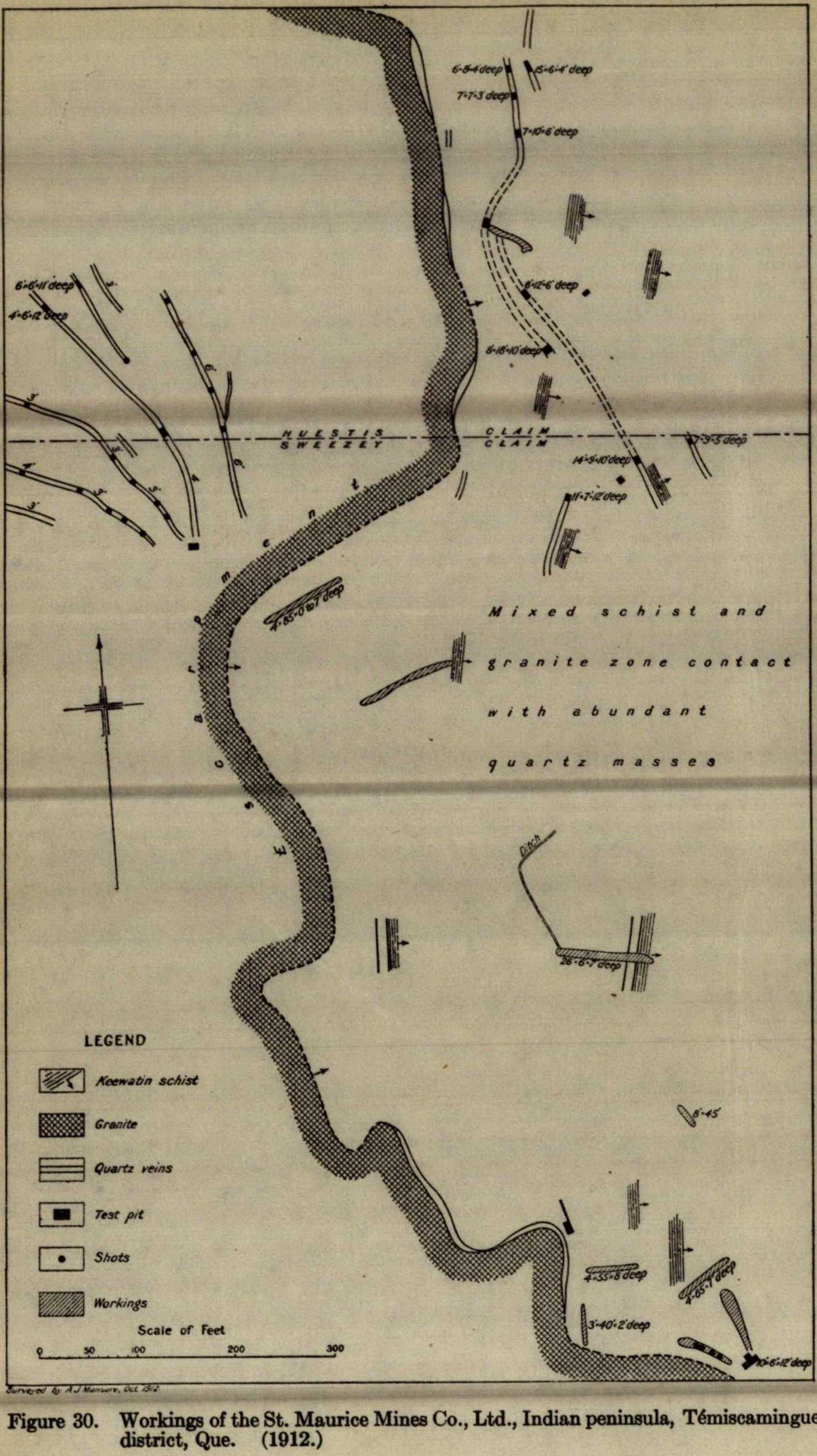


Figure 29. Plan showing position of veins and mine buildings, L. N. Benjamin claims, Eureka molybdenite property, LaCorne township, Abitibi district, Que.



Surveyed by A J Mansure, Oct 1912

Figure 30. Workings of the St. Maurice Mines Co., Ltd., Indian peninsula, Témiscamingue district, Que. (1912.)

to run 5 per cent. During 1920, about 10 other similar veins from 1 to 6 feet wide were opened in the northeastern part of Malartic township, three-quarters of a mile to the southwest. (Figure 29.) A tabulated description of some of these veins will be found in Mr. Mailhiot's report.[1]

Mr. Benjamin states that about 150 tons of ore, averaging 3·0 per cent has been extracted, and sorted into three different lots, but none has been shipped, except a few samples for experimental purposes and which proved it to be a very easy ore to concentrate.

The indications are that there are many other veins still to be found, and the prospect is most encouraging.

Preissac Township

Indian Peninsula: St. Maurice Mines Co., Ltd. This property, covering some 680 acres, consists of five mining claims, the three principal ones, Huestis, Sweezey, and Doucet, being situated mainly on the northwest portion of the Indian peninsula, Kewagama lake, 20 miles southwest of Amos, on the Canadian National railway. They can be reached by motor boat from that place to a point on the west shore of La Motte lake 30 miles down the Harricanaw river, and thence by tramway, portage, and hand car, two miles, to Kewagama lake, then by motor boat, another 20 miles, to the claims. During the winter a 21-mile road can be taken running south from Villemontel on the Transcontinental railway.

The Indian peninsula, a spur of land 10 miles in length, projecting into Kewagama lake from the north, consists chiefly of a granite mass, with well-exposed surfaces that rise two or three hundred feet above the lake level. Within the granite are numerous quartz-filled fissures, forming a system of remarkably regular quartz veins that can in many cases be traced for hundreds of feet in a northwest-southeast direction. The light-coloured granite which ruptured the old Keewatin schists, has formed segregations of quartz, spurs of granite, and aplite dikes in them near the contact.

The molybdenite is associated with quartz and a greenish-white foliated mica, the former being of two types:[2]—

(A) Segregations of quartz on the granite contact, or adjacent schists. Much of this quartz is barren, but contains pay streaks of molybdenite. On the whole, the average grade is less than 1 per cent, but the ore has the advantage of being free from iron sulphides. On the eastern portion of the Sweezey claim there is a mixed zone of granite schist and aplite dikes, in which quartz masses are abundant. There are many rock-cuts and pits from a few feet to 20 feet deep, and a shaft about 70 feet deep along this belt. (Figure 30.) This ground appears to be the most promising on the property.

(B) Very regular, parallel, and persistent veins, about 2 feet to 5 feet wide traverse the granite in a northwesterly direction, and dipping at a high angle are found well within the granite mass, some of them being 2,000 feet west of the actual schist contact.

Several pits and cuts have been made in these veins, in most of which molybdenite has been found. The veins are as a rule of a lower grade than the first type and would probably average less than 0·5 per cent molybdenite.

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[1] Loc. cit.

[2] Mun. Res. Comm., Can., 1920, p. 112. J. C. Gwillim.

In 1912 Messrs. A. T. Mansure and A. E. Lehman surveyed the workings, and made a map showing the distribution and extent of the quartz veins on the Huestis, Sweezey, and Doucet claims. On these claims almost 16,000 feet of quartz veins are exposed. One of these veins is at least 2,000 feet long and several others averaging 3 feet wide are 500 feet, and some have been found to be even 16 feet across. Up to date about 20 different quartz veins carrying molybdenite, have been located and prospected by means of about 50 pits, trenches, and shafts.

Molybdenite and bismuthinite are found on the outer portion of these veins, associated with mica. The bismuthinite which is in the form of long, slender, brittle crystals, shows less tendency to follow the mica, and is found as a rule in the clear quartz; so that by rejecting the central portion of the vein, the bismuth content will be lowered with little loss of molybdenite. In portions of the vein, with mica-filled cracks carrying molybdenite, this cannot be so easily done. The bismuth content of the O'Brien deposit is higher than that of any other on the peninsula.

The main workings are on the eastern side of the Sweezey claim, along the contact of the granite and older schists. (See sketch, Figure 30.) Numerous pits have been sunk on quartz veins that cross the granite farther southwest to within 1,500 feet of the contact. Probably 1,200 tons of rock has been removed from which about 50 tons of ore under 1 per cent has been set aside.

More recent work (summer of 1921) has opened up a lenticular orebody at a break or fault in the contact. Associated with this break is a pyroxene pipe, or intrusion, which assays about 1 per cent and being extensive, is believed by Mr. W. E. Simpson, the general manager, to be of considerable value. Just to the south of this, a pit 12 feet deep has opened up a quartz vein 14 feet wide, carrying the richest ore so far discoverd on the property. An average sample of selected milling ore assayed 5·1 per cent MoS_2. The work done on the other claims which are traversed by the second type of quartz veins is considerably less than on the Sweezey.

In 1911 there were shipped to Queen's University, Kingston, for testing purposes: 1,113 pounds of ore assaying 7·4 per cent MoS_2; 300 pounds, 2·3 per cent; and 760 pounds, 1·8 per cent.

During the same year, Dr. Walker sampled the quartz veins of the Sweezey and Huestis claims. Thirteen of these samples averaged 1·1 per cent MoS_2 and two averaged 7·0 per cent. In 1916 a sampling mill was erected, consisting of a Sturtevant rock crusher, small set of rolls, and a pulverizer, operated by a steam engine and vertical boiler. This greatly facilitated the accurate sampling and examination of the property. In 1919 a complete 100-ton concentrator was erected on the west side of the peninsula, at the lake. It consists of a Buchanan rock crusher; 5-foot ball mill with Dorr classifier, in closed circuit; Groch flotation unit; and the usual bins and accessories. (For detailed description and flow-sheet see Concentration.)

In the mill building is a 6-drill air-compressor; air at 100 pounds pressure is piped to the mine workings, the chief of which are on a hill 200 feet above the lake. Steam power is generated in two multitubular boilers, with wood fuel, which is abundant nearby. The main camp is on Indian bay, about one-quarter of a mile to the west. On the lake shore, close to the treatment plant, there is a small sawmill with boiler, pumps, etc., also a large shed and dock for accommodating a 40-foot flat-bottomed motor boat. (See Plate VI.)

Historical.

In 1901 J. F. E. Johnston of the Canadian Geological Survey first mentions the presence of molybdenite and bismuthinite in quartz veins at Nose point on the east shore of Indian peninsula. This was later staked as the Hervey claim.[1] Since then many reports have been made, including one in 1905, by J. Obalski, Superintendent of Mines, Quebec; in 1910-11, three separate examinations by Dr. T. L. Walker;[2] in 1910 by A. E. Lehman of Philadelphia; in 1911-12, by J. Austin Bancroft[3] who gives a detailed description of all the molybdenite deposits in this region; in 1915, by W. B. Timm of the Department of Mines, Ottawa; in 1916, by Theo. Denis, Superintendent of Mines, Quebec.

In 1916 an option on the properties was given, by the owners, the St. Maurice Syndicate, Ltd., to an organization which is now called the St. Maurice Mines Co., Ltd. In 1918 a controlling interest in the St. Maurice Mines Co., Ltd., was transferred to the Indian Peninsular Mining Company, Ltd. This company was financed and operated by the Penn-Canadian Mines, Ltd., Cobalt, Ontario, under whose management the treatment plant was erected and considerable development work done.

As no diamond drilling or deep sinking has yet been done on the property, the persistence of the ore in depth is not known. In eastern Canada, the molybdenite deposits are as a rule of the contact metamorphic type and have a tendency to be pockety; but the Indian Peninsula deposits are of a different character, being, for the most part, of the true vein type.

Although quartz veins are very numerous over the whole area, a large number of those occurring in the granite are barren of molybdenite, and in others the mineral occurs as irregularly disseminated flakes, especially where mica is present. The veins higher up the mountain, remote from the contact with the schist, are not likely to be worthy of further exploitation.

The work already done on these claims shows a wide areal distribution of molybdenite; but the aggregate content would be only a low-grade milling ore. By a system of selective mining, however, a grade can, in many cases, be so selected as to give a commercially valuable mill feed.

Peninsular Mining Syndicate. The property that originally belonged to this syndicate embraces 8 claims, covering about 700 acres in the central part of the peninsula. (Figure 31.) The chief claims upon which work has been done are the McDougall and Smith properties. Here, as on the Doucet and Sweezey claims, the molybdenite is confined to numerous narrow quartz veins. On the McDougall claim 19 parallel quartz veins cutting the granite and striking northwest were counted across a distance of 90 feet. Some of these veins show flakes of molybdenite,[4] but the deposits do not appear to be so large or rich as those found on the Sweezey. Work has been suspended for several years, the ownership has lapsed and the syndicate is no longer in existence.[5]

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[1] Mining Operations in Quebec, 1911, p. 186.
[2] Molybdenum Ores of Canada, 1911, p. 35.
[3] Mining Operations in Quebec, 1911-12.
[4] Mining Operations in Quebec, 1911, p. 200. J. A. Bancroft.
[5] Mun. Res. Comm. of Can., June, 1917. J. C. Gwillim.

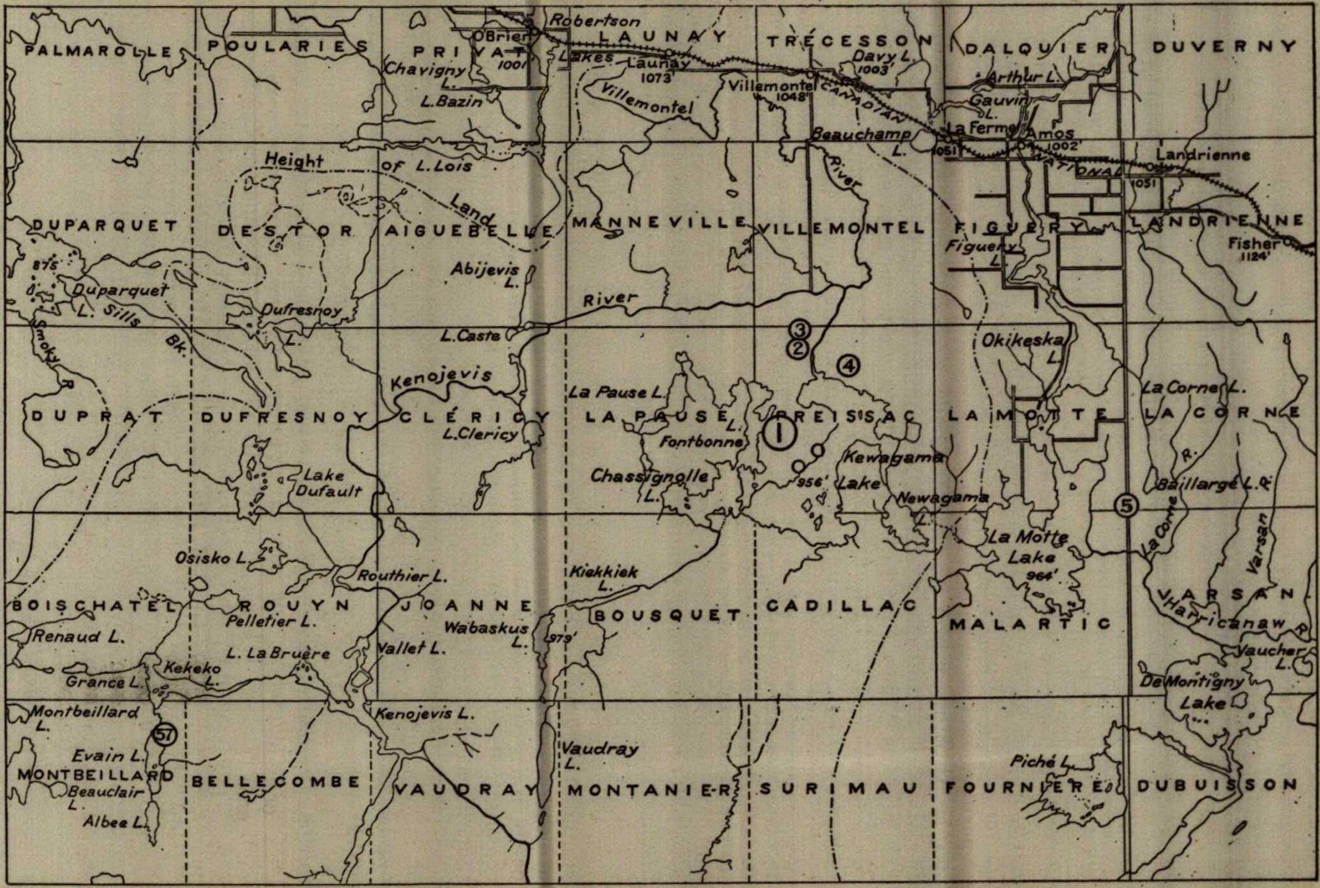

Figure 31. Harricanaw map area showing Indian Peninsula and Benjamin deposits, Que. Scale, 10 miles to 1 inch.

Indian Peninsula, Dion Claim. This claim adjoins the southeast corner of the Sweezey and lies in between the St. Maurice and the old Peninsular Syndicate's properties. It is along the contact of the granite and schist.

The occurrence is similar to all the others on the peninsula; but the molybdenite is in the form of little rosettes and is quite free from other sulphides. A shaft was sunk in a creek bed on the pegmatite phase of the granite, from which about 8 bags of 3·9 per cent ore was extracted and sent to Renfrew, Ont., for treatment, and there is still a few hundred pounds of cobbed ore on the dump. The shaft and a rock pit were sunk in 1916, by Mr. S. W. Cohen of the Crown Reserve Mines, Ltd., Cobalt, Ont., under option from Mr. G. A. Dion of La Sarre. Further work was done in 1916 by Messrs. Dion and W. A. Magor of Montreal, who sent to the Department of Mines, Ottawa, 147 pounds of 2·92 per cent ore, for testing purposes.

The pit shows little promise of commercial ore, but the rocks along the contact are favourable for molybdenite occurrences.

Kewagama River, Height of Land Mining Company. The claims taken up by this company are on the west bank of Kewagama river, about 2 miles north of Kewagama lake. They are about 5 miles north of the St. Maurice Mines Company's claims, and can be reached by the same route. (See map, Figure 31.)

The ground was staked by Mr. C. S. Richmond, in 1906, about two months after J. Obalski, Superintendent of Mines for Quebec, had observed the presence of molybdenite in the locality. The property was at one time under lease to Messrs. Forbes and Campbell, and about 1,200 pounds of 98 per cent molybdenite was extracted. In 1907 it was first worked by the present owners. On the east side of the river a large granite batholith intrudes schists and to it the dikes on the west side of the river, in which the molybdenite occurs, owe their origin.[1]

These pegmatite and granite dikes are very irregular in length and width, and outcrop at varying intervals along the river bank. At the southern end of a succession of outcrops, where a shaft has been sunk, the dikes actually become more predominant than the schists they intrude. At this point, a large quartz vein, 15 feet wide, intersecting the granite, rises from the river and dips at an angle of 58 degrees to the east. Along the contact of the granite and quartz there is an irregular seam of muscovite, containing large crystals of molybdenite. Bismuthinite is irregularly scattered throughout the middle section of the vein.

A good showing of molybdenite can be seen at low water in the river, but all the work has been done on the west bank in the pegmatite-schist rocks. A southerly shaft, 80 feet deep has been sunk close to the river bank, near the schist contact, and reaches the quartz below. At the bottom of this shaft two drifts have been driven in opposite directions, one extending south 60 degrees east for a distance of 60 feet; the other north 60 degrees west for 27 feet, almost at right angles to the general strike of the schists. This easterly drift under the river (which is here about 90 feet wide) found the quartz vein on the granite contact dipping westerly

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[1] Mining Operations in Quebec, 1911, p. 192. J. A. Bancroft.

towards the shaft. (Figure 32.) The material from this vein, now lying on the dump, would not average more than 0·1 per cent MoS_2.[1] Mr. S. P. Wilson, the secretary, stated that for a time the ore raised averaged over 4 per cent.

At the north working, where there is a hoist, blacksmith shop, and ore-house, a second shaft 50 feet deep has been sunk in quartzose pegmatite, but, being full of water, could not be examined. The quartz on the dump, however, contained molybdenite crystals, and more chalcopyrite than was noticed in any other occurrences within the area.[2]

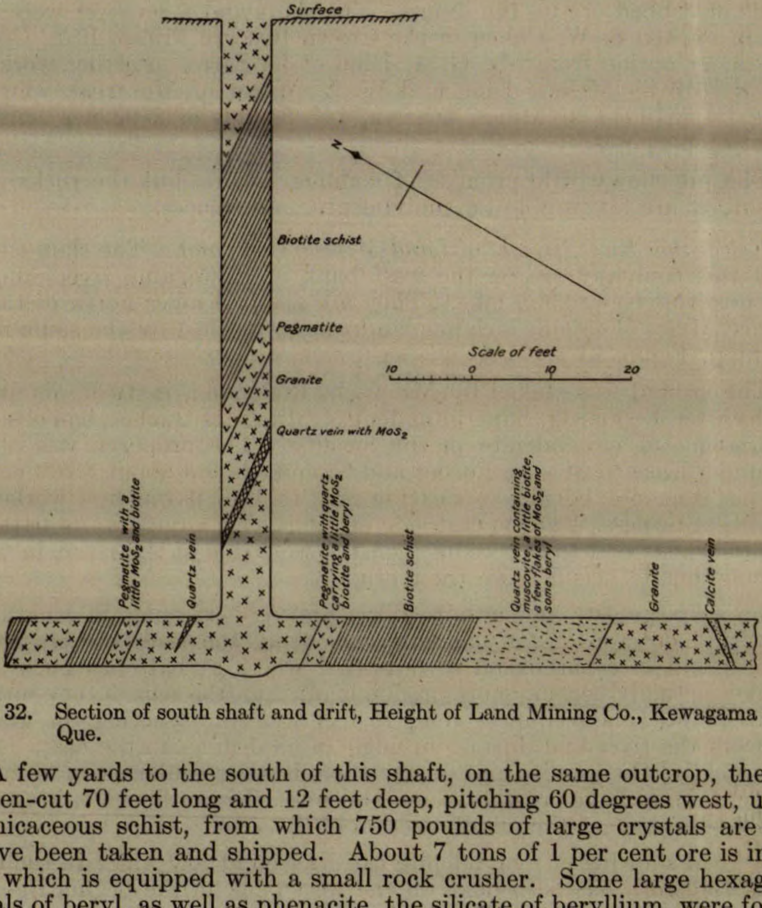

Figure 32. Section of south shaft and drift, Height of Land Mining Co., Kewagama river, Que.

A few yards to the south of this shaft, on the same outcrop, there is an open-cut 70 feet long and 12 feet deep, pitching 60 degrees west, under the micaceous schist, from which 750 pounds of large crystals are said to have been taken and shipped. About 7 tons of 1 per cent ore is in the shed, which is equipped with a small rock crusher. Some large hexagonal crystals of beryl, as well as phenacite, the silicate of beryllium, were found.

Another point of scientific interest is that minute molybdenite crystals were found enclosed in bismuthinite, specimens of which were collected by J. A. Dresser in 1907, while making his report on this property. Prof. R. P. D. Graham[3] mentions an instance of a pseudomorph crystal of bismuthinite after molybdenite, the former mineral occurring in hexagonal form instead of long slender needles. (See Plate XI.)

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[1] Mun. Res. Comm. of Can., June, 1917. J. C. Gwillim.
[2] Mining Operations in Quebec, 1911, p. 192. J. A. Bancroft.
[3] Trans. Royal Society, Sec. IV, Vol. XII, 1918, p. 191. R. P. D. Graham.

Although a large amount of sinking, drifting, and trenching has been done on this property, most of the ore seems to have been taken from two small prospect pits. The area is not very encouraging.

Chicoutimi District

Metabetchouan Township

A showing of molybdenite was first found in a deep railway-cut on the south shore of lake St. John, 1½ miles east of Chambord junction, on the Quebec and Lake St. John railway. The ore occurs in, or along the contact of a quartzose pegmatite dike in granite gneiss. This pegmatite ridge extends down the hill north of the track, to the lake about three-quarters of a mile away. Some of the mineral, together with iron pyrites, penetrates a short distance into the gneiss. It is free from copper, arsenic, bismuth, and mica.

The only development work consists of a small pit about 5 feet deep, in the dike, but the wall rocks on either side were not reached. Large flakes of molybdenite were found in the sides and bottom.

Average assays of a number of samples showed 6 per cent MoS_2, and $3 per ton in gold but there is no record of how these samples were taken, and it is doubtful if the deposit is of economic importance.

Gulf of St. Lawrence

On the north shore of the gulf of St. Lawrence opposite Anticosti island, about 200 miles east of Quebec city, a large number of occurrences of molybdenite were recorded in the early days.

Detailed accounts of these discoveries may be found in the Canadian Geological Survey Report for 1863.[1]

Molybdenite apparently occurs at intervals for a distance of about 150 miles along the Saguenay District coast, starting from a point opposite the centre of Anticosti island, at Quetachu bay. T. L. Walker says that the ore occurs disseminated in a quartz seam in flakes, some of which are 12 inches wide by one fourth of an inch thick. This seam which also contains garnets and black mica was traced for about 50 yards, and would probably furnish a considerable quantity of molybdenite.[2]

The deposit has been referred to several times, and is considered to be far the best showing in the region.

In 1883, H. de Puyjalon made a report on the locality, an account of which can be found in Dr. Walker's report,[3] in which are enumerated all the finds of molybdenite along the coast as far east as Ha Ha bay. In 1898 some interest was taken in the mining of molybdenite, and amongst others the Quetachu and Olomanoshibo (now called Romaine) deposits were worked by the "L'Union Industrielle et Métallurgique du Labrador."[4]

In 1910 Dr. Walker visited this area and found molybdenite mining again active, and that Colonel Carson and associates, of Montreal, were working the deposits on the islands around Romaine. About two tons of ore were obtained for concentration experiments by sinking test pits on McKenzie island, where the molybdenite occurs in grey micaceous gneiss, interbanded with stringers of pink feldspar. The best ore was found in the more quartzose stringers.

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[1] Geol. Surv., Can., 1863, p. 503.

[2] Molybdenum Ores of Canada, 1911, p. 24. T. L. Walker

[3] Loc cit.

[4] Mining Operations in Quebec, 1898, p. 17.

From the old reports, referred to above, it would appear that some of the occurrences are worthy of further investigation.

Hull District

Eardley Township

Range VII, Lot 1, National Molybdenite Company. The property, owned by this company, is situated on the part of Thomas Young's farm which lies on top of the Eardley escarpment, overlooking the Ottawa valley, some 500 feet below. The workings are approached by a steep wagon road from Young's farm, 3 miles northeast of Breckenridge station on the Ottawa-Waltham railway.

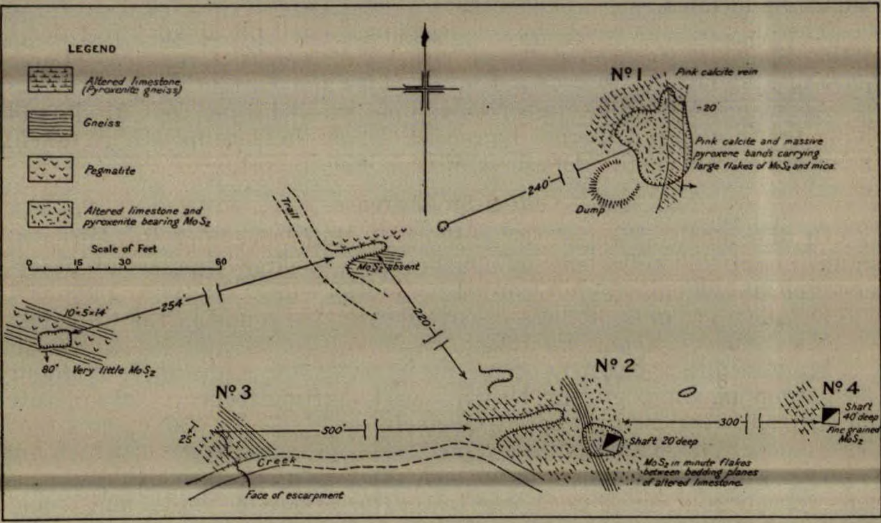

Figure 33. Workings of the National Molybdenite Company, Eardley township, Hull district, Que. (November, 1921.)

The mining rights are owned by Messrs. A. Payne of Breckenridge and Ed. Chaput of Aylmer, who formed the above company.

The ground is a remnant of a mass of rocks of the Grenville series caught up in the surrounding red granite. The mass has been metamorphosed and the limestone appears to have changed into a greenish pyroxenite-gneiss traversed by pegmatite dikes, which probably indicate the best lines of mineralization. Disseminated throughout these banded gneisses, fine-grained molybdenite is frequently found, particularly in seams and between the bedding-planes.

The best values were found in the more massive metamorphic pyroxenite, where the flakes are large and easily cobbed. The tonnage of ore, although of lower grade, is greater in the pyroxenite gneiss.

No. 1. A considerable amount of prospecting work has been done on the property. The most spectacular showing is in No. 1 pit (Figure 33) which is 30 feet diameter and 15 feet deep. Here the molybdenite is closely associated with a massive green pyroxenite through which runs a broad band of pink calcite. Large flakes of molybdenite were also observed embedded in the calcite, near the pyroxenite contact.

No. 2. These workings, located near the camp, consist of an open-cut in the creek bed, 30 feet long, and a shaft 30 feet deep. The occurrence here is entirely different from that in No. 1, the molybdenite being found as small flakes, disseminated throughout the fine-grained pyroxenite-gneiss. The open-cut and shaft are separated by a band of pegmatite. Mr. Chaput stated that some rich ore had been extracted from the northeast corner of the shaft. The average run of the ore, however, would be considerably less than 1 per cent.

No. 3. About 500 feet west of No. 2, there are a set of three cuts in a bluff above the creek.. Ore and rocks are similar to No 2 but show some massive pyroxenite. There is a thin, flat, but rich band of molybdenite that forms the floor of all these cuts, the largest of which is 35 feet across, and 12 feet deep.

No. 4. About 100 yards east of No. 2 a well-timbered shaft has been sunk to a depth of 40 feet in the banded gneiss. Some well-mineralized specimens said to have come from the bottom, were seen on the dump.

No. 5. (Not shown). This is a small pit 200 yards farther to the east, on range X, lot 28, Hull township. It is 10 feet wide and 10 feet deep, in similar rocks to those of No. 2 but more compact, and is adjacent to a pegmatite dike. The ore in the pit was very lean.

During 1917, about 35 tons of ore averaging 0·77 per cent was shipped to the Mines Branch, Ottawa, from which about 460 pounds of pure molybdenite was recovered.

In 1917 Mr. Payne took options from Mr. Young on the range VII properties, and did three or four months' work. Mr. Chaput also worked these pits on range VII and, later, they combined and formed the present company, with Mr. A. D. Parker of Toronto as president.

The possibilities of finding more ore in the present workings is encouraging, especially in No. 1 and No. 4 shaft.

There are several other showings of molybdenite in this locality where the mineral is found in close proximity to pegmatite dikes, and as these dikes indicate the best lines of mineralization they are worth further prospecting.

The creek is too small to afford a large water supply, but plenty of medium-sized timber is available. For the economical handling of a large tonnage of ore, an aerial tram-line would have to be built to the plain below.[1]

Range VIII, S. ½ Lot 6, Wood-Ormond Prospect. This property is situated on the farm of Albert Ormond, about 3 miles north of Breckenridge station.

The working consists of a level entry open-cut on the face of the Eardley escarpment, 300 feet above the plain, and is approached by a steep path.

The ore occurs intimately associated with a massive band of dark green hornblende that intrudes red granite, outcrops along the face of the cliff, and dips flatly into the hillside. It appears to be only a local body, varying from 3 to 10 feet in thickness.

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[1] Mun. Res. Comm., Can., 1920, p. 111. J. C. Gwillim.

The molybdenite is found as nugget-like, or chunky, well formed crystals, disseminated throughout the hornblende, and for a short distance into the granite above, which is of a pegmatitic character. It does not appear to penetrate the granite below the hornblende. Several showings of molybdenite in these hornblende bands have been located at various points at this elevation, in what would seem to be a continuation of the strike of the ore-body in which the main work has been done.

In 1915 an option was taken on the property by Henry E. Wood, of Denver, Colo. The property has now reverted to Mr. Ormond. The deposit might pay to work on a small scale.[1]

Range XI, S. ½ Lot 6, Chatelain Prospect. The property which consists of 200 acres is near the south shore of Harrington (Mouseau) lake, about 200 feet above Little Edwards lake. It is reached by road, 14 miles northwest of Ottawa, to the south end of Harrington lake, and thence 2½ miles by boat and one-half mile of somewhat steep climb by trail up the hillside.

A little prospecting work has been done, chiefly in clearing the creek bottom, and exposing the vein for about 60 to 70 feet. The whole surrounding country is composed of red feldspathic granite.

The mineral zone is a flat quartz stringer, containing pyrites, pyrrhotite, pyroxenite, and calcite, varying in width from 2 to 8 inches. The southern end of this stringer—where it is exposed—carries high molybdenite values; but, because of its flatness and somewhat variable width, it has the appearance of a larger and richer deposit. Pieces of the broken ore are also scattered about for a considerable distance down the creek to the north, at which end the stringer enters the east bank of the creek and is almost barren. About 10 feet to the east there is a small pyritic stringer carrying a little molybdenite, and dipping steeply in the direction of the creek. Some molybdenite may be encountered at the point where these two stringers meet.

About three or four tons of selected ore estimated to run about 1·5 per cent MoS_2, are on the stock pile; but the milling ore would be very low grade; moreover, until a good road is built, the ore would require double handling, by water and wagon.

The property is on the timber limits of the late Senator Edwards of Ottawa. The mining rights have changed hands a large number of times. Mr. R. V. Sinclair, of Ottawa, was one of the first to take an option from the Grey Nuns, to whom the property belonged in 1908, and since then Senator W. C. Edwards, Messrs. M. J. Smith, W. P. Flynn, Charles Higgerty, R. G. Kelly, all of Ottawa, and many others have had interests. The property has now reverted to the Grey Nuns, under Father Chatelain of Buckingham.

Egan Township

Range III, Lots 6 and 7, McKerracher and Wanless. This property, which was at one time owned by the Standard Molybdenite Company, is situated on the farm of Mr. David Moore, of River Desert. It is near the east bank of Desert river, 4½ miles northwest of Maniwaki, the terminus of the Gatineau railway, about 85 miles north of Ottawa.

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[1] Mun. Res. Comm. Can., 1920, p. 110. J. C. Gwillim.

The mineral zones consist of parallel veins of pegmatite, pyroxenite, pyrite, pyrrhotite, and molybdenite. These zones lie on contacts between crystalline limestone and quartz-syenite gneiss. Molybdenite is found unevenly distributed along these contacts. The ore is exposed in three different and almost parallel veins.

No. 1 vein, which is about 150 yards east of the river, consists of a pegmatite dike carrying veins of pyrites and pyroxenite bands. Limestone occurs on the west, and gneiss on the east of the dike. A pit about 60 by 18 feet and 10 to 12 feet deep, has been opened up and the outcrop has been exposed by stripping in a southerly direction. Mineral oxide stains show the continuation of the vein, for at least 100 feet, at each end of the workings.

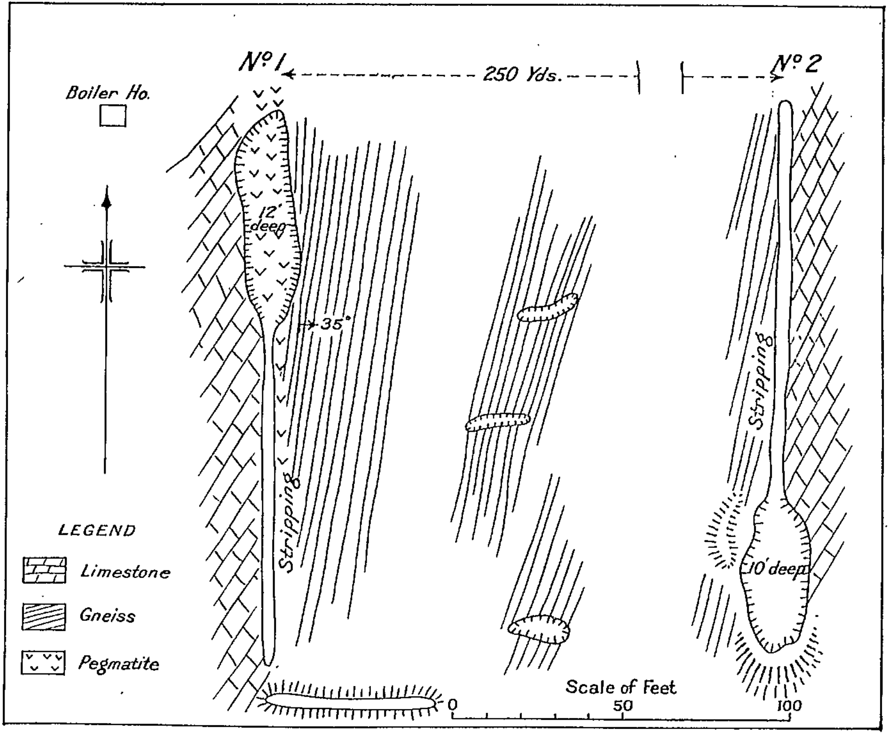

Figure 34. Standard molybdenite mine, Egan township, Que. Between No. 1 and No. 2 there are alternate bands of gneiss and limestone.

A little to the east of this pit the ground has been prospected by a number of irregular and shallow pits or strippings, exposing the gneiss and narrow and contorted bands of limestone and pegmatite. Occasional flakes of molybdenite were observed. (Figure 34.) The molybdenite in the main pit was too much weathered to show any appreciable ore in sight, but it was said that some good ore had been taken from the bottom of the pit which, at the time of the writer's visit, was covered by water.

No. 2 vein. About 200 yards to the east there is another similar and parallel mineral zone. The rocks between these two veins which outcrop in a few places, show alternate bands of limestone and gneiss, with mineral oxide stains near, or on their contacts.

The outcrop is exposed for 150 feet, and at the south end there is a pit 40 by 15 feet, and 10 to 12 feet deep. The vein is similar to No. 1, and dips under white crystalline limestone. There is more pyrite in this zone, and the richest molybdenite ore appears to be next the limestone and in several cross stringers of pyrites. Flakes of molybdenite are sparsely scattered throughout the whole matrix of stained pyroxenite. The bottom of the pit is said to be on limestone, the pyroxenite-pegmatite zone having been passed through. The ore-bearing portion at this point appears to be about 10 feet wide, but as in the case of No. 1, very little mineral was actually seen in place. Small pits, strippings, and surface stains, show a continuation of the vein for about 600 or 700 feet.

No. 3 vein. This vein has not been opened up, but is similar to the other veins already described. The mineralized zone, which is on higher ground than the others, has been shown to be, in some places, 20 feet wide, and is said to have been traced across lots 6 and 7.

Shipments. During 1918 the Standard Molybdenite Company shipped to the Mines Branch, Ottawa, 24,985 pounds of 0·40 per cent MoS_2 from which 75 pounds of pure molybdenite was recovered; also 750 pounds of pure flake was collected and shipped. It is said that altogether about 30 tons of ore was shipped, mainly from No. 2 vein.

Equipment. The plant and machinery, which is at No. 1 vein, consists of a power and hoist-house, containing an 80 h.p. American loco-type boiler, 1 horizontal engine, 1 horizontal 4-drill air-compressor, one 40 h.p. light dynamo; a single winding gear hoist; also a considerable quantity of air and water pipes and fittings. Outside the power house, there is a 5 by 11 air-receiver, pump house, also derrick, ore carriers, various storehouses, and camp buildings.

History. The deposit was apparently located by Mr. J. Callahan, and, in 1917, the mining rights on range III, lots 6 to 13, were purchased by the Standard Molybdenite Company, which was capitalized at $150,000.[1] After erecting the plant, and doing the above described work, they went into liquidation in 1919.

About two years later, the property was taken over by Messrs. McKerracher and Wanless, of Ottawa, in whose name the property still remains. This firm, however, only took over lots 6 and 7, the remainder reverting to Mr. Moore.

Economic features. Transportation can be made to Maniwaki by river or road. There is plenty of available water, and the region is very well timbered.

Summary. There is, probably, a considerable amount of molybdenite throughout the whole region, but it is widely disseminated and scattered, and very bunchy in the veins.[2]

Range IV, Lot 69, LaFleur Prospect. This property is situated on the La France farm near Montcerf, 15 miles by good road north of Maniwaki, and 100 miles north of Ottawa.

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[1] Canadian Mining Journal, Sept. 1, 1917.

[2] Geol. Surv., Can., 1918, M. E. Wilson.

It is one of the oldest known deposits of molybdenite in the region, having been worked more than 25 years ago.

The exposed mineral zone, which is on a contact between gneiss and limestone, consists of parallel pyritic stringers in a decomposed pyroxene and feldspathic rock. Within this decomposed zone large flakes of molybdenite occur. Weathering has converted some of the surface molybdenite into yellow oxide which is intermingled with flakes of decomposed mica as well as pyrites and pyrrhotite. The somewhat loose condition of the foliated aggregates of molybdenite that are found in the decomposed soil is attributed to the weathering and disintegration of a highly pyritiferous pyroxene.[1]

The old workings consist of a prospect pit, or cutting in the hillside, 20 feet long, and 10 feet deep with a 6-foot face, lying about 300 yards east of the road. Farther to the east, along the approximate strike of the vein, an 80-foot tunnel was driven into the hillside, but not far enough to strike the vein. Considerable quantities of flake graphite was noticed disseminated throughout the loose rock that came from the tunnel.

Many years ago, samples from this property were taken for experiments in concentration at McGill University.

Dr. Walker[2] reports favourably on the prospect; and the deposit, though narrow, is somewhat deceptive, on account of its flatness. It is probably worthy of further prospecting.[3]

Hull Township

Range X, Lots 27 and 28, Payne Prospect. This property is situated on top of the Eardley escarpment about half a mile east of the National Molybdenite Company's property of which Mr. A. Payne is also a part owner, in Eardley township.

The rocks and occurrences are similar to those already described under the name of the above-mentioned company. The molybdenite, in fine grains, is sparsely scattered throughout a hornblende-gneiss. Granite outcrops about 30 feet northeast of the workings, and a finer granite and pegmatite were observed in the gully about 150 feet to the southwest.

The only work done consists of an open-cut, 20 feet long, 10 feet wide and with a 7-foot face, driven into the side of a low bluff. No ore was shipped, but there is about 4 tons on the dump that probably runs 0·5 per cent.

In 1918 Mr. A. Payne, of Breckenridge, from whom the prospect takes its name, took an option from Mr. R. Higgins.

The possibility of finding ore throughout this bush-covered area is encouraging, but the grade is not likely to be high.

Range XI, North ½ Lot 13. Molybdenite is exposed in a rock-cut just south of the railway crossing one-fourth of a mile south of Kirk Ferry station on the Gatineau railway, 12 miles north of Ottawa.

The mineral occurs on and near the contact of a highly quartzose pegmatite with banded gneiss. Throughout the former are small stringers of pyrites, and numerous cracks, in both of which molybdenite is splashed as small thin flakes. The mineralized area is at this point approximately

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[1] Geol. Surv., Can., Bull. Molybdenum and Tungsten, 1904. R. A. A. Johnston.
[2] Molybdenum Ores of Canada, 1911, p. 30. T. L. Walker.
[3] No. 21 Sessional Papers, Quebec, 1899. J. Obalski.

40 feet wide and is bordered on the west by gneiss, and on the east by a band of white crystalline limestone. (Figure 35.)

Along the general strike of the rocks, about 400 feet to the northeast, flakes of molybdenite were observed in a similar formation on the west shore of the Gatineau river, indicating that the intermediate rocks, which are covered by bush, are probably sparsely impregnated by the mineral.

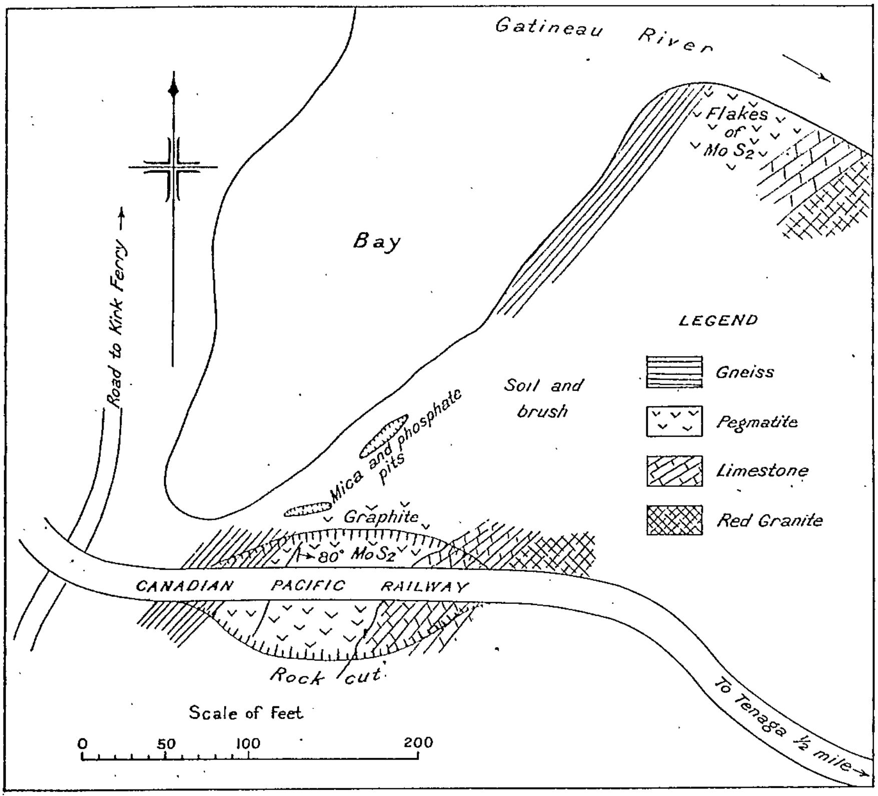

Figure 35. Railway-cut near Kirk Ferry, Hull district, Que.

Mention was first made of this property by C. W. Willimott in 1897, when the late Mr. W. A. Allan, of Ottawa, had an option on the property which is now owned by Mr. Blackburn of Kirk Ferry. No work appears to have been done in searching for molybdenite, although several old pits were noticed from which mica and phosphates had been extracted.

Masham Township

Range X, Lots 53 to 55, Bain Property. This property, which is situated on the north shore of Indian lake, is approximately 36 miles northwest of Ottawa, and is 16 miles by road northwest of Wakefield station on the Gatineau railway, and thence one mile by rough bush road to the workings.

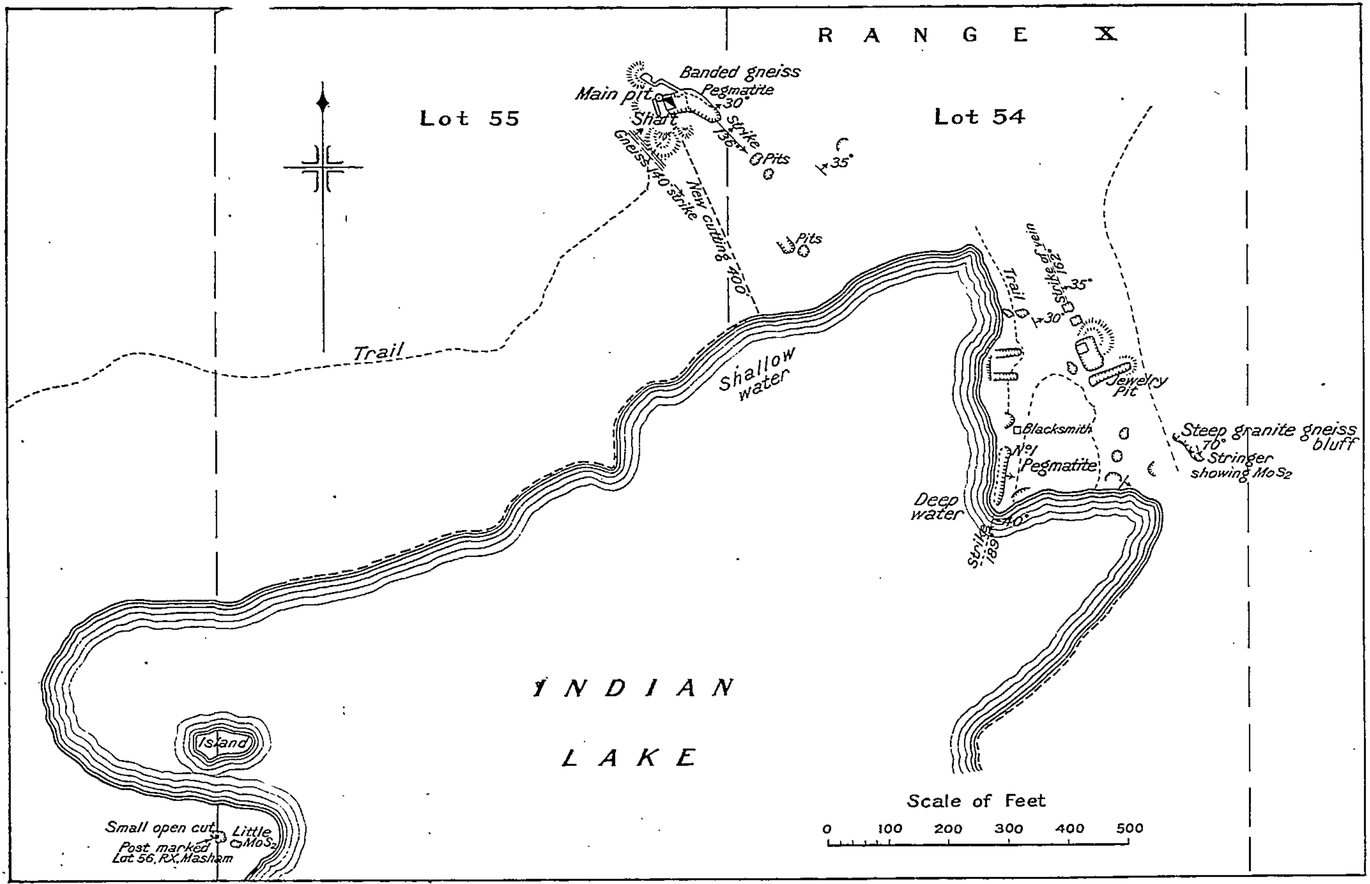

Figure 36. Molybdenite outcrops and workings, Bain prospect, Masham township, Hull district, Que. (July, 1921.)

A considerable amount of development work has been done, chiefly in 1917 by Mr. John Bain of Ottawa, and as a result several promising ore-bodies have been exposed.

The rocks with which these molybdenite deposits are associated are mainly hornblende and granite gneisses intruded by masses of pegmatite granite. All of these have intruded the original limestone, small patches of which are still to be observed. The mineralized zones are of the contact metamorphic type. The molybdenite occurs as large and small flakes and segregations, intimately associated with a light green pyroxene, pyrrhotite, and pyrites, all of which are very abundant in the mineralized zones.

The main pit on the north of the lake is 16 feet deep and 15 feet wide, around which an area of roughly 3,000 square feet has been stripped and blasted exposing a very encouraging deposit of molybdenite. The continuity of this ore-body has been traced by means of pits for over one-fourth of a mile to the lake shore. About 700 feet southeast there are from 15 to 20 pits and strippings, in all of which are exposures of molybdenite. The open-cut on the lake shore is very heavily mineralized, and a considerable quantity of molybdenite was observed in place. (See Plate X and Figure 36.)

In 1918 the Wood Molybdenite Company took an option on the property and shipped one ton of 1·97 per cent ore to the Mines Branch, Ottawa, for testing purposes.[1] At that time methods of concentration for this complex ore were not so good as they are now and the recovery was so very low that the company abandoned the option. In June, 1921, the Daly Molybdenite Company, who also have a property in Thorne township, investigated this deposit under the direction of Mr. H. H. Claudet of Ottawa, and representative samples were taken from the stock piles and tested by the Mines Branch with the following results:—

Heads, 3·66 MoS_2; concentrates, 89·25 per cent; middlings, 19 per cent; tails, 0·17 per cent; recovery (including middlings), 94 per cent.

Owing to these highly satisfactory results, the company is now negotiating for an option, and have done some clearing and prospecting work. Although the richness of the deposit has not been proved, it is, in the opinion of the writer the most promising in this region.

Owing to the past dull market conditions, no more work was done on the property until the winter of 1924–25, when Mr. Claudet and associates restarted operations, and have to date shipped a carload of ore to the Mines Branch, Ottawa, for concentration.

Reference: Geol. Surv., Can., Mem. 136, 1924, p. 84. M. E. Wilson.

Pontiac District

Aldfield Township

Range III, Lots 1 and 2, Ross Property. This property, at one time owned by the Aldfield Mineral Syndicate, is situated 15 miles by fair road northwest of Wakefield Station, on the Gatineau railway.

The country rock which is mostly biotite gneiss, contains irregular masses of green pyroxenite, and is in several places cut by pyritic veins, much stained and decomposed on the surface. Within these mineral zones, molybdenite occurs in irregular patches, in places exhibiting large

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[1] Tests, Mines Branch Summary, 1918, p. 145.

oxidized flakes, and forming yellow incrustations of molybdite on the exposed surfaces of the pits.

There are four or five pits and open-cuts on the hillside. In the main cut, in the southern part of the property, flakes of molybdenite were found embedded in a wall-rock of radiated tremolite.

This is one of the earliest known molybdenite deposits in the region. In 1884, Mr. R. H. G. Clapham obtained some fine specimens of pure molybdenite, one of which is said to have weighed 2½ pounds.

The property was staked by the late Mr. C. G. Ross, of Ottawa; and, later, in 1894, was worked by the Foote Mineral Company of Philadelphia. This company obtained about 100 pounds of good museum specimens, employing eight men, and expending about $800.[1] In 1917 the Mining Corporation of Canada took an option and shipped 25 tons of ore to the Mines Branch, Ottawa. The ore, however, only ran 0·06 per cent MoS_2 from which 21 pounds of pure molybdenite was recovered. With a little care considerably richer ore can probably be extracted, though it is doubtful if ore of more than 0·5 per cent can be mined except by very careful sorting.

In June, 1921, the property was re-staked by Mr. H. H. Claudet, of Ottawa.

Ranges IV and V, Lots 1, 2, and 3. These properties are immediately to the north of and adjoin the Ross property, and the rock and ore occurrences are somewhat similar. The most northerly deposit, which is almost on the border line between Aldfield and Masham townships, is on the top of a bare hill. The molybdenite occurs in pockets and seams in a flat vein of pyrites on the cliff edge, which has been partly blasted away. On the top of the cliff there is a capping of gneiss. A 6-foot tunnel has been driven, exposing some flake molybdenite embedded in green pyroxene.

During 1916 and 1917 the Aldfield Mineral Syndicate, did some work and shipped several tons of ore. The north extension of lot 3, range V, which is on the top of the hill, was re-staked by Mr. O. Kirkham of Philip Lake, in 1921. The whole area of about 12 square miles, radiating from the northeast corner of Masham township is extensively mineralized, and consists of rocks favourable to the occurrence of molybdenite, and from which fair tonnages of high-grade ore may in future be expected. (See also Bain property, Masham tp.)

Range VI, N.E. Lot 53, Moodie Prospect. This prospect lies on the farm of Mr. R. Mattock, near Martin lake, 18 miles by good road north of Shawville station,. on the Ottawa-Waltham railway. It can be reached from Ottawa, 45 miles by good road, and thence 1½ miles north by rough road to the workings.

In a ridge of white crystalline limestone, pale green, massive pyroxene occurs in bands of varying thickness. The working consists of about 60 feet of trenching, 8 feet wide, and 5 to 6 feet deep, in a shallow spoonlike lens of pyroxene which dips flatly to the east and in the direction of the slope of the hill. The west end of this trench has passed through the bottom of the lens, and is in limestone. At the east end, the pit is about 6 feet deep and the floor is in pyroxene. The molybdenite occurs disseminated throughout the pyroxene, in fairly large bright flakes, and is almost free of pyrites. On the north contact between the limestone and pyroxene, there is a strip of mica. Wherever the mica predominates the richness of the

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[1] Molybdenum Ores of Canada, 1911, p. 31. T. L. Walker.

molybdenite appears to be considerably less. Pegmatite dikes traverse the limestone ridge as well as a similar ridge a few hundred feet to the south. At various points within the dikes occur narrow bands and seams of green pyroxene, in some of which flakes of molybdenite are visible on the surface. There was in 1921 about 3 tons of milling ore on the dump, most of it under 0·75 per cent.

Molybdenite may be looked for over a considerable area, but it is probable that any ore extracted will be obtained by cobbing from a series of small, shallow, carefully selected pits.

The above property, which is owned by Mr. John Moodie of Otter Lake, is sparsely wooded, and traversed by streams, which are, however, too small for a water supply.

Bristol Township

Range XII, Lot 3, Dagg Prospect. Molybdenite occurs on the farm of Mr. J. J. Dagg, one mile south of Philip lake. This property which is east of the Welsh and Tippin prospects, is about 10 miles by good road northeast of Shawville station on the Ottawa-Waltham railway.

In the bush about one-fourth of a mile north of the road, there is an irregular pegmatite dike varying from 2 to 8 feet in width. The mineral zone is on its contact with limestone, and consists of green pyroxene, with a few small stringers of pyrites. The molybdenite occurs in irregular patches in the pyroxene and along the pyritic stringers, and in places very sparsely disseminated throughout the pegmatite. Occasional large aggregates are said to have been found.

One open-cut 24 by 12 feet and 5 feet deep, and two pits, 15 by 10 by 6 feet, and 4 by 4 by 3 feet, respectively, have been made in the mineral band. Work was done by Mr. Dagg in 1917, and about one ton of ore of approximately 1 per cent MoS_2, was on the dump.

The property is recorded under the name of Mr. Wood.

Although this prospect is of doubtful economic value, it nevertheless is on the border of the general molybdenite-bearing zone that extends in a northeasterly direction from the Tippin prospect and across Philip lake, so that higher grade mineral will probably be located by further prospecting.

Clapham Township

Range II, Lots 6 and 7, Farrell Prospect. This property is situated on Crown-granted land, about 500 yards east of Mr. E. Pelliter's farm. The property is just within the edge of the bush-covered country 8 miles northeast of Otter Lake, and about 20 miles northeast of Shawville, on the Ottawa-Waltham railway.

Intruding the granite are pegmatite dikes and bands of pyroxenite. Within the pyroxenite are small stringers of pyrites and pyrrhotite, carrying molybdenite. The exposed mineral zone is on the edge of a small, steep bluff running parallel to the ore-body, and has been traced for several hundred yards in a southwesterly direction, and appears to dip into the hill. The width of the area containing alternate bands of pegmatite, pyroxenite and gneiss appears to be approximately 200 feet. At several outcrops where the pyroxenite is exposed, flakes of molybdenite were observed. The work which was done by Mr. Giroux of Otter Lake, in 1917, consists of about 70 feet of stripping, a pit 10 feet deep, and a small portion of cliff blasted away in three places to show the ore-body (Figure 37). About one ton of hand-cobbed ore was shipped to the Renfrew concentrator, and several tons of low-grade ore in large boulders are still on the property. The whole hill, which is brush covered, appears to be composed of mineral-bearing rocks, but the ore is probably too low grade for straight milling purposes. Mining would have to be limited to a series of carefully placed pits and trenches, and the resulting ore hand-cobbed; by this means a considerable tonnage might be extracted. The deposit is worth further prospecting.

Clarendon Township

Range XII, S. ½ Lots 4 and 5, Tippin Prospect. This deposit, which is situated on a steep hillside to the north of the flat comprising Fred Tippin's farm, is on a contact zone of altered limestone and gneiss. The mineral zone consists of small bands of green pyroxene and pegmatite, tremolite, some pyrites, and mica. The molybdenite, which, in places, is in fairly large flakes, appears to be sparsely disseminated throughout this zone.

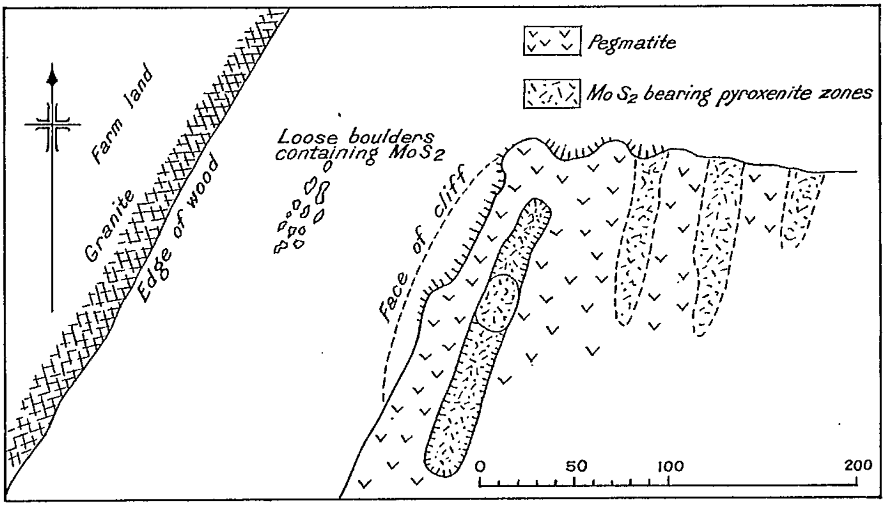

Figure 37. Farrell prospect, Clapham township, Pontiac district, Que. (September, 1921.)

The main workings, which are on lot 5, consist of two open-cuts on the hillside, one being 8 by 8 feet with a 6-foot face and the other, which is at the east end, 60 by 15 feet with a 20-foot face. These are connected on top by about 260 feet of stripping along the ore-body, which however, shows barren zones. About 700 yards to the east, on lot 4, is a small shaft 8 by 4 feet and 15 feet deep, in which there is a small pyritic stringer, carrying some molybdenite. The shaft, however, appears to have been sunk too far to the south of the main ore-bearing zone.

In January 1918 about ten tons of 0·27 per cent ore was sent to the Mines Branch, Ottawa, from which thirty-seven pounds of pure molybdenite was recovered. Five or six tons of low-grade ore is still on the dump.

The deposit was discovered by Mr. F. Tippin in 1909. Mr. Latimer of Ottawa, did some work on an option, and in February, 1916, it was leased to Mr. J. A. Smith of Ottawa.

The molybdenite-bearing portions of the ore-body are neither continuous nor very wide, and are, generally, low grade. The workings are easily accessible, and there is plenty of timber on the property, but the water supply is small.[1]

Range XIII, Lot 1, Welsh Prospect. This occurence is located on the farm of Patrick Welsh one-fourth of a mile southwest of Philip lake and 9 miles north of Shawville, on the Ottawa-Waltham railway.

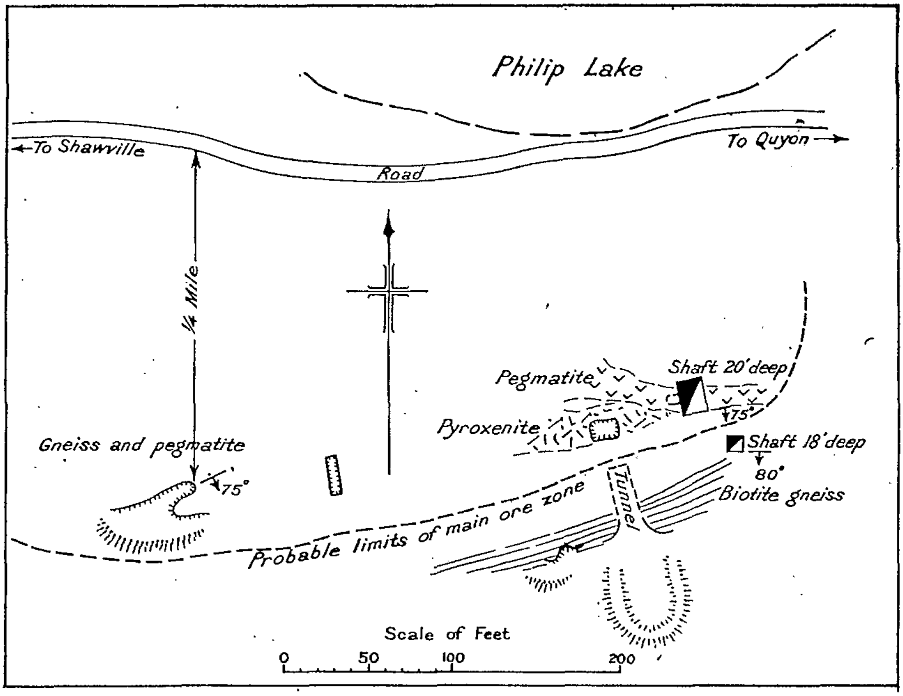

Figure 38. Welsh prospect, Clarendon township, Que. (August, 1921.)

Molybdenite in large and small well-defined flakes is disseminated throughout a low ridge of pegmatite within which are irregular masses of green pyroxene that also carries molybdenite. On the south side of this ridge occur stringers of biotite mica and very micaceous black gneiss, which is barren of mineral. The ore-body runs in a southwesterly direction for a considerable distance, but its northerly continuation, which is mainly of a molybdenite-bearing pegmatite, has only been traced for a short distance.

The mineralized zone, which is exposed by five or six pits and cuttings appears to be a continuation of the Tippin property about two miles to the southwest. In addition to the above pits and cuttings, a tunnel driven 45 feet below and to the south of the ore-body, failed to strike the molybdenite, and is in barren black biotite gneiss (Figure 38). There are a few tons of 1 per cent ore on the dump.

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[1] Mun. Res. Comm. Can., 1920, p. 110. J. C. Gwillim.

The character of the rocks and the occurrence of molybdenite over a fairly large mineralized area would indicate that, by careful mining and selecting, a large tonnage of medium-grade milling ore might be extracted. Accessibility, mill site, water supply, and timber are all good.

The property was staked by Mr. Pat Welsh about 22 years ago, in mistake for silver. In 1916 Messrs. Edward Whelen and Frank Doherty took an option, and later Mr. T. E. Richardson, of Portage du Fort, did a considerable amount of prospecting work. The property reverted to Mr. Welsh in June, 1920.

On the same lot and range, about half a mile south, there is an unprospected showing of molybdenite on the farm of Henderson Harris. The rocks are similar in character to those on the Welsh property.

Huddersfield Township

Range V, Lots 20, 21, 22, Chabot Mine. This property which is 4 miles south of the Squaw Lake camp, is situated about 8 miles up the west branch of the Pickanock river, above Otter lake. The mine is approached by a rough bush road and trail for a distance of 4 miles west of Sandy creek.

Molybdenite is sparsely disseminated throughout a mass of limestone, altered by contact with granite to massive pyroxene. The chief showing of the mineral, which is on the south half of lot 22, is closely associated with secondary pink and white calcite that occurs as segregations or gash veins in the main mass of the pyroxene. One of these calcite bodies is about 15 feet long, and from 1 to 3 feet wide. The ore-body which is exposed in the bottom of a shallow pit, carries heavy flake molybdenite.

The work, which was done in June, 1917, consists of surface pits and rock trenching across an outcrop of greenish pyroxenite rock about 100 feet in diameter. Some of these pits, the largest of which are 60 feet long by 12 feet deep, and 50 feet long by 6 feet deep, show the presence of molybdenite, but others appear to be of no commercial value. In 1917 about two tons of selected ore, running 4·63 per cent, and 14 pounds of pure flake (88 per cent MoS_2), were sent to the Mines Branch, Ottawa, from which 163 pounds of pure molybdenite was recovered. Samples were also sent to Henry E. Wood, Denver, Colorado, for experiments in concentration.

In 1906, this property was staked by Mr. O. Desjardins, of Otter Lake. In 1915, Mr. P. H. Chabot, of Ottawa, obtained a permit to operate, and in 1917, he gave an option to M. J. O'Brien, who did three months' work, and shipped 3 tons of hand-picked ore assaying 1·4 per cent MoS_2 to Renfrew. In 1918, an option was given to Mr. Weldon Young, of Toronto, who spent a considerable sum in development.

Prospecting was confined to a small area, but geological conditions are favourable to the occurrence of small deposits of molybdenite over a fairly large area. In mining such deposits it is probable that the ore would have to be carefully hand-cobbed.

Range VIII, Lots 19 to 26, Squaw Lake. This property is situated at the eastern end of Big Squaw lake, 36 miles by road from Shawville, on the Ottawa-Waltham railway.

The deposits are at the northern limit of surveyed land and are approached by wagon road 2½ miles west of Storey's farm on the Pickanock river, about 13 miles above Otter lake.

The whole area is underlain by igneous gneisses and within the area are bands of intensely metamorphosed sedimentary rocks including crystalline limestones, para-gneisses, and quartzites. The limestones, which are serpentine-bearing, are best exposed at the extreme east end of the property. They are interbanded with gneisses that vary a great deal in composition and colour, but are mainly composed of quartz, biotite, and pyroxene. They carry grains of pyrite and pyrrhotite which in many places give rise to rusty streaks on weathered surfaces. These rocks are traversed in all directions by narrow pegmatite dikes.

According to J. A. Bancroft[1] the molybdenite in this area has been developed under the influence of intense contact metamorphism. In the vicinity of some of the contacts between the granitoid gneisses and the metamorphosed sedimentary rocks, the original limestone has been converted into an assemblage of coarse-grained, dark green pyroxene, mica, and other minerals. Pyroxene is present in places almost to the exclusion of the other minerals. Parts of the bands are irregularly impregnated with molybdenite and iron sulphides, and these minerals are scattered through many of the irregular pegmatite dikes. At some places, where they cut the mineralized bands of pyroxene, there are heavy enrichments of molybdenite in the contacts.

Most of the workings are on lot 24 on the slope of the hill that runs up from the lake about 200 yards to the west. There are five open-cuts and trenches (Figure 39). In nearly every case they are in metamorphosed impure limestone, which in places, is altered to dark green pyroxene, and intruded by bands of granite gneiss which are cut by a few narrow pegmatite dikes. In portions of these re-crystallized masses calcite is the predominating mineral, and may be clearly seen in the large open-cut in the west. In every case, the molybdenite is found intimately associated with the dark green pyroxene and as a rule accompanied by pyrite and pyrrhotite. In some places it is found scattered throughout the pegmatite.

The richest ore was found in the workings A, C, and E, but D and G appeared to be barren.

From a general examination of the property in 1920[2] it appears that there is a thin layer of pyroxene rock about 6 feet thick, extending over the side of the hill, in which the molybdenite occurs in patches, or streaks, along a parallel jointing. The gneisses are not cut by these joints but form the floor of the ore-deposit, approximately paralleling the slope of the hill.

The molybdenite-bearing zones are shaped like elongated shallow saucers, and the method of mining was to follow the exposures and rich streaks until they petered out. This was done so thoroughly that scarcely any of the existing pits show molybdenite either on the walls or floor.

Three diamond drill holes were put down in the positions shown in the sketch. The two vertical ones were 339 and 285 feet deep, and the other, which is at an angle of 25 degrees to the horizontal, is 327 feet long. These holes cut through alternate bands of pyroxenite, gneiss, limestone, pegmatite, and quartz, throughout their entire lengths. In No. 1 hole the first 30 feet was in pyroxenite, and no assays showed over 0·07 per cent MoS_2. Broad bands of pyroxenite were struck at 125 feet, 275 feet, and at the bottom. The average molybdenite content was lower than the above, and the bottom was barren.

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[1] Mining Operations in Quebec, 1917, p. 35. J. A. Bancroft.

[2] Private report. C. S. Parsons.

In No. 2 hole considerably less pyroxenite was found but more quartz. At no place except in the first few feet, were high molybdenite values found. The assays, numbering about 60, were made by the Department of Mines, Ottawa.

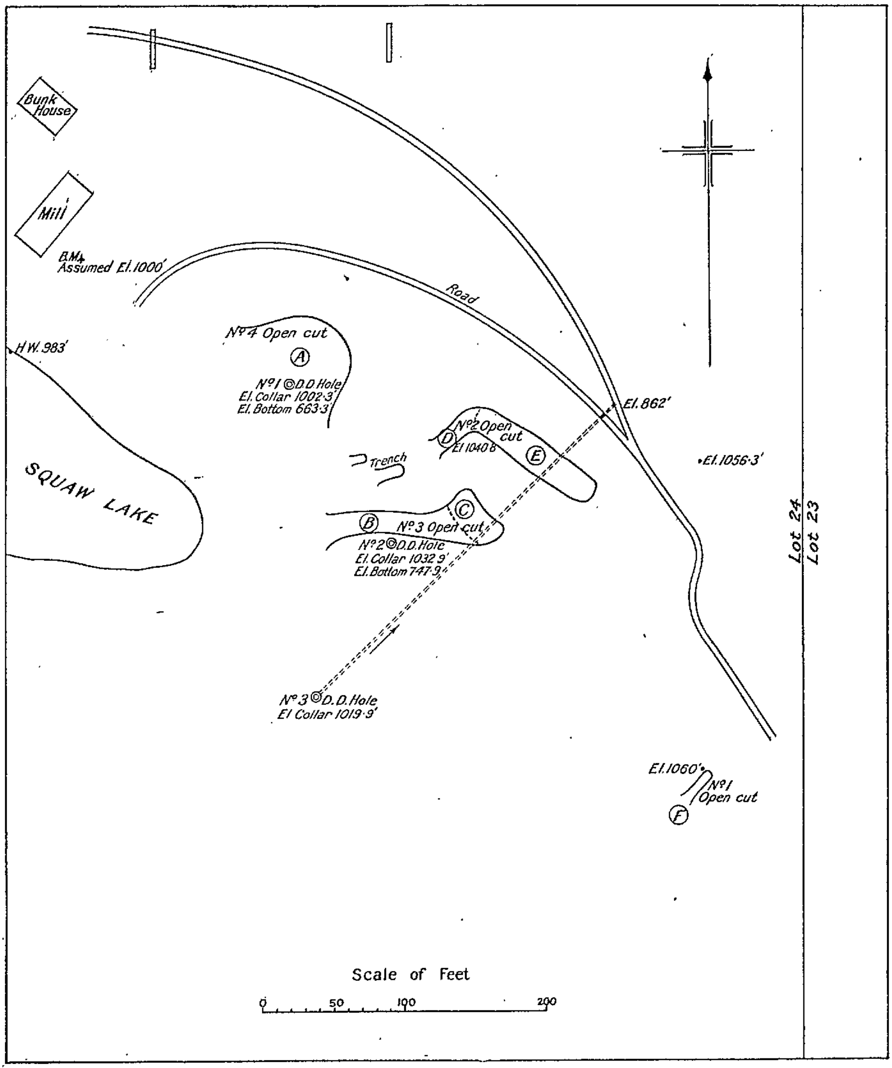

Figure 39. Squaw Lake molybdenite property, Huddersfield township, Pontiac district, Que. (1918).

The property was staked, about 1906, by Mr. J. T. Farrell, of Otter Lake. Later, the mineral rights were taken over by Henry E. Wood of Denver, Colo., who built a camp and erected a 25-ton concentrator, using a water-film flotation machine. (See description of flow-sheet under Concentration.) In 1918, about 700 pounds of concentrates, averaging 72·0 per cent, were sent to the Mines Branch, Ottawa, for re-treatment, from which 457 pounds of pure molybdenite was recovered. The Mining Corporation of Canada took a mortgage on the property, and apparently helped to finance the operations. The mortgage was later foreclosed and the corporation bought the property.

It would appear from the above reports that all the available ore in the immediate vicinity of the workings has been exhausted, but it is more than probable that careful prospecting would disclose other similar shallow deposits.

Range VIII, Lot 27, Moyle Prospect. A molybdenite claim to the west of the above property was staked by Mr. P. B. Moyle of Quyon. The rocks are similar to those of the neighbouring property. A full description of the geology and work done on all these Squaw Lake deposits can be found in J. A. Bancroft's report.[1] Considerable prospecting work was done in a search for molybdenite. Trenches from 1 foot to 4 feet deep were dug to a total length of about 900 feet; and some pits 9 feet deep and 15 feet wide were sunk. According to Bancroft, only in few instances was there a record of "an occasional flake of molybdenite." Summing up he says: "No discoveries have been made in any of the trenches or pits on lot 27 that would warrant the continuation of prospecting work within them."

Litchfield Township

Range IX, Lot 26, Bolan Prospect. This prospect is on J. Bolan's farm about 10 miles north of Campbell's Bay, on the Ottawa-Waltham railway.

Under a capping of granite-gneiss, also on exposed surfaces, there are irregular bands and patches of pale green pyroxenite. Portions of this rock carry well-formed flakes of molybdenite sparsely disseminated throughout. There are a few molybdenite-bearing stringers of pyrite, and a considerable quantity of biotite mica. Wherever mica forms a constituent in the pyroxenite, molybdenite is almost entirely absent.

The work which was done in 1917 by Mr. Bolan, consists of a cutting 30 by 8 feet and 5 feet deep, also two or three small test pits in small bands of exposed pyroxenite. About 15 tons of ore, probably averaging a little over 0·75 per cent, is on the dump. About one ton of 0·60 per cent ore was shipped to the Mines Branch, Ottawa, in June, 1917, from which 7½ pounds of pure molybdenite was recovered.

Several pyroxenite bands carrying flakes of molybdenite, outcrop between the Bolan and Crawford prospects, 1½ miles to the east.

A large tonnage of high-grade ore should not be expected from any of the workings at this elevation, and all ore mined would probably have to be carefully hand-selected.

Range IX, E. ½ Lot 28, Crawford Prospect. This property lies east of the Bolan prospect, about 75 yards west of the new Thornby road. It is on the boundary line between Litchfield and Thorne townships, about 9 miles by fairly good road, north of Campbell's Bay.

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[1] Mining Operations in Quebec, 1917, p. 35. J. A. Bancroft.

The mineral zone consists of several small bands of pyrites and pyrrhotite in altered gneiss and pyroxenite that dip flatly to the northeast. The pyrite stringers are 3 to 6 inches wide and are separated by about 1 foot of metamorphosed material. The molybdenite is intimately associated with other mineral sulphides. Two of the stringers that are exposed in the workings seem to show that the occurrence is local and irregular, there being barren zones in the exposed surfaces. The mineral zone is cut off on the northeast by a wall of granite, which is visible in the small shaft. On approaching this wall the mineral zone becomes narrower and leaner.

The prospecting consists of about 200 feet of stripping and three shafts from 10 to 15 feet deep. Approximately 15 tons of roughly hand-picked ore averaging a little more than one per cent is on the dump. No shipments appear to have been made. This property was leased in 1914 to Mr. Weldon Young of Toronto, and also to a Mr. Isaac Wilson.

Owing to the nature of the deposit, it is unlikely that any large body of ore will be discovered at the present location of the workings.

Range XI, S.W. ½ Lot 21, Giroux Prospect. This property is situated on the farm of Cadice Giroux, of Bellmount, close to the east shore of Bear lake (Lac L'Ours), about 14 miles north of Campbell's Bay.

On the top of a steep rocky bluff there is a capping of greenish schistose rock, varying in width from 15 to 25 feet, on top of a band of pale green massive pyroxene. Within the pyroxene molybdenite occurs in large, chunky flakes, aggregates, and well-formed crystals. The rocks everywhere appear to have been subjected to distortion and alteration and show a great variety of minerals, many of which are very fine crystal specimens.

Throughout the whole area of 5 or 6 acres that was visited by the writer, the pale green pyroxene outcrops in numerous places and shows traces of molybdenite; in some places the mineral was found in contact with pegmatite dikes.

In the main working on the side of the rock bluff about 100 feet of ore and rock has been blasted away and about 50 to 60 tons of unselected ore, in large boulders, lies strewn about at the bottom. Mr. Giroux has also sunk at least six test pits on the molybdenite-bearing pyroxene throughout the mineralized area.

On account of the massive nature of the molybdenite flakes, limited quantities of high-grade hand-picked ore could easily be collected; mining problems are not difficult; and there is plenty of water and timber on the property. The property is approached by half a mile of hilly road, south from the government road to the farm, and by bush trail for half a mile to the workings.

It is stated by C. W. Willimott[1] that about 20 years ago, many pits were sunk on this property in prospecting for mica, and that appreciable quantities of molybdenite were met with in all the pits.

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[1] Geol. Surv., Can. Notes on Molybdenite. C. W. Willimott, 1904.

Onslow Township

Range VII, Lots 9 and 10, Moss Mine. This mine is situated three miles north of Quyon station on the Canadian Pacific railway, and 33 miles by good road west of Ottawa.

The presence of molybdenite-bearing rock on Mr. Robert Steel's farm had been known for many years, but the occurrence was not investigated until 1915. In the autumn of that year Messrs Archie MacLean and Arthur Latimer took an option on the property. They sold the option the following March to Mr. Harvey Fitzsimmons, of Ottawa, who formed the Canadian-Wood Molybdenite Company. The company also purchased 250 acres of other mining lands in the vicinity.

Mining operations were immediately begun and the property quickly outstripped all other molybdenite mines in quantity of production. In a few months it became the world's leading individual molybdenite producer and kept up its output to such an extent that it has produced over 80 per cent of the total Canadian output since 1916.

Topography.

The mine lies on a bench at the foot of the high escarpment which overlooks the Ottawa River valley. The surface of the bench near the workings is covered with a deposit of sand of varying thickness from which rocky knobs outcrop. About 300 yards north of the mine the escarpment rises as a rocky broken slope to a height of several hundred feet above the valley.

Geology.

As a rule the country rock consists of masses of fine-grained pink granite, or syenite, cut by many small aplite and pegmatite dikes. The ore-bodies are segregated, irregular, and in poorly-defined masses of darker coloured rock. The mineral zone consists mainly of granular quartz and feldspar, in which pyrite, pyrrhotite, pyroxene, fluorite, and molybdenite occur. At many places, zones of coarse crystallization occur, in which are found aggregate crystals of dark pyroxene, black mica, pyrites, etc.

Although rich pockets of molybdenite have been found, it is in most cases disseminated in the rock as small flakes, and large crystals of the mineral are very uncommon. The flakes, occurring in the pegmatite, are larger than those found in the aplite dikes. The dissemination is irregular, but being confined only to a number of closely connected areas, does not materially affect the aggregate tonnage of ore extracted. Daily analyses of the last 50,000 tons mined during a period of two years, showed that the grade of mined ore was remarkably consistent.

History of Operations.

The Canadian-Wood Company first shipped their hand-picked ore, to Henry Wood's concentration plant at Denver, Colorado. Shipments were also sent to the Mines Branch concentrator at Ottawa, in which the Wood process had already been installed and proved to be fairly successful. In addition, shipments were sent to the International Molybdenite concentrator at Renfrew which had used a modification of the water-film process. (See description under Concentration.)

During the year, the company erected on their property a concentrating plant of about 60 tons capacity, consisting of jaw-crushers; a Krupp and a Traylor ball mill; and eight Wood water flotation machines. A second concentrating plant was secured by installing nine Wood flotation machines in the plant of the Canada Cement Company, at Hull, Quebec, the ore being crushed by the cement company. This concentrator was said to have a capacity of 150 tons per day, but was apparently not very successful and was abandoned early in 1917. The company also built large and comfortable bunk houses, offices, etc., and installed a water supply system.

Early in March, 1917 the property was purchased on behalf of an American syndicate, operating under the name of the Dominion Molybdenite Company, the president being Mr. W. J. Boland, of Toronto.

In the summer of 1917 the new company carried on extensive diamond drilling operations and about 12,000 feet of drill holes were put down by the E. J. Longyear Company. Experiments were also undertaken on the concentration of the ore, and it was shown that the Callow pneumatic oil flotation process gave the best results. The Wood flotation machines put in by the Canadian-Wood Molybdenite Company gave a comparatively high-grade concentrate, but made a low recovery. As a result of these experiments a 150-ton concentrator was erected, in which a Marcy ball mill, Dorr duplex classifier, and 6 Callow cells were installed. A description of the concentrator and flow-sheet will be found under the heading of Concentration.

During 1918 a total output equal to that of the previous two years was reached. In March, 1919, when the company closed down owing to the collapse of the market, good ore was being extracted, and excellent results were being obtained from the concentration, in which a 91 per cent concentrate with a 97 per cent recovery was being steadily maintained.

Mining and Development.

Work has been done on five different deposits.

No. 1, the main deposit from which almost the whole output of the mine was obtained, is on the south half of lot 9. A pit on this deposit is 150 feet long, 65 feet wide, and 125 feet deep, at the north end. (See Plate V.) In 1918 the system of mining was changed from open-pit to the underground method, and hoisting was done by a two-compartment shaft inclined 70 degrees to the east and 200 feet deep. This shaft was sunk about 70 feet west of the northwest end of the pit, a crosscut being driven into the deposit from the bottom of the shaft for a distance of 120 feet and connexion made with the bottom of the pit by a raise from a drift. From the east end of the crosscut there is 60 feet of drifting to the north and 70 feet to the south. (Figure 40.)

The richest ore came from the northeast end of the pit. Some hand-sorting was carried on in the open-pit, but the total amount of waste rock was small, apparently little more than 10 per cent. Mining was done by machine drills, and hoisting, by means of boom derricks; but after the shaft was started, all hoisting was done by means of the usual mine skips. Work was proceeding at full speed in the drifts when operations ceased and ore that was even richer than the average for the preceding year was being extracted.

No. 2 deposit, which is about 150 feet long and from 5 to 25 feet wide, is situated at the north end of lot 9 and is about 1,500 feet northwest of No. 1 deposit. The work done consists of a quarry about 60 feet across and 25 feet deep in the face of the escarpment. The rock is fine-grained, pink granite or syenite, with massive jointed structure. It is cut by small aplite and pegmatite veins, and contains a number of small pyroxene inclusions. The veins, (which strike diagonally up the slope of the hill), and the pyroxene, are mineralized by fine-grained molybdenite. Diamond drilling located good ore between 100 and 200 feet in depth and the deposit looks very promising, but had not been touched since 1916, when it was worked by the Canadian-Wood Molybdenite Company, who abandoned it for the more favourable and higher grade No. 1 deposit. The cobbed ore was shipped to Denver. During 1924 the Canadian-Wood Molybdenite Company started operations on No. 2 deposit and shipped about 10 tons of high-grade concentrates.

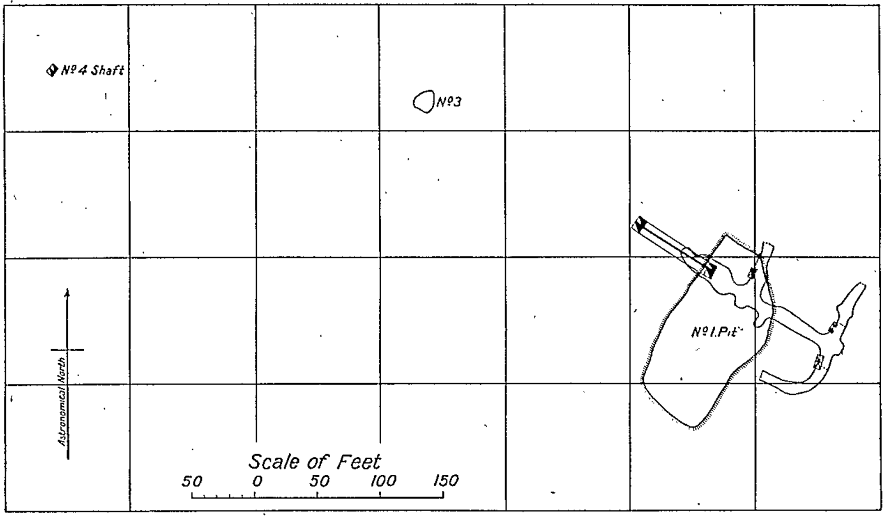

Figure 40. Plan of surface and underground workings, Dominion Molybdenite Company, Onslow township, Pontiac district, Que.

On No. 3 deposit, which is about 250 feet northwest of No. 1 shaft, there is a pit about 20 feet across and 10 to 15 feet deep. Some high-grade ore is said to have been shipped. A 10-foot band of low-grade and much weathered ore cuts diagonally across the pit.

No. 4 shaft, which also has two compartments, is timbered, and sunk to a depth of about 85 feet on an incline of 60 degrees east, and follows the ore-body. This shaft is about 500 feet west of No. 1 and about half-way between it and the mill buildings. The outcrop on which the shaft was sunk appears to be a lens about 5 feet wide, which gradually widens, and at the bottom of the shaft is about 18 feet wide. About 20 tons of ore was shipped.

No. 5 deposit is an irregular mass about 10 feet in diameter, exposed near the bottom of the escarpment on range VII, lot 11. The richest ore is exposed on the contact of a pegmatite mass, but is of small extent.

Diamond Drilling.

About 12,000 feet of drill holes were put down during 1917, most of which were in the immediate vicinity of No. 1 pit. A few holes were around No. 4 shaft and in the ground between the two where from 36 to 40 holes were bored varying from 150 feet to 350 feet in length. Most of these were vertical, but some dipped 60 degrees west, which is approximately at right angles to the dip of the ore-body. Eight or nine holes were also drilled on top of the ridge, just above No. 2 workings.

It appears that No. 1 ore-body is a lenticular wedge-shaped mass, elongated in a north-south direction, the greatest area being at the surface, where the ore-body is about 350 feet long, and 75 feet wide at the centre, with a gradual taper to the north, and a more abrupt taper to the south. The centre of the lens, which is at the northeast corner of the pit, appears to be a solid mineral-bearing zone for a depth of about 150 feet, after which it breaks up below into a number of gradually tapering fangs which slightly flatten with depth. These fangs have been traced for at least 350 feet below the surface.

Plant and Equipment.

The company has an up-to-date and efficient plant as well as comfortable and commodious boarding houses, offices, shops, etc., and a number of ore-bins, both at the main workings and at the mill.

The water supply station contains one 30 h.p. boiler and one 7- by 5- by 7-inch Duplex pump. The mine power-plant, which is housed in a building 100 by 60 feet, consists of one 145 h.p. and one 60 h.p. Rand air-compressors, and three 80 h.p. R.T. boilers. Hoisting equipment consists of two 7- by 12-inch derrick hoists and two 6- by 8-inch mine hoists. Steel shop equipment consists of one No. 5 Leyner drill sharpener and one Leyner oil forge. Concentrator contains: crushers, 64½-inch Marcy ball mill; Dorr duplex classifier; Callow pneumatic oil plant complete; one 100 h.p. and one 60 h.p. engines; one No. 5 Connersville blower; lighting generator; and two 85 h.p. R.T. boilers.

Production and Shipments.

Approximately 61,000 tons of ore have been mined and 58,000 tons milled, from which about 383 tons of pure molybdenite was recovered and shipped. This forms approximately 81 per cent of the total production in Canada since 1916.

The accompanying table shows the production of the Moss mine since it was first started:—

TABLE XIII

Production Statistics, Moss Mine, Quyon, Que., 1916-1919

Year	Company	Tons mined	MoS_2	Concentrator	Tons milled	Concentrates			MoS_2 shipped	Remarks
						Concentrates made	MoS_2	Contents MoS_2		
			per cent			Lbs.	per cent	Lbs.	Lbs.	
1916	Canadian-Wood Molybdenite Co.	10,500		Mine and Hull	2,808	....	....	31,430	....	Includes 24 car lots of ore originally sent to Renfrew that were shipped back to Hull and treated there in 1917. Sold to Imperial Munitions Board
			2·07	Ottawa.....	1,007	....	....	27,782	....	Nine tons sold in U.S.A., remainder to Imperial Munitions Board
			1·23	Renfrew....	1,766	....	....	32,378	....	Sold to Imperial Munitions Board
			4·75	H. E. Wood Denver	460	40,604	90·6	37,684	....	All sold in U.S.A., 6½ tons concentrates assayed 96·0%, 9½ tons 91%, remainder 74-85%. Ore hand-picked
1917		8,000		Mine and Hull	1,079	249,540	....	64,903	....	These concentrates include 50 tons of middlings and 12 tons of low-grade concentrates that were re-treated at Ottawa, and concentrates sold to Imperial Munitions Board
			1·01	Ottawa	660	13,700	72·0	9,852	....	Sold to Imperial Munitions Board
	Dominion Molybdenite Company.	11,266	0·91	Ottawa	527	9,650	72·0	6,949	7,000	Sold to Imperial Munitions Board
			0·59	Mine	12,246	193,470	72·9	141,108	....	“ “ “
1918		30,160	0·59	Mine	30,450	384,253	88·7	340,655	332,001	137 tons sold Canada and Imperial Munitions Board. Remainder in U.S.A.
1919		1,280	0·55	Mine	6,783	79,940	90·5	72,350	88,953	Operations ceased Mar. 10, 30 tons sold at $1 per lb. Remainder including old stocks were sold later at 50c. per lb., all to U.S.A.
Totals..	....	61,206	....	....	57,786	....	....	765,091	....	

The ore carries about 0·01% copper and the concentrates under 0·1% copper.

Pounds of pure MoS_2 produced

1916....................................	129,274	1918....................................	340,655
1917....................................	222,812	1919....................................	72,350
			765,091

Summary.

Although it would appear that, in the main workings, most of the richest ore had been extracted, there is still a considerable area of surface ore, covered by sand, to the north of the main pit. Mr. Fitzsimmons informed the writer that the lower assay returns for mill feed, during the last period of operations, were partly due to the fact that the company at that time put through a large tonnage of second-class ore and old mill tailings that had been mined and discarded by the Canadian-Wood Molybdenite Company in their earlier operations. It would seem that the main ore-body tends to slightly increase in richness towards the north, but decreases in volume as the end of the lens is approached. There is a considerable untouched mineral area around the north drift on the 200-foot level, and the ore-shoots, although narrow, have been traced down for another 150 feet, at least. There are also good indications of mineral to the southwest of the main pit. It is probable that there is as much ore still in place in and around the main pit as has been extracted, though, possibly, the average grade is somewhat lower.

Very little attention has been paid to the other showings on the property, or to prospecting for new deposits. A considerable tonnage of ore should be won from No. 2 deposit which, being on the face of the escarpment, can be economically and easily mined.

References: (*a*) Sum. Rep. Geol. Surv., 1916, p. 207. C. Camsell. (*b*) Geol. Surv. of Can., Mem. 136, Arnprior-Quyon and Maniwaki areas, Ontario and Quebec, 1924. M. E. Wilson.

Range VII, N. ½ Lot 10, Foley Prospect. This deposit is about half a mile northeast of the main pit of the Moss mine, and some 400 feet above it, on the Eardley escarpment.

It occurs in a massive, pink syenite somewhat similar to that found in the vicinity of the Moss deposit but is coarser in texture, and contains small patches of pyroxenite. Molybdenite occurs on the contacts of this pyroxenite with the syenite.

A shaft 8 by 5 feet and 50 feet deep was sunk in 1917, and is timbered for the first 20 feet.

The property was worked in 1917 by the late Mr. Foley, of Toronto, using a portable steam-boiler to supply power for drills and hoists. A small creek runs close to the shaft and there are two bunk houses at the foot of the hill.

Very little ore was seen at time of examination, and the occurrence does not appear to be of economic value.

In 1917, about 12,600 pounds of ore averaging 0·90 per cent MoS_2 was shipped to the Mines Branch, Ottawa.

During 1917 and 1918, when the Moss mine was working at full capacity, almost all the surrounding country was staked for molybdenite claims. Little or no work appears to have been done on these claims and although most of them have showings of the mineral, it is doubtful if any will prove of commercial value.

Mr. M. Joyce of Quyon states that he has a good prospect on range VII, lot 7, but it was not visited by the writer.

Thorne Township

Range I, Lots G and J, Daly Molybdenite Co. This property is at the northeast end of Philip lake, about 10 miles north of Shawville, on the Canadian Pacific railway.

The country rock is white limestone and biotite-granite gneiss. The outcrop is in a creek bed and consists of a small stringer of quartz, calcite, and pyroxene rock, carrying a little molybdenite. On the north of the outcrop is an irregular pegmatite dike. About 30 feet south of the outcrop a partly timbered shaft, 7 by 9 feet, was sunk vertically to a depth of 50 feet on a calcite vein, but scarcely any molybdenite was encountered. At the bottom of the shaft a crosscut was driven both north and south. A small pocket of molybdenite was found 25 feet north of the shaft, and a stringer followed for a few feet, but no more ore was located.

The present owners, the Daly Molybdenite Company, relying on the optimistic reports of an engineer, sunk the shaft, built an office, bunk and cook house, blacksmith shop and hoist house, cleared a space for a concentrator and cut all the necessary heavy timber.

Nearly all the work was done in 1919, and Mr. H. H. Claudet, of Ottawa, was engaged to construct the mill. After pumping out the shaft and continuing the crosscut for a few feet more the lean nature of the deposit was revealed, and in June, 1921, the work was abandoned.

In all about half a ton of low-grade milling ore was extracted.

Range IV, Lot 2, Riley Prospect. Molybdenite has been found on the farm of James Riley of Ladysmith, about 3 miles south of the Moodie prospect in Aldfield township and about 15 miles north of Shawville, on the Canadian Pacific railway. The lot can also be reached by a very steep road from Thorne Centre post-office, or by footpath 1½ miles south from Martin lake.

Bands of pegmatite and massive, green pyroxene in which occur seams of pyrites carrying molybdenite are distributed over a wide area. The mineral is also disseminated throughout portions of the pyroxene. The rocks are gneissic, and in some places are found as a capping over the molybdenite-bearing pyroxene.

Mr. Riley discovered the deposit in 1916, and, with Mr. Nolan, that summer, did some work consisting of about 60 feet of stripping and pits. In July, 1917, Paul Leger, agent for Mr. Riley, shipped to the Mines Branch, Ottawa, 750 pounds of hand-picked ore, running 1·03 per cent MoS_2.

The whole area of the Riley farm, is well mineralized, and a number of pyroxene and pegmatite outcrops carrying flakes of molybdenite were observed.

TABLE XIV

Molybdenite Deposits and Occurrences in Quebec

	Township	Name and locality	Mode of occurrence	Quantity of ore shipped	Classification	Remarks	References
ABITIBI DISTRICT							
1	Preissac......	Indian peninsula, St. Maurice mines	Quartz veins in granite and sericite schist	1½ ton for testing	B.	Extensive strippings and pits; small Groch concentrator	(5)
2	"	Kewagama river, Height of Land Mining Co.	Pegmatite veins in schists	1,200 pounds pure flake	C.	Open-cuts; 50-foot shaft and tunnel; about 7 tons 1% ore extracted	(5)
3	"	Kewagama river, McLaren	In small quartz veins in granite and biotite schist	Nil.	P.	2 deep trenches...............	(2) 1911, p. 196
4	"	Kewagama river, Small	In quartz veins in granite and schist	"	P.E.	2 trenches....................	(2) 1911, p. 196
5	LaCorne......	R. I, Lots 1 and 2..... Benjamin	Quartz veins in sericite schist and in pegmatite granite and mica schist	"	A.	1,000 feet trenching; 15 pits; property in four townships: 150 tons 3% ore extracted	(5)
CHICOUTIMI DISTRICT							
6	Métabetchouan	Lake St. John.........	Pegmatite contact with granite	Nil.	F.	One small pit	(5)
HULL DISTRICT							
7	Eardley......	R. VII, Lot 1, National Molybdenum Company's mine	Fine flakes in Grenville limestone and coarse flakes in pyroxenite	35 tons, 460 lbs. of MoS_2 recovered	B.	Many local occurrences; 40-foot shaft, 6 pits, and stripping	(5)
8	"	R. VIII, lot 6, Wood-Ormond	Associated with dark green pyroxene in red granite	Nil.	D.	Two tons ore extracted. Two open-cuts	(5)
9	"	R. XI, lot 6, Chatelain	In pegmatite quartz in red granite with pyrites and pyrrhotite	"	E.	Stripping in creek bed, about 4 tons 1·5% ore extracted	(5)
10	Egan.........	R. I, lot 4............	Disseminated through quartz and pyroxenite	120 pounds......	F.	Little prospecting. Ore 0·25% MoS_2	Mines Br. Sum. Rep., 1919, p. 73
11	" ..	R. III, lots 6-7, McKerracher	Sulphide contact zones between gneiss and limestone	30 tons..........	C.	Several open-cuts and pits, ore low grade and pockety; machinery and buildings on property	(5)

TABLE XIV—*Continued*

Molybdenite Deposits and Occurrences in Quebec—Continued

	Township	Name of locality	Mode of occurrence	Quantity of ore shipped	Classification	Remarks	References
			HULL DISTRICT—*Continued*				
12	Egan	R. III, lots 8-13, Moore	Sulphide contact zones between gneiss and limestone	Nil.	C.	Few small pits. A continuation of McKerracher prospect	(5)
13	“	R. IV, lot 5, Robitaille	Scattered flakes in pale green pyroxene in pegmatite and pyroxenite	“	M.	A few shots for prospecting	(4)
14	“	R. IV, lot 69	Massive flakes; much decomposed iron sulphides in limestone	“	C.	Pit and tunnel	(5)
15	“	R. VI, lot 44, Villeneuve	Near contact zone of massive pyroxene in granite	“	F.	Two small pits	(4)
16	“	R. VII, lot 42, Donnie	Iron sulphide in pyroxene in gneiss	“	F.	“	(4)
17	Hull	R. X, lots 27 and 28, Payne	Same as National Molybdenum Company	“	C.	One open-cut; 4 tons 0·5% ore extracted	(5)
18	“	R. XI, lot 13, Kirk Ferry	Pegmatite contact with gneiss and limestone	“	M.C.	No development; exposure in railway-cut	(5)
19	“	R. XI, lot 16	Pyroxene-pegmatite contacts in red felsite	“	M.	No development; occurrence in old mica mine	Mines Br. Rep. No. 118 Mica, p. 112
20	“	R. XIII, lot 12a	Pyroxene-pegmatite contacts in red felsite	“	P.	No development; one-half pound lumps found in mica prospects	Mines Br. Rep. No. 118, Mica p. 101
21	“	R. XV, lot 23, Farm Point	With pyrites in granite and limestone	“	M.	Exposure in railway-cut	(4)
22	Masham	R. X, lots 53-55, Bain	Highly pyritiferous contact pyroxenite zone; pegmatitic granite and gneiss	1 ton	A.	About 25 pits and stripping; several hundred tons of good ore extracted	(5)
23	“	R. X, lots 56-57, Edwards	Pyrites with contact pyroxenite in biotite-gneiss	Nil.	E.	Two small pits, close to Bain deposit	(4)
24	Templeton	R. XIII, lot 12 McGregor lake	With iron pyrites in apatite and pyroxenite	“	M.	No development	(4)
25	Wakefield	R. I, lot 6, Copeland Ferry		“	M.	“	(4)

MEGANTIC DISTRICT

26	Leeds........	R. XV, lot 17, Harvey Hill	Semi-amorphous in copper-bearing slates	Nil.	C.	Extensive development for copper only	(1) 1863, p. 755
27	Coleraine.....	Thetford............	With asbestos in serpentine.	"	M.	No attempt made to save the molybdenite values	(4)

PONTIAC DISTRICT (Southeast)

28	Aldfield......	R. III, lots 1 and 2, Ross	With other sulphides in contact pyroxenite in biotite gneiss and green pyroxene	About 30 tons..	C.	Four or five pits and open-cuts; shipments very low grade but better ore on property	(5)
29	"	R. IV and V, lots 1 to 3, Kirkham	In flat pyritic seams in gneiss and pyroxenite	Several tons....	C.	Several open-cuts............	(5)
30	"	R. VI, lot 53, Moodie.	Clean flakes in massive pyroxene in white limestone and pegmatite	Nil.	D.	One trench; 3 tons 0·75% ore extracted. Iron pyrites absent	(5)
31	Alleyn........	R. II, lot 1, Heeney...	In pegmatite dike in hornblende gneiss	80 pounds flake.	E.	One small pit................	(1) 1904
32	Bristol........	R. XII, lot 3, Dagg...	In pyritic stringers with pyroxenite in limestone and pegmatite	Nil.	D.	3 pits; 1 ton 1% ore on dump...	(5)
33	Calumet......	R. VII, lot 28........	Crystalline limestone and garnetiferous gneiss	"	F.	Little prospecting; several reported occurrences	(3) p. 32
34	Clapham.....	R. II, lot 6 and 7, Farrell	In pyritic and pyroxene stringers in pegmatite and granite	1 ton cobbed....	C.D.	Little quarrying and stripping	(5)
35	Clarendon....	R. XII, lot 2, A. Tippin	Pegmatite and pyroxenite zone in altered limestone	Nil.	M.	No development............	(5)
36	" ..	R. XII, lots 4 and 5, F. Tippin	Pegmatite and pyroxenite zone; little pyrites; in altered limestone and gneiss below red granite	10 tons.........	E.D.	Deep open-cut, pits and stripping	(4)
37	" ..	R. XIII, lot 1, Welsh	Disseminated through pegmatite gneiss; pyrites almost absent	Nil.	B.	Tunnel, pits and shafts; a few tons extracted	(5)
38	" ..	R. XIII, lots 26-27, Richardson	....	"	P.	Little prospecting; some ore extracted	(4)
39	Huddersfield.	R. V, lots 20-22, Chabot	Disseminated through massive pyroxene in altered limestone	5 tons cobbed..	D.	Fairly extensive trenching and pits	(5)
40	" ..	R. VIII, lots 19-26, Squaw lake	In lenses of pyroxenite with pyrites in altered limestone and gneiss	700 pounds concs.	C.	5 open-cuts and trenches; 3 D.D. holes; deposits shallow, all ore extracted; 25-ton concentrator	(5)
41	" ..	R. VIII, lot 27 Moyle.	" "	Nil.	E.	900 feet of trenches and pits...	(5)
42	Leslie........	R. IV, lot 30, Moore..	....	"	M.	....	(4)

TABLE XIV—*Concluded*

Molybdenite Deposits and Occurrences in Quebec—Concluded

	Township	Name and locality	Mode of occurrence	Quantity of ore shipped	Classification	Remarks	References
			PONTIAC DISTRICT (Southeast)—*Continued*				
43	Leslie........	R.V, lot 45, Stephens.	In pyroxenite in limestone...	Nil.	M.F.	A few prospecting shots.......	(4)
44	Litchfield....	R. VIII, lots 14 and 15, Ranger	" "	"	E.	Very little prospecting; small quantity extracted	(4)
45	"	R. IX, lot 26, Bolan..	Large flakes in pyroxene bands in granite-gneiss	1 ton...........	D.	1 cut and 3 test pits; 15 tons of 0·75% clean ore extracted	(5)
46	"	R. IX, lot 28, Crawford	Highly altered sulphide zone in red granite and gneiss	Nil.	D.	Stripping and 3 small shafts; 15 tons of 1·0% ore extracted	(5)
47	"	R. X, lot 3, Davis....	Contact pyroxene and pegmatite in gneiss and altered limestone	"	E.	Stripping and a few pits.......	Mun. Res. Comm. Can., 1920, p. 16
48	"	R. XI, lot 21, Giroux.	Large lumps in massive green pyroxene in greenish schistose rock; also pegmatite and granite	"	D.B.	Quarrying and many test pits; about 60 tons of ore extracted	(5)
49	Onslow.......	R. VII, lot 10, Foley..	On pyroxene contacts in pink syenite	6½ tons cobbed..	F.	50-foot shaft.................	(5)
50	"	R. VII, lots 9 and 10 Moss mine	Small flakes disseminated through highly altered limestone and massive pink syenite	58,000 tons milled	A.	Very extensive pits and shafts; tunnels; 12,000 feet D.D. holes; 80% of Canadian output; considerable ore in sight; 150-ton Callow concentrator; 388 tons MoS_2 produced	(5)
51	Thorne.......	R. I, lots G & J, Daly	In quartz and pyroxenite veins in limestone and biotite gneiss	Nil.	F.	50-foot shaft and tunnels......	(5)
52	"	R. I, lot 3, Welsh No. 2	Decomposed pyrite stringers in syenite gneiss and pegmatite	"	E.	5 small pits....................	(4)
53	"	R. IV, lot 2, Riley....	Pyrite seams in pyroxenite and pegmatite	750 pounds cobbed	C.	Strippings and pits...........	(5)

			PORTNEUF DISTRICT				
54	Montauban...	R. I, lots 40-41........	In altered limestone in gneiss associated with galena, zinc and pyrrhotite	Nil.	M.	No development............	Minerals of Quebec, 1915, p. 126
			SAGUENAY DISTRICT				
55	"	North shore, gulf of St. Lawrence near Quetachu bay	In quartz and pegmatite dikes in granite and mica schists	2 tons..........	C.	Very little prospecting but known 60 years ago	(5)
			TEMISCAMINGUE DISTRICT				
56	Caire.........	Caron lake...........	In pegmatite dikes in granite	Nil.	M.	No development............	(1) Mem. 39, 1913, p. 120
57	Montbeillard..	Evain lake...........	" "	"	M.	"	(1) Mem. 39, 1913, p. 120
			TERREBONNE DISTRICT				
58	St. Jerome....	St. Jerome...........	In bands of red gneiss in limestone	Nil.	M.F.	Very little prospecting. Fourth mention of molybdenite in Canada	(1) 1853, p. 40
			TERRITORIES				
59	Abitibi.......	Plamondon hill, Turgeon basin	In pegmatite dikes in granite and hornblende schist	Nil.	M.	No development............	(1) Mem. 109, 1919, p. 57
60	Mistassini.....	East coast of James bay. Paint Hills islands	Associated with feldspar dikes in quartz and red feldspar	"	M.	"	(1) 1899, p. 23 R
61	New Quebec..	East coast of Hudson bay; north of Great Whale river	....	....	....	Reported occurrence.........	Min. Res. of Can., 1904 Bull. on Molybdenum and tungsten, p. 10

In addition to the above, some half dozen other occurrences have been noted, about which no information is available.

In the above tabulation the following *tentative* classification has been adopted for grading purposes.

A. Economic conditions favourable, and probably a considerable producer.
B. Probable producer.
C. Has possibilities and worthy of further investigation.
D. Has possibilities on a small scale, suitable for economic hand-cobbing.
E. Prospect not very encouraging.
F. Prospect not worthy of further investigation.
P. Prospect—no definite information.
M. Mineral occurrence only.

Key references—
(1) Geological Survey of Canada.
(2) Mining Operations in Quebec, Ann. Rep.
(3) Mines Branch No. 93, Molybdenum Ores of Canada, 1911, T. L. Walker.
(4) Private information Mines Branch
(5) See description in Report.

CHAPTER V

FERRO-MOLYBDENUM IN CANADA

During the period 1916 to 1918, two Ontario firms, the Tivani Electric Steel Company, Belleville, and the International Molybdenum Company, Orillia, undertook the manufacture of ferro-molybdenum and molybdenum salts.

TIVANI ELECTRIC STEEL COMPANY

In March, 1916, the Tivani Electric Steel Company suspended its production of high-grade steel made from the iron ores of the Orton mine, and began the manufacture of ferro-molybdenum direct from molybdenite concentrates. The concentrates, mixed with lime and coke, were charged into an electric furnace without previous roasting.

J. W. Evans, manager of the Tivani Steel Company, gives an account of the types of furnaces employed, various charges, output, etc.[1]

The original two-phase tilting furnace used at the plant for iron smelting proved unable to withstand the high temperature (over 1,900° C.) necessary for the smelting of molybdenite concentrates and was replaced by six furnaces of the single-phase type. These furnaces are constructed of heavy boiler plate, water-jacketted and specially lined with fire and silica-brick.

The lower electrode is bronze or copper and the upper, either graphite or carbon. The electrodes carry from 3,500 to 4,500 amperes at 50 volts and the larger carbon electrodes last for 50 hours. The charge consisted of the following:—

Concentrates (75 per cent molybdenite, 9 per cent iron)............................	100 lbs.

Lime, 120 lbs.; coke, 10 lbs.; scrap steel, 5 lbs.

The furnace was tapped every four hours and yielded a product containing 70 per cent molybdenum, 0·4 per cent sulphur, and 4 per cent carbon.

The sulphur in the molybdenite was almost entirely taken up in the slag, or converted into sulphur dioxide, resulting in an almost sulphur-free ferro-molybdenum, as shown by the analyses.

Mr. Evans[2] stated that the company treated about 150,000 pounds of molybdenite concentrates running from 40 to 94 per cent MoS_2 with an average of 70 per cent. It takes a 75 per cent concentrate to make 70 per cent ferro, and there is generally enough iron in this grade of concentrate to give the necessary amount of iron; in treating 80 per cent concentrates, however, iron has to be added. Scrap steel turnings make a convenient form in which the iron may be supplied. In this connexion it has been suggested that molybdenite concentrates should not exceed 70 per cent MoS_2, if pyrite and pyrrhotite are the only impurities, as these will furnish the necessary iron for the alloy and, incidentally, will effect a saving in the initial cost of concentration. Mr. Evans states that they have smelted

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[1] Trans. Can. Min. Inst., 1918, p. 154; Annual Meeting, Montreal, March, 1918. J. W. Evans

[2] Private correspondence, Sept. 24, 1921.

concentrates containing over 30 per cent iron sulphides, and that in Canadian ores iron pyrites are always present in quantities varying from 5 to 25 per cent.

For making the salts a concentrate with much lower molybdenite content can be used, as the roasted material is treated with ammonia which does not take up anything but the molybdenum, and copper, if present. Both copper and arsenic, especially the latter, are very detrimental to the manufacture of ferro-molybdenum and molybdenum salts.

No molybdenum salts were made in the Tivani plant, but it is understood that small quantities were made recently in Mr. Evans' laboratories.

There were probably three or four tons of ferro produced during 1916, but the work done during this period was largely experimental.

During 1917 and three months in 1918, 69·1 tons of concentrates, averaging slightly above 70 per cent molybdenite, were treated and 85,193 pounds of ferro-molybdenum, valued at $200,703, was produced. About twelve men were steadily employed. The company closed down in 1918.

THE INTERNATIONAL MOLYBDENUM COMPANY, ORILLIA, ONT.

The International Molybdenum Company was, from 1916 to 1918, the only concern in the world that mined and purchased molybdenum ores, developed its own process of concentration, operated its own concentrator, and at the same time purchased ferro-molybdenum and pure molybdenum salts.

B. C. Lamble, general superintendent of the Orillia plant, describes the types of furnaces used, production, charges,[1] etc.

The molybdenite concentrates were first converted into the oxides by roasting at a low temperature. The oxides were then leached with a strong solution of ammonia water and filtered. The solution was strongly heated until the ammonia was driven off leaving crude molybdic acid or oxide. This acid was reduced in a special electric furnace, with coke and steel scrap turnings, the voltage required being 55 and the amperage between 4,000 and 5,000.

The costs of this process were considered high as was the mechanical loss due to the preliminary treatment of the concentrates. The company then smelted the crude concentrates direct, without preliminary roasting, using lime and coke as the fluxes. It proved to be most satisfactory, over 80 per cent of the molybdenum fed to the furnace being recovered as the metal. The chief losses were (1) dusting, 11 per cent, (2) slagging, 7 per cent. The dusting loss was recovered by bags placed over the furnaces and 90 per cent of the loss in the slag was recovered by table concentration.

The furnace used was a single-phase, or one electrode type.

It was the company's intention to install a two-phase furnace with a roof, from which it was anticipated a better extraction would be obtained at a lower cost.

A second 250 h.p. electric furnace was installed in July, 1917, and also produced ferro from October until the company closed in January, 1918.

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[1] Trans. Can. Min. Inst., 1919, p. 64. Ann. Meeting, Montreal, March, 1919. B. C. Lamble.

The International Molybdenum Company did not start the regular production of ferro-molybdenum until October, 1916, the previous output having been more or less experimental. The company closed down after a run of two weeks in 1918. The average number of men employed was 30.

Altogether the company treated 157 tons of molybdenite concentrates and produced 137,215 pounds of ferro-molybdenum, valued at $326,937. During 1916 the company made 5,254 pounds of molybdic acid and ammonium molybdate, valued at $18,867.

In all about 232 tons of molybdenite concentrates were smelted in Canada by these two companies, producing about 115 tons of ferro-molybdenum, roughly valued at $530,000.

CHAPTER VI

WORLD'S MOLYBDENUM OCCURRENCES AND DEPOSITS

DISTRIBUTION

Probably 90 per cent of the world's molybdenum supply is obtained from molybdenite. But the greater part of the early production in the United States was from wulfenite, from Arizona. The Austrian, Spanish, and Jugo-Slavian outputs have been almost entirely from the latter mineral.

The following tabulation shows at a glance the world's distribution of molybdenite and wulfenite occurrences:—

TABLE XV

World's Distribution of Molybdenum Ores

Continent	Country		Number of provinces, states, etc.	Number of counties, districts, etc.	Number of recorded occurrences
N. America	Canada P.	M.	8	71	350
	United States* P.	M. W.	30	143	290
S. America	Bolivia P.	M.	2	2	2
	Brazil	W.	1	1	1
	Chile P.	M. W.	1	1	3
	Colombia	W.	1	1	2
	Peru P.	M. W.	11	13	15
	West Indies P.	M.	1	1	1
Africa	Cape of Good Hope	M.			2
	Namaqualand	M.			2
	Natal P.	M.			2
	Rhodesia	M.			8
	S.W. Africa	M.			9
	Transvaal P.	M. W.			12
	Zululand	M.			4
Asia	Borneo	M.	1	1	2
	Ceylon	M.	1	1	3
	China P.	M.	1	1	2
	India P.	M.	5	8	12
	Japan P.	M. W.	9	10	10
	Korea P.	M.	1	1	1
	Malay States	M.	1	1	1
	Siam	M.	2	2	2
Australia	Queensland* P.	M.			60
	N.S. Wales* P.	M.		23	53
	S. Australia P.	M.			6
	Tasmania	M.			5
	Victoria P.	M.			26
	New Zealand	M.			9

M. Molybdenite. W. Wulfenite. P. Producing countries.

*A careful survey of records would reveal a considerably greater number of occurrences, but of minor importance.

TABLE XV—*Concluded*

World's Distribution of Molybdenum Ores—Concluded

Continent	Country		Number of provinces, states, etc.	Number of counties, districts, etc.	Number of recorded occurrences
Europe..................	Austria-Hungary......P.	M. W.	5	5	20
	British Isles—				
	England..............	M. W.	....	5	13
	Ireland...............	M. W.	....	3	5
	Scotland.............	M. W.	....	2	6
	France..................	M. W.	....	2	5
	Germany.............P.	M. W.	4	5	15
	Italy.................P.	M. W.	2	4	11
	Norway*.............P.	M.	3	12	36
	Russia...............P.	M. W.	4	8	12
	Spain.................P.	W.	1	2	3
	Sweden..............P.	M.	....	3	8
	Switzerland............	M. W.	....	2	3
	Jugo-Slavia...........P.	W.	....	....	2
Total........... 6	42		....	....	1,034

WORLD'S PRODUCTION OF MOLYBDENUM ORES

Previous to 1900, the output of molybdenum ores recorded was very small. The ores were then produced in Queensland, Scandinavia, and the United States, the first Swedish output being in 1880, when 1,400 pounds of 95 per cent molybdenite concentrates, and 5 tons of 9 per cent molybdenite ore were exported to Germany from the island of Ekholmen.[1]

The first recorded production in the United States was in 1898, when 8 tons of molybdenite concentrates, and 12 tons of wulfenite were produced in Arizona and New Mexico.[2]

Owing to the difference between the various statistical reports, and confusion between the mineral and the metal, the following tables of world's production are necessarily only approximate. Some statistics, such as those of the United States, are based on the metallic contents of crude ore or low-grade concentrates, the actual recovery being unrecorded. The Canadian figures on the other hand show the actual recovery of the pure mineral. Whenever the metallic contents were known, the output, for purposes of comparison, has been converted into terms of pure molybdenite, but in many cases this has been calculated from the prevailing price of the mineral. For details refer to individual descriptions.

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[1] Ind. Aust. and Min. Stand., Aug. 8, 1918, p. 210.
[2] Min. Indust., 1898, Vol. VII, p. 514.

TABLE XVI

World's Recorded Pre-War Production of Molybdenite

	North America				Asia		Australia				Europe	
—	Canada		United States *b*		Japan *b*		Queensland *a*		N.S. Wales *a*		Norway *c*	
	Short tons	Value $	Short tons	Value $	Short tons	Value $	Short tons	Value $	Short tons	Value $	Short tons	Value $
Up to—												
1900	0·1	100	51·0	2,600	......	......	12·3	2,700	......	......	7·0	4,620
1901	......	......	15·0	750	......	......	29·1	7,750	......	......	3·3	1,890
1902	0·4	400	15·0	750	......	......	42·6	25,600	16·8	8,960	21·0	16,200
1903	0·9	1,275	795·0	60,860	......	......	12·0	6,350	32·4	21,690	33·0	21,600
1904	......	......	14·0	2,170	......	......	23·5	13,010	28·5	13,270	31·8	17,550
1905	......	......	6·0	1,050	......	......	70·6	41,340	21·7	12,200	28·5	16,470
1906	......	......	......	......	......	......	118·7	74,300	36·5	23,350	25·0	14,310
1907	......	......	......	......	......	......	74·6	41,080	24·4	17,340	23·0	12,960
1908	......	......	15·0*a*	6,000	85·0*b*	590	99·5	44,960	9·5	4,520	23·5	13,560
1909	......	......	......	......	9·5*b*	59	105·0	45,120	31·4	15,810	18·0	12,150
1910	......	......	......	......	......	......	131·1	58,640	53·5	27,580	......	......
1911	......	......	......	......	......	......	111·4	64,610	23·4	12,610	1·5	740
1912	......	......	......	......	210·0*b*	674	114·5	84,420	63·2	18,030	8·0	3,510
1913	......	......	......	......	3·9*a*	1,280	74·3	92,460	88·6	33,100	1·0	3,240
Totals	1·4	1,775	911·0	74,180	308·4	2,603	1,019·2	602,340	429·9	208,460	224·6	138,800
Estimated MoS_2 contents	1·4	......	105·0	......	4·5	......	860·0	......	300·0	......	224·6	......

*a*Concentrates, MoS_2 contents uncertain. *b*Ore, MoS_2 contents uncertain. *c*Estimated MoS_2.

In addition to the above the following odd shipments totalling about 13 tons of MoS_2 have been recorded—

South Australia	1908–1913	0·34 tons valued at $355.
Sweden	1880–1913	About 5 tons of pure MoS_2.
Natal	1904	64 tons crude ore.
Chile	1913	2 tons concentrates.
Virgin islands	1870	About 5 tons hand-cobbed ore.

TABLE XVII

World's Recorded Production of Molybdenite during and since the War

(In terms of MoS_2)

	1914		1915		1916		1917		1918		1919		1920		War and post war Totals		Total production	
—	Short tons	Value $	Short tons	Value $	Short tons	Value $	Short tons	Value $	Short tons	Value $	Short tons	Value $	Short tons	Value $	Short tons	Value $	Short tons	Value $
N. America—																		
Canada	1·9	2,063	14·6	28,920	78·2	188,316	144·4	320,006	189·2	428,807	41·8	69,203	......	......	470·1	1,037,315	471·5	1,039,090
United States	1·1	1,297	151·5	114,866	156·3	205,000	264·7	495,350	650·1	1,253,700	295·5	341,814	29·1	17,207	1,548·3	2,429,234	1,653·3	2,503,414
S. America—																		
Bolivia[1]	......	......	3·0	5,475	4·0	7,663	......	......	......	......	......	......	......	......	7·0	13,138	7·0	13,138
Chile[1]	1·0	800	0·7	800	0·5	900	5·0	9,836	......	......	......	......	......	......	7·2	12,336	8·5	13,036
Peru	......	......	2·5	7,175	5·2	14,210	5·8	21,545	3·2	7,278	4·0	5,820	2·5	2,160	23·2	58,188	23·2	58,188
Asia—																		
China	......	......	......	......	4·5	1,700	4·0	1,600	1·8	3,689	......	......	......	......	10·3	6,989	10·3	6,989
India	......	......	......	......	0·4	1,017	1·5	3,046	0·3	302	0·4	515	0·1	94	2·7	4,974	2·7	4,974
Japan[1]	0·3	300	5·5	22,967	15·0	31,171	14·5	30,124	7·0	12,746	......	......	......	......	42·3	97,308	46·8	99,911
Korea	......	......	......	......	3·2	12,463	16·0	19,034	10·7	25,884	......	......	......	......	29·9	57,381	29·9	57,381
Australia—																		
N. S. Wales	68·5	55,732	32·0	82,432	48·3	107,395	60·0	153,836	80·0	147,509	53·3	150,530	44·0	42,000	386·1	739,434	686·0	947,894
Queensland[2]	87·2	185,871	108·8	219,307	91·1	167,273	124·5	236,623	123·3	234,472	131·9	259,089	41·4	76,270	708·2	1,378,905	1,568·2	1,981,245
S. Australia	......	......	0·3	574	......	......	0·4	812	0·4	815	0·2	340	......	......	1·3	2,541	1·6	2,896
Victoria[1]	......	......	......	......	......	......	1·0	2,430	0·5	875	9·0	12,300	4·5	5,476	15·0	21,081	15·0	21,081
W. Australia[1]	......	......	......	......	......	......	0·3	770	0·2	472	0·3	486	......	25	0·8	1,753	0·8	1,753
Northern Territory	......	......	......	......	0·1	218	0·1	218	0·1	282	......	29	......	......	0·3	747	0·3	747
Europe—																		
Italy[2]	......	......	......	......	......	......	0·5	450	1·1	845	1·6	1,590	1·4	2,480	4·6	5,365	4·6	5,365
Norway	59·5	119,732	82·6	278,000	95·0	385,000	150·0	533,333	123·0	1,248,804	......	......	......	......	510·1	2,564,869	734·7	2,703,669
Russia[2]	......	......	......	......	2·7	3,000	1·7	4,000	......	......	......	......	......	......	4·4	7,000	4·4	7,000
Sweden	1·0	523	7·0	4,599	0·8	1,309	39·1	199,238	44·9	578,789	......	......	......	......	92·8	784,458	97·8	786,958
Totals	220·5	366,318	408·5	765,115	505·3	1,126,635	833·5	2,032,251	1,235·8	3,945,269	538·0	841,716	123·0	145,712	3,864·6	9,223,016	5,366·5	10,254,729
Wulfenite Ore— (Contents uncertain)																		
Spain	74·8	4,653	29·0	1,888	748·4	92,208	171·2	46,030	112·4	31,146	34·8	3,071	61·2	14,721	1,231·8	193,717	1,231·8	193,717
Jugo-Slavia	26·0	......	41·2	......	25·0	......	16·0	......	......	......	......	......	......	......	108·2	......	591·8	......

[1] Estimated MoS_2 contents. [2] Concentrates, MoS_2 contents uncertain.

Approximate total production up to 1923 equivalent to 4,000 tons of metallic molybdenum, according to Mineral Industry, 1923, p. 454.

NOTE.—Both Germany and Austria produced small quantities of molybdenite and wulfenite. Since 1913 there has been a steady production from Germany totalling 14 tons of molybdenite.

During 1921 and 1922:—New South Wales produced the equivalent of 1·5 tons of MoS_2.
Queensland produced the equivalent of 9·0 tons of MoS_2.
Victoria produced the equivalent of 4·5 tons of MoS_2 and exported 590 tons of ore.
China exported 1,886 tons of ore.

Unless otherwise stated all the above production is in short tons of pure molybdenite.

WORLD'S DEPOSITS

AFRICA

South Africa. Although molybdenite occurs in a number of localities there has been no output for many years. About 65 tons of ore was exported in 1904 from Impendhle, Natal, and a small quantity of ore containing 15 per cent MoS_2 was sent to Europe in 1915 from the Waterberg district of the Transvaal.

Dr. Versfeld's book on the "Base Metal Resources of the Union of South Africa" gives a detailed account of a number of molybdenite deposits and modes of occurrence throughout the Union.

The molybdenite usually occurs in granites, associated with other metallic minerals; but an interesting occurrence is noted in the Hlatimba valley, Natal, where it is found in sandstone, underlying oil shales.[1]

Several occurrences of molybdenite and wulfenite have also been recorded in Nigeria, Southern Rhodesia and South West Africa.[2]

UNITED STATES

GENERAL

Both molybdenite and wulfenite occur widely scattered throughout the United States. These minerals have been found in about 30 different states, the principal of which are: Colorado, Arizona, New Mexico, California, Montana, and Washington. A brief account of the principal deposits in these states will be found in the following pages.

Probably three-fourths of the reported molybdenite occurrences are in acid igneous rocks, such as granites, pegmatites, and syenites. Other important deposits are found in metamorphic rocks, chiefly gneisses, also in mica schists, chlorite, etc. Many occurrences have been noted in sedimentary rocks, such as conglomerates and limestone.[3]

Before the great war, the principal production of molybdenum ore in the United States was in 1903, when 795 tons of wulfenite and molybdenite concentrates, valued at $60,865, were marketed.[4] About 750 tons of this output consisted of wulfenite concentrates obtained by sluicing tailings from a cyanide mill of the old Mammoth gold mines, Arizona. The remainder, consisting of molybdenite concentrates, was probably from the Crown Point mine, Chelan county, Washington. Previous to 1903 almost the whole commercial output of molybdenum ore in the United States consisted of 20 to 30 tons of high-grade molybdenite from the Crown Point mine.[5] With the exception of a few small parcels of ore from the Crown Point and Homestake mines, there was no further molyb-

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[1] South African Jour. Sci., Nov., 1916, p. 153. A. L. DuToit.

[2] (*a*) Union of S. Africa, Dept. of Mines, Mem. 1, 1919, p. 62. W. Versfeld.
(*b*) S. African Mining Jour., June 28, 1918.
(*c*) Ind. Aust. and Min. Standard, Aug. 22, 1918, p. 284.
(*d*) Union of S. Africa, Geol. Surv., Mem. 7, 1918. P. A. Wagner.
(*e*) Bull. Imp. Inst., Vol. XIII, 1915, p. 501.
(*f*) Trans. Geol. Surv., S. Africa, 1907, p. 115. J. P. Johnson.
(*g*) Bull. Imp. Inst. "Molybdenum Ores," 1922, p. 17. R. H. Rastall.
(*h*) Imp. Min. Res. Bureau, "Molybdenum," 1923, p. 22.

[3] U. S. Bull. 111, 1916, p. 8. F. W. Horton.

[4] U. S. Geol. Surv., 1904, p. 308.

[5] U. S. Bull. 111, 1916, p. 32. F. W. Horton.

denum production in the United States until 1914, when a small quantity of wulfenite concentrates was obtained from the Mammoth tailings. From that date to 1919 the production of molybdenum ores showed a very marked increase. Arizona was at first the principal producing state, the product being chiefly in the form of wulfenite; but, later, the discovery of large deposits of molybdenite on Bartlett mountain, Colorado, soon led to the Colorado mines becoming the world's leading producers. The most notable of these properties are the claims held by the Climax Molybdenum Company, who are said to have about six million tons of molybdenite ore blocked out, and who are erecting a 1,000-ton concentrator. During 1919 six companies did some work on deposits in Maine, Colorado, Utah, and New Mexico, but the market was so poor that the Climax and Primos companies in Colorado closed down in April and July, respectively. During 1920 the only production came from the mines of the Molybdenum Corporation of America, near Questa, New Mexico.

Concentrators, both for molybdenite and wulfenite, have been erected throughout the producing states. A short description of the principal mills will be found under the heading Concentration.

IMPORTS OF MOLYBDENUM ORES INTO THE UNITED STATES[1]

No record of imports of molybdenum ores was kept by the Bureau of Foreign and Domestic Commerce before July, 1918; but, in the first half of that year, it was known that 25,000 pounds of 75 per cent MoS_2 was imported from Chosen, Korea, and 19,000 pounds from some undesignated part of Asia.

—	Molybdenum ore	Value
	Pounds	$
1918 (last six months)	140,222	123,924
1919	106,743	77,572
1920	15,639	9,707

PRODUCTION OF MOLYBDENUM ORE WITHIN THE UNITED STATES

The statistics concerning United States molybdenum production have been obtained by estimating the quantity of metal in the crude ore, or low-grade concentrates. The concentrates sold were mostly low grade, so that the values quoted do not in any way represent the true market values of the metal, or of 90 per cent concentrates, but are the actual amount obtained for the crude ore, or low-grade concentrates.

Since 1914 the United States has been the largest producer, though the value of its output appears to be slightly exceeded by that of Norway, owing to the fact that the Norwegian market price during the heavy production years of 1917-1918 was double that of the United States.

The earlier production was largely in the form of wulfenite, the metallic contents of which have been converted into terms of MoS_2 for the sake of comparison.

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[1] U. S. Min. Res., 1920, p. 403. F. L. Hess.

TABLE XVIII

United States Production of Molybdenum Ores[1]

Year	Crude ore mineral	Ore and concentrates	Molybdenum content	Equivalent MoS_2 content	MoS_2 per cent in ore and concs.	Value
	Short tons	Short tons	Short tons	Short tons	Per cent	Per cent
Up to—						
1913	....	911·0	63·0*a*	105·0*a*	12·0*a*	74,180
1914	....	....	0·6	1·1	....	1,297
1915	3,498	....	90·9	151·5	4·3	114,866
1916	....	1,228·0	93·8	156·3	12·7	205,000
1917	....	1,311·0	158·8	264·7	20·2	495,350
1918	....	2,280·0	390·8	650·1	28·5	1,253,700
1919	83,700	971·0*b*	177·3	295·5	30·4	341,814
1920	1,607	42·4*b*	17·5	29·1	68·6	17,207
			992·7	1,653·3		2,503,414

a Estimated, no definite records.
b Concentrates only.

There remained in the United States at the end of 1922, molybdenum for about two years' requirements. Most of the molybdenum on hand was in stock at steel mills producing molybdenum steels.[2]

There are approximately 300 known occurrences of molybdenite or wulfenite in the United States. Detailed descriptions and tabulations of many of these will be found in F. W. Horton's report[3] and in the Industrial Australian and Mining Standard.[4]

Alaska

Molybdenite has been found in about a dozen localities in Alaska; but, so far, the only one that gives promise of being of commercial importance, is situated on Shakan island.

In most of these occurrences the mineral is found in quartz fissure veins, usually associated with other sulphides.

Ketchikan District: The Shakan Molybdenite Mine. This mine, which is about 600 feet above sea-level, is situated about one mile south of Shakan, near the northwest end of Prince of Wales island. It is 180 miles south from Treadwell, Douglas island, and about the same distance north of Prince Rupert.

The deposit had been known for several years. When first discovered it was mistaken for galena, but as no lead was recovered in assays, the prospect was abandoned. In 1917 it was re-located by W. H. Butt, and bonded to the Alaska Treadwell Gold Mining Company.

The country rock consists of tuffaceous sediments intruded by diorite. The lode is a fissure vein that cuts this diorite. The vein consists essentially of feldspar and quartz, with some secondary minerals and outcrops for over 500 feet, with an average width of 5 feet. It has a strong, clean-breaking, hanging-wall, and an indistinct foot-wall, and varies consider-

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[1] Statistics up to 1914 from Mineral Industry, 1898 to 1914.
Remainder from Mineral Resources of the U.S.A., mainly 1919, p. 714. F. L. Hess.

[2] Mineral Industry "Molybdenum," 1922. W. Norman Bratton.

[3] U. S. Bull. 111, 1916. F. W. Horton.

[4] Ind. Aust. and Min. Stan., July, 1918, pp. 30-67.

ably in strike and dip, as is shown by the crookedness of the main tunnel. Considerable faulting is apparent, particularly along the hanging-wall, and from these fault zones the best ore has been extracted. The molybdenite is associated with pyrite, pyrrhotite, and chalcopyrite, and is concentrated in the fault zones, and in places scattered throughout the quartz and pegmatite. The pyrrhotite generally occurs in pockets or as kidney-shaped segregations.

Between the years 1918 and 1921 the company sunk numerous open-pits, and drove a tunnel along the strike for a distance of 400 feet, from which a 50-foot raise was made in one of the fault zone ore-bodies. At 250 and 300 feet from the portal cross-faults were met, and offsets made at both places.

The average assays of the ore ran about 1·5 per cent molybdenite; but, beyond the 300-foot fault in the tunnel, the vein is very low grade and it is probable that this fault has affected the mineralization. The probable ore reserves are estimated to be about 100,000 tons. The ore mined, consisting of approximately 18,000 tons, averaging 1·4 per cent MoS_2, is still on the property.

A tramway has been constructed from the portal of the tunnel across a small dock at tidewater. All drilling was done by hand, until September, 1919, when a compressor plant was installed. Ferro-molybdenum can be produced by means of a 2-ton Heroult electric furnace at Treadwell.[1]

TABLE XIX

Molybdenite Occurrences in Alaska

Name of locality	Occurrence and geology	Reference	Remarks
Central Alaska			
Dry delta, Tanana valley.	Network of veins in granite.	U.S. Bull. 712, 1918, p. 24.	Developed in 1918; no ore shipped.
Healy river, Rainy mtn.	Quartz fissure veins in granite.	U.S. Bull. 692, 1917, p. 329	Transportation difficult.
Southeastern Alaska			
Ketchikan dist., Shakan mine.	Quartz and pegmatite veins in diorite and tuffaceous sediments.	Eng. & Min. Jour., Jan. 17, 1920, also U.S. Bull. 714, 1919, p. 118.	Considerable development, 18,000 tons 1·4 per cent ore extracted. Large ore reserves; electric furnace; tramway.
Skagway..............	Mineral zone in granite..	U.S. Bull. 692, 1917, p. 30	Some development.

Molybdenite also occurs on Lemesurier island; Kenai peninsula; Willow creek; Chetina river; Fairbanks; and on the Seward peninsula. Nearly all these, however, are mineral occurrences only.

References—U.S. Geol. Surv., Bulls. Nos. 587, 662, 692.

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[1] Excerpts from Report by F. W. Bradley, Oct., 1918, Eng. and Min. Jour., Jan. 17, 1920. U. S. Geol. Surv., Bull. No. 714; Min. Res., Alaska, 1919, p. 118.

Arizona

Until quite recently most of the molybdenum output of the United States came from Arizona. Most of the output was in the form of wulfenite, which almost always occurs as a secondary mineral in veins in association with other lead minerals and often with vanadinite. Most of the deposits are, however, associated with copper minerals. Gold and silver are also present in many cases.

In 1915 the principal operations were at the Tucson and Mammoth mines, which produced wulfenite.

Extensive mining and development work was carried on in the Leviathan mines, and various other properties in the Hualpai mountains, near Kingman in Mohave county. F. W. Horton,[1] who described these deposits in some detail, considered them to be the most notable molybdenite deposits then known in the United States. In Pima county, there are a large number of wulfenite and molybdenite deposits. Among the most important is the old Yuma mine, northwest of Tucson, from which high-grade wulfenite was extracted in 1915, the mineral having been discarded when the mine was worked for gold. It is of interest to note that when the wulfenite is black it carries gold values. F. W. Horton[2] gives details of concentration tests on these ores. Other deposits in Pima county are those owned by L. Ezekeels; R. O. Boykin at Kelvin; at Marble Creek; at the Ridlay Mine; at Madero canyon; Providencia canyon; and with the copper ores at Vail.

The Mammoth mines at Schultz, in Pinal county, are famous old gold mines, in which wulfenite occurs abundantly. Some beautiful museum specimens of this mineral have been found in these mines. The St. Anthony Mining and Development Company, and Messrs. Hereford and Boykin treated some of these old tailings for wulfenite in 1918. During 1903 about 750 tons of wulfenite concentrates, or practically the whole United States output was obtained from these tailings.

Many concentrators have been erected in Arizona, amongst which are the following:[3]

The Arizona Molybdenum Company installed a dry process for concentrating their wulfenite ores in Blue Tank mining district; the Duquesne Mining and Reduction Company mined and concentrated molybdenite found in their copper ores at Naples; the Mammoth Development Company's mill at San Pedro river was enlarged in 1917 by adding flotation machinery; the Arizona Rare Metals treated the old Mammoth tailings; the Arizona Molybdenite Consolidated, which is an amalgamation of several companies, after a great deal of experimental work, erected a mill on their property in the Hualpai mountains; the Leviathan Mines Company, in Copper canyon, produced a mixed concentrate consisting of 30 per cent molybdenite and 25 per cent copper in their mechanically aerated oil flotation plant, but had trouble because of scarcity of water. The copper was afterwards separated by the Smith-Emory process.[4] The American Molybdenum Company also erected a mill at their mine in Copper canyon; the Standard Minerals Company, at Kingman, treated their ores in a K & K oil flotation plant.

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[1] U. S. Bull. No. 111, 1916, p. 52. F. W. Horton.

[2] Op. cit., pp. 111-115.

[3] U. S. Geol. Surv., 1917, pp. 907-911. F. L. Hess.

[4] For description of Leviathan mine and mill see "Mohave County Miner," Ariz., July, 1919, p. B.

The following shows the recorded output from this state from 1916 to 1918:—

Year	Metallic molybdenum	Value
	pounds	$
1916	203,580	203,000
1917	344,950	487,985
1918	154,923	219,010

References:—

U. S. Geol. Surv., Min. Res., 1915, p. 807; also 1916, p. 777; also 1917, p. 907; also 1918, p. 798. F. L. Hess.
Min. Indust., 1917, p. 457; also 1918, p. 493, A. W. G. Wilson; also 1920, p. 463, W. N. Bratton.
U. S. Bull. No. 430, Some occurrences of Molybdenum in Santa Rita and Patagonia Mts., Ariz., 1909, pp. 152-162. By F. C. Schrader and J. M. Hill.
University of Arizona, Bull. No. 5. Molybdenum, 1915-16. P. E. Joseph.
U. S. Geol. Surv., Bull. No. 111, 1916, pp. 45-58. F. W. Horton.
Min. and Scientific Press, May 19, 1917, p. 699. L. Webster Wickes.
Econ. Geology, Vol. XII, 1917, pp. 237-69. F. C. Schrader.
Imp. Inst. Bur. "Molybdenum Ores," R. H. Rastall, 1922, p. 67.
Imp. Min. Res. Bureau, Molybdenum, 1923, p. 64.
A complete tabulation of the Arizona deposits will be found by referring to Bull. No. 111. F. W. Horton.

California

In California, molybdenite is widely distributed as flakes in quartz and crystalline rocks, also in contact metamorphic deposits.

There was no production in California up to 1915. In that year a little ore was mined in Plumas county, but was not marketed.

In 1916, 8 tons of picked ore and concentrates were produced from Inyo and Plumas; and in 1917, about 228 tons of ore from Shasta county. This contained some 58 per cent picked flake, but most of it was 1·5 per cent ore. In 1918 a flotation plant was erected at Boulder creek, Shasta county, and 2·6 per cent MoS_2 ore was treated, from which about 15 tons of concentrates were produced.

The principal prospecting and development has been in Shasta, San Diego, and Inyo counties. One of the principal California deposits, which is described in detail by H. E. Davis,[1] is 30 miles east of San Diego, in San Diego county.[2]

Colorado

Colorado has produced by far the largest quantity of molybdenite, and has the greatest number of known occurrences of the mineral in the United States. The mineral has been noted in almost every mountain county at altitudes between 9,000 and 12,000 feet, but it has been found in commercial quantities only in igneous and metamorphic rocks, or in contact deposits on the borders of igneous rocks. P. G. Worcester[3] points out that it is useless to look for this mineral in Colorado except in the areas underlain by the above type of rocks. Broadly this area is confined to a north and south belt occupying a central third part of the state, and extending

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[1] Salt Lake Mining Review, June 15, 1918.

[2] Mineral Industries, 1916, 1917, 1918. A. W. G. Wilson.
U. S. Mineral Resources, 1916, 1918. F. L. Hess.
U. S. Bull. No. 111, p. 59. F. W. Horton. (Tabulated occurrences.)
California State Mining Bureau, No. 4, March, 1918, p. 21.
California State Mining Bureau, Bull. No. 87, January, 1920, p. 63.
U. S. Geol. Survey, Bull. No. 640 D, Molybdenite and Nickel Ore in San Diego county, Cal., 1916. F. C. Calkins.

[3] Colorado Geol. Surv., Bull. No. 14, Molybdenum Deposits of Colorado, 1919. P. G. Worcester.

from Wyoming on the north to New Mexico on the south. The richest portion is in Summit county, about the centre of Colorado. Worcester describes in detail over 80 different occurrences and deposits that occur in 25 different counties in the state. In summarizing the Colorado deposits this author states that:—

> Granite intrusions and pegmatite dikes are particularly likely to contain molybdenite, and the borders of all such masses should be prospected. Other intrusions of acidic igneous rocks, such as rhyolites, trachytes, acid porphyries, syenites, etc., may also contain deposits of molybdenite. Basalts and other basic rocks are not likely to contain molybdenite, except as there may be deposits on the contacts of these rocks and younger acidic intrusives. Sandstones and other sedimentary rocks are unlikely to contain molybdenite unless they are cut by acidic igneous rocks.
>
> There seems to be a rather widespread, erroneous impression among prospectors that molybdenite occurs only at high altitudes, and that the ore does not extend to any considerable depth. There are no known grounds for such beliefs. It is true that many, although by no means all, molybdenite deposits in Colorado are located at high altitudes, but this is undoubtedly due to the fact that prospecting for molybdenite is a new industry, and it is much easier to find outcrops above timber line than below. There are no very deep molybdenite mines yet, but, again, the industry is young. In the Winfield district a large quartz vein, which contained considerable molybdenite, was cut in the Banker tunnel at a depth below the surface of more than 1,000 feet. Pegmatite dikes are known to extend to a great depth, and there are good reasons to believe that molybdenite "goes down." There are, of course, some deposits where the geological conditions indicate shallow depths of the ore, but usually they can be readily recognized by the geologist.
>
> The regions of acidic igneous and metamorphic rocks in Colorado should be thoroughly prospected, and particular attention should be given to old dumps and prospect holes, for, until recently, molybdenite has not been a well-known mineral, and doubtless it has escaped the attention of many prospectors and mine owners.

The Climax Molybdenum Company. The largest known molybdenite deposit in the world is located on the southwest slope of Bartlett mountain, near Fremont pass (Climax station), about 13 miles northeast of Leadville.

The country rock is mainly granite gneiss, which has been intruded by granitic rock in which the molybdenite deposits occur. The gangue is largely quartz, with a little feldspar. Throughout the mineralized zone the rock is traversed by an intricate network of molybdenite-bearing quartz stringers that are undoubtedly of magmatic origin.[1] The ore-body is apparently terminated on the northeast by a normal fault dipping 60 degrees northeast; but whether this is the limit of the ore-body has not yet been proved.

The occurrence differs from the general type, in that the molybdenite is extremely fine-grained, and the mineral values are remarkably uniform throughout the ore-body. Mineralization, which is invariably confined to the fractures, in many cases shows the presence of the yellow molybdite, even at depths of 500 feet below the surface. No other minerals occur, with the exception of some pyrite. Several million tons of ore estimated to average from 0·5 to 1 per cent MoS_2 are said to have been blocked out.

The deposit is mined by a series of parallel stopes each 800 feet long and 25 feet wide with pillars between of the same width. At present the ore is brought from the upper tunnel, delivered to bins, and carried 500 feet down the mountain by a two-bucket tramway to the crusher plant. It is planned later, to bring all the ore through the lower tunnel, which is at the same elevation as the crusher plant. The ore then goes to the crusher

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[1] Eng. and Min. Jour., May 18, 1918, p. 905. H. L. Brown and M. W. Hayward.

bins and thence over the main tramway to the mill, which has recently been enlarged to handle 1,000 tons of ore per day. (See description under Concentration.)

The company has very fine equipment, including steam-heated mine and office buildings. Electrical power is used throughout. Several reports have been written giving full details of the Climax deposit.[1]

New Mexico

Since the closing down of the molybdenite mines on Bartlett mountain in Colorado, New Mexico has been almost the only state that has produced molybdenum ores. Both molybdenite and wulfenite are found. Molybdenite occurs in scattered areas, associated mainly with copper ores, but also with silver-lead ores and in metamorphosed sedimentary and igneous rocks. Wulfenite deposits are almost entirely confined to Dona Ana, Sierra, and Grant counties, in the southwestern corner of the state.

A number of claims were staked for molybdenite in 1917 in the vicinity of Nacozari, Sonora, where the mineral occurs disseminated in granite, carrying about 2·0 per cent molybdenite.[2] Mr. George Fast, owner of the San Julian and Tres Piedras molybdenum mines in the Sahuaripa district, Santa Ana, concentrated a considerable amount of ore in his flotation plant.[3] In the same district a large tonnage of high-grade molybdenite and scheelite was shipped during the war by Mr. J. S. Douglas and associates, the ore being packed overland for 150 miles on mules.

In San Miguel county the Romero Mining Company did considerable development, and shipped a few hundred pounds of rich molybdenite concentrates from their small experimental mill. The mineral is associated with chalcopyrite, scheelite, bismuth minerals, and fluorite, and occurs in a fine-grained pink feldspathic granite.[4]

A quantity of wulfenite was shipped in 1918 from the Stephenson-Bennett mine, at Organ, Dona Ana county.

The American Smelting and Refining Company erected a flotation plant and treated a considerable quantity of molybdenite ore from the Continental Mining Company's Pannco mine, at Monclora, Coahuila, Mexico. The Lower California Metals Company also erected a 100-ton mill at Nogales, Arizona, and treated molybdenite ores imported from Sonora.[5]

The R and S mine, near Questa, Taos county, which was taken over in 1920 by the Molybdenum Corporation of America, has been a steady producer of molybdenite since 1918. A 50-ton concentrator, employing a Ruth flotation process, was erected in 1919. During 1920, this company, which was the only producer of molybdenum ore in the United States, treated 1,607 tons of ore, making 84,770 pounds of 68·62 per cent molybdenite concentrates.[6]

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[1] Eng. and Min. Jour., May 18, 1918, p. 905. "Molybdenum Mining at Climax, Colorado." H. L. Brown and M. W. Hayward.

Bull. No. 14, Colorado Geol. Survey. "Molybdenum Deposits of Colorado," 1919, p. 87. P. G. Worcester.

Trans. Am. Inst. of Mining Engineers, Sept., 1918. "Molybdenite operations at Climax, Colorado." D. F. Haley.

[2] Min. and Sci. Press, Dec. 22, 1917, p. 908.

[3] Min. and Sci. Press, Dec. 17, 1921, p. 869.

[4] U. S. Bull. 111, 1916, p. 78. F. W. Horton.

[5] U. S. Min. Res., 1917, p. 799. F. L. Hess.

[6] Econ. Geology, Nov., 1920, p. 567, E. S. Larsen and C. S. Ross. Also Eng. and Min. Jour., Dec. 13 and 20, 1919, p. 922.

In the Gold and Copper Deep Tunnel Mining Company, on Baldy mountain, near Elizabethtown, Colfax county, there is an interesting occurrence of molybdenite at depth. Several veins of molybdenite, 3 inches to 2 feet wide, and assaying 5 per cent MoS_2, were encountered in the tunnels at a depth of 1,100 feet and 5,150 feet from the portal. The molybdenite has apparently not been developed on account of the dull market and lack of suitable treatment plant.[1]

SOUTH AMERICA

Bolivia

Exports of molybdenite from Bolivia in 1915 totalled 6·5 metric tons, valued at $5,475,[2] of which Great Britain took about 5·5 tons and the United States the remaining ton. In 1916, 5·7 metric tons, valued at $7,663, was exported.

The mineral is found in the Illampu range in the province of Larecajia, department of La Plaz.[3] Deposits are also said to occur in Tasna, Chicahs Paria.[4]

Chile

Molybdenite was mined in 1917 near Cupane, in the mountains, 60 miles from the port of Arica, but transportation is extremely difficult. Some small shipments were made from the province of Tacna. In all about 30 tons of the mineral has been shipped from the Chilean mines.

References:—

Queensland Mining Jour., July 1, 1917.
Mineral Deposits of S. America, 1919, B. L. Miller and J. T. Singewald.
Mineral Industry, 1917, p. 461.
Ind. Aust. and Min. Standard, Aug. 22, 1918, p. 284.

Colombia

Wulfenite occurs at Antiaquia, in the gold sands of Riochico. The mineral also occurs at Paramorico, near Pamplona, and contains 10 per cent MoO_3.

Peru

Molybdenite has been known for many years in Peru. It was discovered as far back as 1853, by A. Raimondi, in limestone, at Atamina, in the province of Huari. It also occurs in seven or eight other provinces, but they are mostly in distant and roadless regions. Almost the whole output of 20 tons was obtained from the Ricran district in the province of Jauja.

References:—

Ind. Aust. and Min. Standard, Aug. 8, 1918.
Mining Jour., Dec. 30, 1916.
Mineral Industry, 1916, 1919.
Imp. Min. Res. Bureau, 1923, p. 75.

West Indies

Molybdenite occurs in the island of Virgin Gorda. In 1867 the deposit was worked as a copper mine, and the molybdenite ore was thrown on the waste dump, but subsequently 5 or 6 tons was extracted by hand-sorting.

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[1] Eng. and Min. Jour., July 23, 1921, p. 125; also private correspondence. W. P. McIntyre, Supt.
[2] U. S. Min. Res. 1918, p. 800, "Molybdenum." Frank L. Hess,
[3] Mineral Industry, 1918, p. 514. A. W. G. Wilson.
[4] Chem. and Met. Eng., April 12, 1922, p. 700. Minerals of Latin America. O. Wilson.

A quantity of molybdenite ore was used as filling in the mine. The mine was closed in 1867 owing to the low price of copper, but about fifteen years ago it was leased by a Mr. Hollings of the Leeward islands.

S. J. Johnstone[1] refers to an occurrence in the West Indies as follows:—"A sample from the Virgin islands, stated to be from an old tailings heap, was examined in the Scientific and Technical Department of the Imperial Institute and found to contain 81·5 per cent MoS_2." This sample probably came from the Virgin Gorda mine, which appears worthy of further investigation.

ASIA

China

Small lots of molybdenite have been exported from various districts in China to England, France, and the United States. Considerable quantities of the mineral can be mined, especially in southern China, Canton district, the majority of the shipments having been taken from this locality, mainly from surface pockets.[2]

India

Although molybdenite has been recorded as occurring in twelve different localities[3] only about two tons have been shipped, mainly as a by-product from the Tavoy wolfram mines, Burma.[4]

An occurrence has been noted in pegmatite at a depth of 2,500 feet in the Kolar gold fields of Mysore.

Japan

Although there has been a steady production of molybdenite in Japan since 1908, very little information regarding its occurrences is available. The mineral has been mined in a number of provinces, and during the war period the production assumed considerable proportions.

The following is a list of some of the molybdenite deposits that were known about 20 years ago.[5]

TABLE XX

Molybdenite Occurrences in Japan

Name of locality	Province	General character of molybdenite occurrence[6]
Kawachi	Echigo	As large hexagonal crystals in white quartz.
Komatake and Isuruze.	Kai	As crystals in quartz veins traversing granite.
Sannotake	Buzen	As minute flakes in metamorphosed hornblende.
Shirakawa	Hida	As crystals in quartz.
Tamatsukuri	Izumo	As plates in quartz.

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[1] Jour. Soc. of Chem. Ind., Dec. 16, 1918, p. 480.

[2] Imp. Min. Res. Bureau, 1923, p. 76.
Spec. Rept. Geol. Surv. China, No. 1, 1921, p. 33. V. K. Ting and W. H. Wong.

[3] Geol. Surv., India, Vol. XLVI, 1915, p. 284; Vol. L, Pt. II, 1919, p. 101, J. C. Brown; Vol. LII, 1921, p. 305, G. H. Tipper.
Min. Industry, 1918, p. 497. A. W. G. Wilson.
Jour. Soc. of Chem. Ind., Dec. 16, 1918, p. 450.

[4] The Ore Minerals of Tavoy, Min. Mag., Feb., 1919, p. 85. J. M. Campbell.

[5] Ind. Australian and Min. Standard, Aug., 1918, p. 210.

[6] Minerals of Japan, Tsunashoro Wada and Tagudzi Ogawa, Tokyo, 1904.

More recent discoveries of molybdenite are recorded from the Gifu prefecture, Onari-gun; Toyania prefecture, Nogi-gun and Ohara-gun; and Hyogo prefecture, Shishikuri-gun.[1]

Other Asiatic Countries

An appreciable quantity of molybdenite has been exported from the Chosen district in Korea, but information as to the nature of the deposit is lacking.

The mineral has also been reported from the Malay States,[2] Siam,[3] Borneo,[4] and Ceylon.[5]

AUSTRALIA

Of the six molybdenite-producing states in Australia, by far the largest output has come from Queensland and New South Wales. The first definite records of production are from Queensland in 1900, since which year it has been a regular annual shipper, over 1,700 short tons of concentrates, valued at almost $2,000,000, having been produced. New South Wales first made shipments in 1902, and since that date has recorded an output of almost 800 tons of concentrates, valued at over $900,000.

The following table shows the recorded production and value to the end of 1920. Details of the individual annual statistics will be found by referring to the world's tabulated production.

TABLE XXI

Australian Molybdenite Production

State	Year when first produced	Total ore or concentrates	Approximate value
		short tons	$
New South Wales[a]	1885	772·0	947,894
Queensland[a]	1900	1,727·4	1,981,245
South Australia[b]	1908	1·5	2,896
Victoria[c]	1917	199·8	21,081
West Australia[a]	1917	29·4	1,753
Northern territory[a]	1916	0·7	747
Commonwealth totals	....	2,730·8	2,955,616

*a*Concentrates.
*b*Pure molybdenite.
*c*Ore.

During the war the price of molybdenite in Australia was controlled by arrangement between the Imperial and the Commonwealth governments, under which the former contracted to pay £5 per unit for 85 per cent molybdenite concentrates, and this arrangement remained in force until March 31, 1920.

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[1] (*a*) Mineral Industry, 1917, p. 466. A. W. G. Wilson.
(*b*) Modern Applied Minerals, Japan, 1915. Hiki and Shibata.
(*c*) Mineral Industry, 1919, p. 473. A. W. G. Wilson.

[2] Imperial Institute circular, 1915.

[3] Mineral Industry, 1917, p. 467. A. W. G. Wilson.

[4] Ind. Aust. and Min. Standard, Aug. 8, 1918, p. 120.

[5] (*a*) Imp. Inst., Vol. VI, 1908, p. 188.
(*b*) Jour. Soc. of Chem. Ind., Dec. 16, 1918, p. 450.

New South Wales

The earliest record of the output of molybdenite from New South Wales is for the year 1885, when the Whipstick mines produced 2 tons.

All the molybdenite deposits of New South Wales are associated intimately with granites of varying ages. Certain types of these appear to contain most of the important pipe deposits, but others contain small veins of quartz, or pegmatite, associated with minerals such as tin; others are associated with true, white quartz veins, and some others have small flakes of molybdenite scattered irregularly throughout their mass.[1]

The pipes, which are cylindrical, and in some places tortuous deposits, are characteristic of the Australian molybdenite-bearing deposits, and have yielded the largest tonnage of ore. There are several types of pipes: (*a*) quartz pipes, the finest examples of which occur at Kingsgate, in New England; other important ones being at Whipstick, near Pambula, and at Boro creek, near Deepwater; (*b*) pegmatite pipes, as at Wilson's Downfall, Bolivia, Deepwater, etc.; (*c*) granite pipes, as at Whipstick, and also in the same localities as the quartz and pegmatite pipes; (*d*) mica-garnet and garnet pipes, as at Whipstick.

Besides these pipe deposits, molybdenite occurs in pegmatite and aplitic segregations in eastern New South Wales. Bismuth is very frequently associated with the molybdenite, especially in the coarse sandy type of deposits, wolframite being another commonly associated mineral.

E. C. Andrews[2] gives a detailed description of the geology of all the known New South Wales deposits.

In a later report, written in May, 1917, Mr. Andrews says that although the present output of molybdenite in New South Wales is derived from the pipe deposits, the true reefs, at Bega, or the great seams, at Yetholme, may be large producers in the near future.

The great majority of the molybdenite deposits occur along the great dividing range of mountains that run approximately parallel to, and about 75 miles from the east coast of New South Wales, the richest and largest deposits being in the Kingsgate mining area about 20 miles east of Glen Innes. In these mines, at Glen Innes, spectacular finds of molybdenite ore in lumps of 500 and 600 pounds have been recorded.

Besides the Kingsgate mines, at which a new concentrator was installed in 1919, the following are among the most important molybdenite-producing properties in New South Wales: Mount Booroolong mines, at Guyra, where a 30-ton concentrator was erected in 1919;[3] the Mount Tennyson deposits at Yetholme, on the western slopes of the Blue mountains,[4] operated by the Mount Tennyson Molybdenite Mining Company, and the Mammoth Molybdenite Mining Company, both of which also erected concentrators in 1919.

From the Whipstick mines near Pambula, Auckland county, there has been a considerable production of molybdenite, though for a time this mineral was discarded, the chief product of the mines being bismuth. The concentrator is equipped with the Minerals Separation flotation machines.

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[1] N. S. W. Min. Res. No. 24, "The Molybdenum Industry in New South Wales," 1916. E. C. Andrews.

[2] Loc. cit.

[3] Ann. Rept. Dept. Mines, N.S.W., 1920, p. 109. M. Morrison.

[4] Ann. Rept. Dept. Mines, N.S.W., 1915 and 1917, pp. 176 and 162. J. E. Carne and E. C. Andrews.

The New South Wales molybdenite production up to the end of 1919 is approximately 900 short tons of concentrates, the exact grade of which is not known, but probably averages about 80 per cent MoS_2, the value of which amounted to about one million dollars.

The production figures of some of the principal producers, taken from the Annual Report of the Department of Mines for 1919, are as follows:—[1]

TABLE XXII

New South Wales Principal Molybdenite Producers in 1919

—	Long tons of ore	Tons of concentrates	Value
			£
Allies Consolidated Molybdenite Syndicate	200	18·7	9,440
Kingsgate Molybdenite, N.L.	2,506	....	2,833
Mammoth Molybdenite Co., Ltd.	4,424	9·0	3,150
Mount Booroolong Molybdenite Mines, N. L.	500	3·0	1,200

The following table shows the deposits from which the main New South Wales output has been obtained, or from which future supplies may be expected. The majority of these are equipped with concentrators.

TABLE XXIII

Principal Molybdenite Deposits in New South Wales

Name of locality	General character of MoS_2 occurrence	Country rock and gangue	Reference to literature where cited	Remarks
Bathurst, Roxborough county.	Flakes in quartz	Granite and quartz.	N.S.W. No. 24, 1916, p. 60. E. C. Andrews.	Mineral specimen only. Large deposit said to have been recently discovered.
Bega, Auckland county.	Fine flakes in true quartz vein.	Granite and quartz.	I. A. & M. S. May 2, 1918, p. 428.	Promising and probable producer.
Booroolong, Hardinge county.	Scattered through pegmatite and aplitic granites.	Coarse granite and quartz.	I. A. & M. S. May 2, 1918, p. 429. N.S.W. Ann. Rep., 1920, p. 109.	Large low-grade deposit.
Booroo, Clive county.	In granite pegmatite pipes filled with quartz.	Sandy granite and kaolin.	I. A. & M. S. May 2, 1918, p. 429.	Very promising specimens obtained: bismuth present.
Deepwater, Clive county.	Flakes in granite pipes and veins—large crystals and rosettes.	Coarse granite and pegmatite and quartz.	I. A. & M. S. May 2, 1918, p. 429. N.S.W. Ann. Rep., 1918, p. 152.	Field prolific and ore produced assoc. with wolframite and bismuth.
Glen Eden, Gough county.	Flakes in quartz veins and masses.	Granite and quartz and sedimentary rocks.	I. A. & M. S. May 2, 1918, p. 429.	Mining restricted to open-cut on small veins assoc. with wolframite and bismuth.
Glen Elgin, Clive county.	In quartz veins and scattered throughout granite.	Granite and quartz.	I. A. & M. S. May 2, 1918, p. 429.	Much prospected, no mining assoc. with wolframite and bismuth.

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[1] Mineral Industry, 1920, p. 465. W. Norman Bratton.

TABLE XXIII—Concluded

Principal Molybdenite Deposits in New South Wales—Concluded

Name of locality	General character of MoS_2 occurrence	Country rock and gangue	Reference to literature where cited	Remarks
Guy Fawkes..... Clarke county.	Flakes in quartz veins, also pipe-like masses of quartz.	Sandy granite and quartz.	I. A. & M. S., 1918, p. 429.	Encouraging possibilities.
Kingsgate........ Gough county.	In granite pipes containing quartz.	Granite and clay-stone, quartz gangue.	N.S.W. No. 24, 1916, p. 92. E. C. Andrews.	Mining and production on a very extensive scale.
Oban............ Clarke county.	Flakes in small quartz veins.	Hornblendic granite and quartz.	I. A. & M. S. May 9, 1918, p. 462.	Mining on large scale, not encouraging.
Rocky River..... (Wungelbang) Clive county.	Scales in quartz and pegmatite pipes.	Coarse granite and quartz porphyry.	I. A. & M. S. May 9, 1918, p. 463.	Considerable quantities of MoS_2 produced and future favourable.
Whipstick........ Auckland county.	Flakes in quartz and in garnetiferous pipes	Granite and altered sediments quartz and feldspar.	N.S.W. No. 24, 1916, p. 158. E. C. Andrews.	Mines are regular producers and future encouraging.
Wilson's Downfall Buller county.	Scales in quartz veins and pegmatite pipes	Hornblendic granite, quartz and granite.	I. A. & M. S. May 9, 1918, p. 463.	Several properties, but possibilities not very encouraging.
Yarras........... Mocquarie county.	Bunches in quartz matrix.	Siliceous granite and quartz.	N.S.W. No. 24, 1916, p. 170. E. C. Andrews.	Prospecting stage.
Yetholme........ (Mt. Tennyson)	Finely disseminated in a garnet rock, also in pegmatite and aplite.	Granite and altered sediments. Quartz feldspar and garnet.	I. A. & M. S. May 16, 1918, p. 495. N.S.W.Ann.Rept., 1915,p.176; 1917, p. 162.	Considerable ore extracted from large low-grade deposits

New Zealand

Although tungsten ore in the form of scheelite is widely distributed throughout many districts in New Zealand, molybdenite appears to be only of sporadic occurrence and has not been found in commercial quantities. The known occurrences of the mineral are in the Waihi Extended mine, where thin irregular veins and small patches of molybdenite occur in a quartz vein, about one foot in width, cut by the shaft at the 1,318-foot level. The mineral also occurs at Tararu creek, Thames; in the Champion mine, Neavesville; at Richmond Hill, Parapara; at Mount Radiant, Upper Karamea in the Otago district, where it occurs in quartz veins traversing granite, and which is said to be one of the most promising districts;[1] at Dusky sound, in quartz; in quartz veins at Sylvia creek; at Bavo island, near Stewart island; at Greymouth near Fourteen-mile creek, and at the Paparoa ranges.

In October, 1916, molybdenite was found at Takata and the samples assayed contained 50 per cent molybdenum oxide. It is very probable that all the sulphide ore of the Waihi mines contains a little molybdenite.[2]

There has been no commercial production of molybdenite reported.

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[1] Jour. Soc. of Chem. Ind., Dec. 16, 1918, p. 448. S. J. Johnstone.

[2] Report on Molybdenite and Manganese, 11th Ann. Rep., New Zealand, 1917, p. 17. By P. G. Morgan.

Northern Territory

In the northern Territory molybdenite is found at Yenberrie associated with wolfram, where it is stated that the ore increases in richness as the workings become deeper.

References:—

1. Northern Territory of Australia, Bull. 15A, Jan., 1916, G. J. Gray and R. J. Winters.
2. Northern Territory of Australia, Bull. 21, Dec., 1916, T. G. Oliver.
3. Australian Official Year Book, No. 14, 1921, p. 362.

Queensland

Queensland has been producing molybdenite steadily for the last twenty years, and ranks among the leading producers of the world.

The principal molybdenite deposits are in the Chillagoe mining field, the most important occurrences being at Wolfram, Bamford, Khartoum near Almaden, and Sandy Tate river. Other noted deposits occur at Kidston, in the Etheridge gold field; Ollua creek in the Star mineral field near Townsville; and at Stanthorpe near the New South Wales border.[1]

The rocks associated with molybdenite deposits are as a rule rich in quartz and poor in mica, and include various types of granite, aplite, pegmatite, quartz porphyry, and felsite. The deposits are in many cases in an igneous rock close to sedimentary rocks. The most common type is the irregular quartz masses in granites and gneisses, other deposits being in quartz lodes more or less defined, also in long, inclined, and ill-defined bodies of quartz known as pipes. A pyroxene, at the contact of pegmatite and limestone, is very rarely molybdenite-bearing in Queensland. The pipes, especially near the contact of a granite and a sedimentary, are as a rule tortuous, but can in most cases be followed down for hundreds of feet, generally with lessening values as the distance from the granite contact increases.

The gangue is almost always quartz, with which feldspar and sometimes mica is associated. The commonly associated metallic minerals include wolfram, native bismuth, bismuthinite, mispickel, iron and copper pyrites, while other minerals such as magnetite, cassiterite, galena, zinc blende, and scheelite are not infrequently met with.

The Wonbah mine near mount Perry, is the principal molybdenite producer in Queensland. The ore occurs in a pure white quartz pipe in granite, close to a quartz porphyry dike. This pipe, which is much larger than the famous Kingsgate pipe, in New South Wales, is 42 to 60 feet in diameter, is known to be 200 feet deep, not tortuous, and has a regular dip of 85 degrees. The outer portion of the pipe is richest in molybdenite, and the mineral is extracted by mining a 16-foot face all around from two or three different levels, leaving a central core standing. The molybdenite occurs in coarse and fine flakes and masses, together with small segregations of chalcopyrite, pyrite, and galena. The milling ore, after it has been hand-sorted over picking belts, averages 0·8 per cent molybdenite.[2] A description of the mill will be found under Concentration. From the Wonbah mine during 1918-19 about 8,500 long tons of crude ore was milled, giving 55½ long tons of 90 per cent molybdenite concentrates, valued at £24,152.

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[1] Queensland Geol. Surv., Art. 4 "Molybdenite," 1920. B. Dunstan.

[2] Eng. and Min. Jour., Nov. 13, 1920, p. 947. J. H. Reid.

The mine closed down in 1920 as a result of the market and litigation between the company and the original vendors.

The Thermos Electric Ore Reduction Corporation of London, England, who acquired important holdings, during 1917, at Wolfram, in North Queensland, have been operating on a large scale. The ore occurs in pipes, or fissures filled with quartz, and lies between walls of porphyry and granite. These pipes are irregular in form, and the mineral content generally higher in the narrow portions than in the wide.

The Kitchener Blocks Molybdenite Company, at Tate, near Bamford, North Queensland, who have a very promising deposit, ceased operations in March, 1919, owing to the closing of the local stamp-battery concentrator at Bamford.

The government battery was apparently not entirely suitable for the treatment of the Kitchener molybdenite ore, and the company is said to be building their own concentrator. The ore-body at the Kitchener mine, upon which a very considerable amount of development work has been done, is estimated to be not less than 4·5 feet in width and to average 3 to 4 per cent molybdenite. In several places the ore will yield up to 8 per cent and widths of 12 feet of good ore have been encountered. E. C. Saint-Smith, who gives a full account of the Kitchener mine and its prospects, expressed the opinion that this ore-body would rank among the world's most important individual molybdenite-producing deposits during the next two years.[1]

The production figures of the individual producers for 1919 to 1921, are as follows:—[2]

TABLE XXIV

Queensland Principal Molybdenite Producers, 1919-1921

District	1919		1920		1921	
	Long tons	Value	Long tons	Value	Long tons	Value
		£		£		£
Chillagoe	73·5	33,088	23·30	10,809	8·75	2,187
Herberton	0·16	53				
Mount Perry	42·75	18,540	5·00	2,270		
Ollera (Star river)	1·33	531	0·60	254		
Stanthorpe	0·04	22				
Miscellaneous			8·00	2,153		
Totals	117·80	52,234	36·90	15,486	8·75	2,187

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[1] Queensland Min. Jour., May 15, 1917, p. 226. E. C. Saint-Smith.

[2] Queensland Min. Jour., April, 1921, and April, 1922, p. 143.

In the following table will be found some of the more important Queensland molybdenite deposits.

TABLE XXV

Important Queensland Deposits

Name of locality	General character of MoS_2 occurrence	Country rock and gangue	Reference to literature where cited	Remarks
Bamford......... Chillagoe district.	Flakes in quartz pipes, quartz rock and greisen.	Granite, porphyry and sedimentaries; quartz and granite gangue.	I.A. & M.S., May 23, 1918, p. 527, also Queens. Min. Jour., Apl. 15, 1921, p. 130	One of the largest fields in Queensland
Kitchener........ Khartoum district	Small flakes and lumps disseminated through white quartz reefs	Fine-grained biotite granite	I.A. & M.S., May 23, 1918, p. 528, also June 5, 1919, also Q. M. J., May 15, 1917	Free from assoc. metallic sulphides A large and steady producer
Lappa Lappa.....	Flakes irregularly distributed through quartz reefs	Coarse acid granite and aplite dikes	I.A. & M.S., May 23, 1918, p. 528	Ore low grade and irregular mining; uncertain
Wonbah.......... Mount Perry district	Scales in granite veins and in a pure white quartz pipe	White quartz and granite	I.A. & M.S., May 23, 1918, p. 528, also E. & M. J., Nov. 13, 1920, p. 947.	Up-to-date plant, and is premier producer in Queensland
Stanthorpe....... Baleandean district	Flakes in granite and quartz veins	Aplitic granite and sedimentaries	I.A. & M.S., May 23, 1918, p. 528, also Q. M. J., Oct. 15, 1918	Very many assorted minerals; molybdenite abundant
Wolfram camp.... Dimbulah district	Fine flakes in quartz pipes and granite	Sandy granite and quartz	I.A. & M.S., May 23, 1918, p. 528	Assoc. with bismuth and wolfram: one of the earliest producers of MoS_2

The Industrial Australian and Mining Standard, May 30, 1918, gives a tabulation of sixty of the known Queensland occurrences.

South Australia

Molybdenite has been found in about half a dozen localities in South Australia, but apparently the only production has been from the Yelta mine, at Moonta, about 125 miles north of Adelaide. The mineral occurs in copper sulphide veins which are considered to be of igneous origin.

The mine was worked by the South Australian government, and subsequently a little work was done by a party of tributers. During the period it was worked by the state, 709 pounds of molybdenite was recovered by hand-picking, and 16,552 tons of crude copper ore, from which 8,033 tons of dressed copper ore was prepared for smelting. The Yelta being essentially a copper mine, the molybdenite is recovered as a by-product.

Tasmania

There is no record of the output of molybdenite from Tasmania, but a small amount of the mineral is said to have been produced from the Squib mine, in the Mount Claude district. The total output did not exceed five tons. As a rule the molybdenite occurs in quartz veins which in many cases persist for considerable distances, 1,000 feet being quite common. Another type is that of pegmatite veins, or dikes, that carry the mineral in patches. Contact metamorphic deposits consisting of sedimentary rocks altered to quartz-mica schists that are situated near the main granite contacts and carry quartz lodes containing wolframite and molybdenite are quite common. A typical example of this type of deposit is at Constable creek, in the Scamander mineral district, northeastern Tasmania, where the wolfram-molybdenite lodes on the Hartnett section show good values in both minerals.

At the Squib mine, north of Dolcoath hill, $1\frac{1}{2}$ miles east of Moina, wolfram, molybdenite, bismuthinite and cassiterite are mined. Sandstone occupies the largest area, but the richest ore appears to be contained in quartz veins in the quartzite. Mining consists of about 1,200 feet of tunnels on two levels, an adit, and 300 feet of raises. Molybdenite and wolfram are most abundant in the end of the west drive, main level.

The mine is equipped with a small concentrator driven by a 12 h.p. oil engine. Ordinary gravity methods are employed. The molybdenite is brought up to 25 per cent in the jigs, and is sold for further treatment. This appears to be the only mine in Tasmania that has attempted to produce molybdenite, but no record of the output is available.

References:—

Ind. Aust. and Min. Stan., June 13, 1918, p. 624. (Tabulation and references.)
Mineral Resources of Tasmania. Tungsten and Molybdenum, No. 1.
    Part I, North Eastern Tasmania—Loftus Hills, 1915.
    Part II, Middlesex and Mt. Claude—Loftus Hills, 1916.
    Part III, King Island—L. L. Waterhouse, 1916.
Tasmania Geol. Surv., Bull. No. 29, Mining fields of Moina, Mt. Claude, and Lorinna, A. McIntosh Reid, 1919.
N.S.W., Min. Res., No. 24, 1916. E. C. Andrews, p. 18.
Imp. Inst. Bull. "Molybdenum Ores." R. H. Rastall, 1922, p. 51.

Victoria

In every case molybdenite occurs in granite, or similar rocks, either in the rock itself, or in quartz lodes, or irregular quartz veins. Although the mineral has been found in 25 or 30 districts in Victoria, the Everton district is the only one that has produced any quantity of ore, and previous to 1917 Victoria was not recognized as a producer of molybdenite. All the deposits occur in an area within 150 miles of the coast.

A detailed description of the Everton field is given by P. T. L. Kenny, of the Department of Mines, Victoria,[1] who says that the rocks are cut by two classes of dikes, (1) pegmatite, (2) porphyry. The former are associated with granite veins which occur in the surrounding sedimentary rocks, and are intersected by quartz veins carrying molybdenite. The quartz-feldspar porphyry dikes, up to 20 feet in width, intersect both the granite and the sedimentaries, and, apparently, do not carry molybdenite.

The richest ore-body discovered is that of the Standard Molybdenite mine at Everton, 14 miles from Wangaratta, and covers an area 3 miles long by one-fourth of a mile wide. A concentrator using the Minerals Separation process was erected in March, 1920, to treat about 1,350 tons of 4·0 per cent molybdenite ore that had been laid aside on the dump.[2] About 250 tons of ore was treated in the new mill, giving approximately $8\frac{1}{4}$ tons of ·85 per cent molybdenite concentrates. The company has a modern power and electric light plant.

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[1] (*a*) Ind. Aust. and Min. Stan., May 1, 1919. (*b*) Rec. Geol. Surv. Victoria 4, Pt. 3, 1921, p. 296. P. T. L. Kenny.

[2] For full description see Chem. Eng. and Min. Review, Sept. 5, 1920, p. 448.

The ore-body at Malden,[1] which was worked in 1918, is reported to have a width of 42 feet at the 400-foot level, and 52 feet at the 500-foot level, and an average content of 35 per cent molybdenite.

In 1918 a rich deposit of molybdenite is said to have been found in a creek bed near Tenterfield, upon which an option was taken by the MacKay Prospecting Syndicate of Melbourne.[2] In 1921 approximately 110 tons of 5·0 per cent molybdenite ore was produced in the state.

West Australia

Molybdenite figures only in a very minor degree in the annual statistics of mineral production for West Australia, although there are about 20 different occurrences of the mineral known. Apparently none of these are of economic importance, except those at mount Mulgine in the Yalgoo field, and possibly North Dandalup in the Darling ranges.

All the molybdenite occurrences are confined to a granite and gneiss area, which occupies an area about 500 miles square in the southwestern part of the state.

The total recorded molybdenite production of the state is about 26 tons, most of which came from mount Mulgine. It is believed that a small quantity of the mineral was also obtained from the Darling deposits.

Mount Mulgine, near Warriedar, in the Yalgoo gold field. The deposit consists of a granite boss, intersected by quartz and pegmatite veins, which are in turn traversed by later narrow dolerite dikes.

The molybdenite, in the form of flakes and rosettes, occurs in thin veins, and finely disseminated throughout the granite. A number of sheet zones impregnated with molybdenite, scheelite, and fluorite have been found. The country rock is a microcline-muscovite granite. The mineral is found associated with iron pyrites, and in some places embedded in pyrite crystals. Rich ore is stated to occur in widths varying from 6 to 8 feet, and ten lodes have been located, and partly opened up by crosscuts.[3] The deposits are of deep-seated origin and seem capable of producing a large amount of ore, averaging about 1 per cent molybdenite.[4]

North Dandalup. Darling ranges. Many occurrences of molybdenite have been discovered in the Darling ranges near Swan view, in a granite area 50 miles square. The finds include those at Dandalup; Clackine; Mahogany creek and Mokine. The molybdenite occurs finely disseminated throughout pegmatite dikes, the country rocks being granite and greenstone in which, at the Dandalup deposit, a highly feldspathic pegmatite gangue intrudes between two fault-planes. The only associated mineral is iron pyrites. Although the Dandalup deposit is too low grade to warrant large scale mining, there is a possibility that better deposits will be found in the region.

The rare mineral powellite (calcium molybdate) was observed in pegmatite veins at Mahogany creek and mount Mulgine, in the form of a milk-white, or pale grey pseudomorph after molybdenite.

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[1] For detailed descriptions of the Victoria occurrences see "Molybdenite Occurrences in Victoria," Aug., 1915, H. Herman.

[2] Iron and Coal Trade Rev., Aug. 30, 1918, p. 253.

[3] Ind. Aust. and Min. Stan., Jan. 6, 1919, p. 111.

[4] Bull. Imp. Inst., Vol. XVIII, 1920, p. 568. A. Gibb Maitland. Also Ind. Aust. and Min. Stan., June 13, 1918, p. 623.

A description of the remaining Australian occurrences is given in the following:—

Ind. Aust. and Min. Stan., June 13, 1918, p. 623.

West. Aust. Min. Handbook, Chapter II, "The Molybdenite Deposits of Western Australia." A. Gibb Maitland, 1919.

EUROPE

Austria-Hungary

Austria has been producing molybdenum ores for a large number of years, and was probably one of Germany's main sources of supply during the war, but no authentic records of production at that time are available. The most extensively mined deposits appear to consist of wulfenite, this ore having been discovered in Carinthia, and at Ruskitza, by the Austrian mineralogist, Wülfen, in 1785—after whom it was named. It also occurs in Silesia, Tyrol, and Bohemia.

The Hungarian wulfenite consists chiefly of the red variety of crystals of lead molybdate, containing a small quantity of chrome. It is found at Moldawa and Ruskberg, Rezbanya, and Szaska.[1]

Molybdenite has been known on the Austrian side of the Erzgebirge since about 1800,[2] where it occurs as small flakes in quartz at Zinnwald, and as larger plates in transparent quartz at Schlaggenwald, in Bohemia.

British Isles

The occurrence of molybdenite in the British Isles was reported in 1866 when C. Le Neve Foster drew attention to the discovery of the mineral in Leicestershire.[3]

In England molybdenite occurs in granites or closely allied rocks in Cornwall, Cumberland, Leicestershire, Westmoreland, and Somersetshire; and in Invernessshire in Scotland.[4]

None of these occurrences has so far furnished sufficient quantities of the mineral to warrant their being of commercial importance, and no shipments have been recorded.

The most promising occurrences in the British Isles appear to be those near Galway, Ireland, where at Roundstone the mineral is found in considerable quantities disseminated in a wide granitic vein. The ore as a rule is accompanied by yellow molybdite. Prospecting and boring operations were carried on in 1915 with the object of proving the extent and depth of lode, but work was suspended owing to difficulties regarding the title.[5]

France

No commercial molybdenum is found in France, but small quantities of molybdenite occur at Chessy; and as far back as 1847 wulfenite was reported from the Dauphine. This mineral also occurs in thin tabular

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[1] Ind. Aust. and Min. Stan., Aug. 22, 1918, p. 284.

[2] Ind. Aust. and Min. Stan., Aug. 8, 1918, p. 211.

[3] Geol. Mag., Vol. III, 1866.

[4] (a) Ind. Aust. and Min. Stan., Aug. 8, 1918.
(b) Geol. Surv., Mem. Spec. Reports on the Min. Res. of Great Britain, Vol. I, 1916: Vol. V, 1917.
(c) Molybdenum within the Empire, Jour. Soc. Chem. Ind., 1918, p. 448 R. S. J. Johnstone.
(d) Imp. Inst. Bull. Molybdenum Ores, 1922, p. 13. R. H. Rastall.

[5] (a) Min. Ind., 1919, p. 472.
(b) Commerce Reports, Oct. 2, 1919, p. 38.
(c) Trans. Inst. Min. Eng., "Notes on Mining in Ireland," 1904, p. 265. G. H. Kinahan.
(d) Imp. Min. Res. Bureau, Molybdenum, 1923, p. 21.

crystals in quartz near Chemelette, Rhone department; at Chalanches, department of Isere; and at Beaujolias.[1]

Germany

Very little information is available concerning molybdenum production in Germany during the war. Before the war the metal was used almost solely in chemicals and only in the works at Teutschenthal was ferro-molybdenum produced, mainly for export to England.

One of the first recorded occurrences of molybdenum ores in the world was at Altenberg near Sadisdorf in Saxony. A specimen from this locality furnished the material for the analytical research work of C. F. Buchholz and H. W. Brandes in 1804. The mineral has been found on the Saxon side of the Erzgebirge,[2] embedded in quartz and in hard greenish marl. It is also found at Ehrenfriedersdorf and at Lomnitz, near Hirshberg in Silesia; at Hochstätten, near Auerbach au der Bergstrasse, and at Jeuschenthal, near Halle on the river Salle. During the earlier part of the war, the company operating the Deutsche Molybdänwerke at the Halle deposit was expected to be in a position to supply all the requirements of the European steel industry for ferro-molybdenum, or molybdenum metal. It was further stated that the company owned mines producing an abundance of ore.[3]

One of the most important ore-producing districts is the Höllenthal valley near Garmische-Partenkirchen in the Alps of Upper Bavaria. Mining was begun there in 1914 by a Swiss corporation, and taken over by the German Army Administration in 1916. H. Müller[4] discusses the geology of the district and gives data on the production of wulfenite.

Wulfenite is also found in Saxony, at Bleiberg, Annaberg, Berggieshübd, Johanngeorgenstadt and Schneeberg; and in Baden at Badenweiler and Schwarzwald.

Italy

Molybdenite and wulfenite have been recorded from about eight different districts in Italy and Sardinia, in most cases associated with galena, pyrites, and chalcopyrite. The total production has been about 16 tons of concentrates.[5]

Jugo-Slavia

Wulfenite occurs in considerable quantity in the lead mines of Misitsa in Northern Slovenia.[6] The workings in these mines are said to date from the fifteenth century and consist of about 13 miles of levels over a vertical depth of 3,000 feet.

Wulfenite has been steadily produced since 1902, and a total of 600 tons of the ore has been obtained, the highest production being 150 tons in 1910. The ore is hand-sorted and exported to France, but no record of its grade or value is available.

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[1] (a) Ind. Aust. and Min. Stan., Aug. 22, 1918, p. 284.
(b) Imp. Min. Res. Bureau, "Molybdenum," 1923, p. 52.

[2] Ind. Aust. and Min. Stan., Aug. 8, 1918, p. 211.

[3] According to Zeitschrift Für angewandte Chemie—see "Mineral Industry," 1916, p. 515. A. W. G. Wilson.

[4] Edel-Erden und Erze, Vol. 1, 2, and 3, Oct. 1, 2, and Nov. 1, 1919, pp. 3-5, 17-19, 29-30. H. Müller.
Also: Bergban, March 24, 1921, p. 217.

[5] (a) Ind. Aust. and Min. Stan., Aug. 22, 1918, p. 284.
(b) Min. Ind. of Brit. Empire and Foreign Countries, Imp. Res. Bureau, 1921, p. 61.

[6] Geology and Min. Rec. of the Serb Croat Slovene State, 1921, p. 63. D. A. Wray (Brit. Econ. Mission to Serbia).

Norway

Production of molybdenite commenced in Norway about 1885, at which time the mineral was used chiefly as a substitute for graphite. Although only 15 tons was produced from 1910 until 1913, Norway was one of the chief pre-war producers of the mineral. During the war the prices of molybdenite in Norway soared to spectacular heights, and in a very short time about 30 mines were actively producing.

The geographical situation of Norway and her neutrality caused her molybdenum supplies to be in great demand. It was impossible to impose the British controlled price of 105 shillings per unit and local prices rose to extraordinary figures. During the summer of 1917 the price of a 75 per cent molybdenite concentrate rose to $4.60 per pound. In order to prevent the mineral reaching the Central Powers, the British government contracted for almost the whole output of 1917 and the first half of 1918, at $4.25 per pound.[1] The result was that dozens of companies, owning nothing but the merest prospects, hurriedly erected large and expensive plants in an attempt to reach the production stage before prices dropped. Adverse conditions caused the total cessation of molybdenite mining during 1921.[2] For detailed information concerning Norwegian molybdenite deposits and concentration of ores the reader is referred to articles by H. H. Claudet,[3] E. R. Woakes,[4] and O. Falkenberg.[5]

In the latter part of 1919, about 15 of the largest molybdenite mine-owners amalgamated and formed the "Norske Molybden-produkter A/S" (Norwegian Molybdenum Products, Ltd.), to sell molybdenite concentrates, and to make and sell ferro-molybdenum and other molybdenum products. Reports on the properties that entered the amalgamation show that at least 200 tons of molybdenite per annum can be expected.[6]

Molybdenite is found in many parts of Norway, but the largest deposits appear to be in the southern part. The country rock is largely granite, or granite gneiss. Ernest R. Woakes[7] recognizes three well-defined types of ore deposits.

The first and most important is the quartz lode, of which the Kvina and Knaben No. 1 mines are good examples, although the actual mineral occurrences are very different in the two mines. The rich Dalen mine is another instance, but there the country rock is a siliceous slate.

The second type, which is the most common, is highly mineralized fissures in granite. These fissures are in some places filled with decomposed granite with very little quartz. The mineralization is, as a rule, confined to the surface, and a few feet down there is only an ill-defined fissure, or fracture. There are many examples of this type in Norway, but, according to Mr. Woakes, they are the least likely to lead to permanent ore-bodies of commercial value.

The third type is the molybdenite-impregnated granites, or other igneous rocks. There are two or three promising looking occurrences of this type, of which the Knaben No. 2 mine, and the Undal mine, are examples.

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[1] Eng. and Min. Jour., Jan. 18, 1919, p. 162.
[2] Can. Min. Jour., May 26, 1922, p. 326.
[3] Notes on Molybdenum Operation in Norway, Can. Min. Inst., Bull. 51, 1916, p. 609. H. H. Claudet.
[4] Molybdenum in Norway. Trans. Inst. Min. and Met., Jan. 17, 1918. Ernest R. Woakes.
Also Eng. and Min. Jour., Vol. 105, No. 11, 1918, p. 499.
[5] Translation—Eng. and Min. Jour., Vol. 112, No. 4, July 23, 1921, p. 125. Otto Falkenberg.
[6] The Metal Bulletin, Jan. 27, 1920.
[7] Molybdenum in Norway, loc. cit.

Mr. Woakes gives a detailed description of the various Norwegian mines and a classified list of those operating at the time of his report.

The Knaben mines are the oldest and largest in the country. The No. 1 mine has been worked intermittently since 1885 and in total production ranks within the first half dozen of the world's leading producers. From 1905 to 1918 these mines belonged to the Blackwell Development Corporation, Ltd., England. Another early producer was the Tjaerdalskampen in Saltden, which produced about 10 tons of concentrate previous to 1890. In 1906 the British Molybdenite Company made an output of about 100 tons of 3 to 4 per cent molybdenite ore, from their mine at Oersdalen.

A deposit, which is said to be extensive, was discovered in 1917, at Lier,[1] less than 50 miles from Christiania, from which about 4 tons of pure molybdenite was produced. The molybdenite occurs in a quartz vein running through red granite. Several other deposits are said to have been discovered in the northern part of the country.

According to Otto Falkenberg, "the downward dimensions of the ore-bodies seem to be quite limited, and there is probably no molybdenum mine over 100 feet deep." The deepest Norwegian mines from which ore was extracted are the Knaben mines. The average grade of milling ore of the larger mines appears to be about 1 per cent molybdenite or under.

Nearly all the successful concentrators in Norway employ the Elmore vacuum process. During 1914 and 1915 Mr. H. H. Claudet, of Ottawa, erected and operated the first units which were installed in the Knaben mines. (See chapter on Concentration.)

For further reference to the Norwegian molybdenite industry see:—

(*a*) Ind. Aust. and Min. Stan., Aug. 8, 1918, p. 210.
(*b*) Mineral Industry, 1920, p. 466, W. N. Bratton.

The total Norwegian production to date has been about 900 tons of concentrates.

The reported production of ores and concentrates is as follows:—

TABLE XXVI

Norwegian Production

Year	Up to 1900	1901	1902	1903	1904	1905	1906	1907	1908	1909
Ore or concentrates........tons	10	4·40	22·04	34·16	33·06	50·69	28·63	33·06	38·57	33·06
MoS_2 contents............ "	7	3·30	21·0	33·0	31·8	28·5	25·00	23·00	23·50	18·00
Value...................... $	4,620	1,890	16,200	21,600	17,550	16,470	14,310	12,960	13,500	12,150

Year	1910	1911	1912	1913	1914	1915	1916	1917	1918
Ore or concentrates..tons	......	2·20	12·12	3·86	78·00	101·00	141·00	201·00	165·00
MoS_2 contents........ "	......	1·50	8·00	1·00	59·51	82·65	95·00	150·00	123·00
Value................ $	......	740	3,510	3,240	119,732	278,000	385,000	533,333	1,248,804

Totals—Ores and concentrates, 991·84 tons; approximate MoS_2 contents, 734·7 tons; value, $2,703,609.

Figures obtained from—U.S. Mineral Resources Bull., 1918—Molybdenum, p. 800, F. L. Hess.
Mineral Industry, 1919, p. 471, A. W. G. Wilson.
The MoS_2 contents up to 1914 have been calculated from the prevailing prices.

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[1] Mineral Industry, 1917, p. 463. A. W. G. Wilson.

Russia

Although ores of molybdenum occur in several places in Russia and Siberia, local conditions have retarded prospecting and the minerals have not been found in commercial quantities. About a dozen different occurrences are recorded from the Caucasus and the Urals, and when conditions are more stable it is probable that the more important Siberian deposits will be developed.

A considerable quantity of ferro-molybdenum was imported into Russia during 1918 for war uses. When the country collapsed all orders were cancelled, and the molybdenum thus released assisted materially in causing the collapse of the markets.

According to R. C. Tredwell, Consul at Petrograd, the molybdenite production for 1916 was 5,417 pounds, and in 1917, 7,220 pounds of 45 per cent molybdenite concentrates, all of which was used within the country.[1]

Spain

Wulfenite has been produced and exported from Spain since 1913. The Société Procédés Paul Girod of Lyons[2] started the development of the most important and best known deposit, which is situated in the Sierra Nevada, 12 miles from Granada. The wulfenite occurs associated with galena in Triassic limestone, but the ore is very pockety and the cost of mining considerable. This company also took a lease on another wulfenite occurrence at Albunuelas in the same province. Altogether about 1,200 tons of wulfenite has been produced.[3]

Sweden

Sweden has been a small, but fairly regular shipper since 1914, previous to which a few small shipments were made.

The following list of deposits is quoted from the Industrial Australian and Mining Standard:—[4]

> Important deposits of molybdenite occur along the coast of the Baltic, for instance, on the island of Ekholmen, Oak Island, and at Lindas (Smalaud), Bohusläu, Skhmolen, Bastnaes and Numedal. One of the earliest deposits worked is that of Ekholmen; as far back as 1880 shipments of 1,400 pounds ore of 95 per cent molybdenite and 10,000 pounds of screened ore, assaying 9 per cent molybdenite, were sent to Germany. Ekholmen is a little island, situated in the archipelago of Westervik, on the southeastern part of Sweden (20 miles north of Westervik township). The country rock consists of micaceous rock and horneblende gneiss, which is traversed by a number of distinct veins, containing chiefly molybdenite and ferri-molybdenite, with very little copper pyrites and a gangue of quartz and feldspar. The ore is easily dressed and concentrates free of copper are obtained with far less costs than at some of the Norwegian mines.

During the war, A. D. Bredenberg of London, England, made a report on the Udd molybdenite mines, near the iron mines of Grängesberg, and stated that the ore occurs in large flakes, in quartz veins, or in gneiss, and that the deposit is very favourably situated for development as regards slope, power, and transportation. Some stripping has been done, and shafts have been sunk on the property near lake Hatjern.

During 1916 and 1917 about 24 tons of ferro-molybdenum was manufactured. Between 1914 and 1918 over 15,000 tons of ore was mined, having a total molybdenite content of approximately 100 tons.

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[1] Min. Jour., July 6, 1912, p. 678. E. de Hautpick.
Ind. Aust. and Min. Stan., Aug. 8, 1918, p. 210.

[2] Min. Jour., Dec. 1, 1917.

[3] Imp. Inst. Bull. "Molybdenum Ores," 1922, p. 61. R. H. Rastall.
Imp. Min. Res. Bureau "Molybdenum," 1923, p. 61.

[4] Indust. Aust. and Min. Stan., Aug. 8, 1918, p. 210.

PART II

COSTS, ANALYSES, AND CONCENTRATION

CHAPTER I

COSTS AND ANALYSES

PRODUCTION COSTS

The total cost of production of molybdenite concentrates per pound depends on so many conditions that no standard estimates can be given. Total costs of various molybdenite producers throughout the American continent range between $5 and $12 per ton of ore treated.

The application of oil flotation for the concentration of molybdenite was not generally recognized during the early war period when the mineral was in great demand, and most of the mills did not have a standard system of procedure. By the time efficient operating conditions were established, the market for their output had almost disappeared and most of the producers were forced to close. It was partly because of these conditions that the production costs of molybdenite were abnormally high.

The present period of inactivity has given engineers and future producers time to consider more fully the problem of cheaper production. As a result, and because of the approach of more normal labour conditions, it is thought that future production costs will be greatly reduced.

Unless the tonnage of available ore is very large, it is not good policy to consider a concentrator with a capacity exceeding 50 tons per day. Possibly only one-half of this amount may be the extent of the continuous supply from most deposits; consequently, in such cases the grade of the ore must be high enough to offset the higher operating costs attending small installations. The total operating costs of such a plant in eastern Canada at present is estimated from actual experience to be about $7 to $8 per ton of ore treated. It is unlikely that the price of concentrates will reach the war level, and it is generally expected that when the market re-opens the prices quoted will be about 70 cents per pound of contained molybdenite. At this price, if the average recovery of molybdenite per ton of ore treated can be maintained at about 15 pounds, there is a possible margin of profit, but it would not be advisable for an owner of a low-grade (0·5 per cent MoS_2) molybdenite property to attempt to operate, unless he is certain of being able to supply continuously at least a 100-ton concentrator.

Mining Costs. Records of different molybdenite producers show mining costs varying between $2.50 and $5 per ton. These figures necessarily depend upon the quantity mined, nature of the rock, accessibility of the ore, method of mining—open-cut, quarrying underground, sinking, etc.,—the quantity of timber required and its available supply, power and general overhead costs. In most cases there is no difference between the actual mining of molybdenite and of any other ores of similar nature and occurrence, so that mining costs are comparable.

Experience has shown that on the average the mining costs of various Canadian molybdenite operators are between $3.50 and $4.50 per ton of ore treated, the daily tonnage extracted being between 25 and 100 tons. In most cases the rock mined was hard, and fuel costs abnormally high.

Concentration Costs. From information obtained from different sources, concentration costs vary between $1.50 and $8 per ton of ore treated, the latter figure being due to the extremely low tonnage of ore milled. Now that the problem of molybdenite concentration has been simplified and standardized, these costs should not vary to any great extent in different localities, provided that the concentrator is suitably constructed to treat the ore. Tonnage treated, mill and running time, efficiency, and power costs, are big factors in the variation of milling costs per ton of ore.

The cost per pound of concentrates varies, of course, in proportion to the grade of the ore treated, and the grade of the concentrates produced.

In one case, where power costs were very high and running time averaged as low as 30 per cent, the cost per ton milled came to about $6. The milling costs per pound of concentrates averaged nearly 50 cents when making a concentrate of over 90 per cent molybdenite. In a 100-ton concentrator the milling, including proportional overhead, was approximately $4 per ton of ore treated. In this case, however, fuel costs were from $2 to $3 per ton.

ANALYSES AND TESTS FOR MOLYBDENUM AND ITS ORES

LABORATORY TESTS FOR MOLYBDENUM MINERALS

Molybdenite.

(*a*) By looping a piece of platinum wire and burning on it some of the powdered ore with a little borax, the resulting bead in the oxidizing flame, is yellow when hot, colourless when cold, and brown to black opaque in the reducing flame. If, instead of borax, sodium ammonium phosphate is used, in the oxidizing flame, the bead is yellow-green when hot and colourless when cold; in the reducing flame it is emerald green.

(*b*) Oxidize a small quantity of the finely powdered ore either by roasting in air, or by treating in a porcelain crucible with concentrated nitric acid and evaporate to dryness. Treat the residue with one-half c.c. of concentrated sulphuric acid, and again evaporate to dryness. By allowing this to stand from 2 to 12 hours, the presence of molybdenum is indicated by the residue turning blue.

(*c*) Fuse the finely powdered ore with equal parts of sodium and potassium carbonates and a small amount of potassium nitrate. Powder the fusion and dissolve with hot water and filter. Acidify the filtrate with hydrochloric acid, boil, and add potassium or ammonium thiocyanate and a small piece of metallic zinc. If molybdenum is present a bright cherry-red colour rapidly develops, which disappears on standing in the presence of the zinc. If hydrogen peroxide is added to the solution immediately after the cherry-red colour has developed, the colour disappears, returning as soon as the peroxide has been reduced.[1]

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[1] Colorado School of Mines. H. J. Wolf.

The permanence of this colour depends on the iron present, as the solution becomes colourless through the reduction of the iron to the ferrous condition; also if the solution is strongly acid the colour verges to red, and is less sensitive; if nearly neutral it resembles the colour of permanganate.

If the amount of molybdenum present is known to be small, this test may be made more delicate if immediately after the thiocyanate and zinc have been added to the acidified filtrate from the leached carbonate fusion, the solution be shaken with a small volume of ether. The colour will be intensified as a golden brown in the ether ring that forms at the top of the liquid on standing.

(*d*) A solution containing a trace of alkali molybdate, when acidified with acetic acid and treated with a little hydrazine sulphate and boiled, rapidly turns deep blue and retains this colour on boiling.

(*e*) When a solution of molybdic acid is treated with an excess of potassium iodide and boiled, iodine is slowly liberated and the solution turns blue.

By adding potassium ferro-cyanide to molybdic acid in a mineral acid in the absence of iron a brown precipitate is obtained which still contains molybdenum.

(*f*) In the presence of acetic acid tannin gives a similar reaction. Better results can be obtained, according to Dr. Moir,[1] by substituting pyrogallol, or pyrocatechol, for tannin. Either of these, when added to a molybdic acid solution previously treated with sodium acetate, gives a very delicate orange colour.

Molybdite.

The following tests for molybdite suggested by Schaller have been recorded by Horton.[2]

(1) On heating the mineral in a closed tube abundant water is easily given off and the mineral assumes a dark olive colour; on further heating it again becomes lighter in colour.

(2) On heating the mineral in a crucible the colour changes are very marked. At first the yellow mineral darkens and becomes a dark grey, appearing almost black and with slight olive tint, then it becomes a light yellow again, and on further heating changes to a deep orange colour. If the mineral now be allowed to cool, the orange changes to yellow and back to orange again on re-heating. If the dark-coloured material be allowed to cool, it retains its dark grey colour, and on re-heating passes through yellow to the orange. On heating for some time at a higher temperature, the mineral on cooling becomes a permanent bright green. By further heating all of the molybdenum is volatilized and the dark red ferric oxide remains.

(3) The mineral is readily soluble in hydrochloric acid, and is decomposed by ammonia, taking on a brown colour (probably due to the separating ferric hydroxide). After a while, all the molybdenum of the mineral goes into solution, leaving the insoluble ferric hydroxide.

(4) When heated on charcoal it fuses, and leaves a coating of minute yellowish crystals. If this coating is heated for an instant in the reducing flame it turns deep blue, and with continued heating becomes dark red.

Wulfenite.[3]

Before the blowpipe wulfenite decrepitates and fuses below 2. With borax bead in oxidizing flame it gives a colourless glass; in reducing flame it becomes opaque black or dirty green with black flecks. With salt of

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[1] Journal of the Chemical, Metallurgical and Mining Society of South Africa, 1917. Dr. Moir.

[2] U. S. A. Bur. of Mines, Bull. 111, 1916, p. 12. F. W. Horton.

[3] A System of Mineralogy. Sixth edition, p. 991. Dana, E. S.

phosphorus in ordinary flame it gives a yellowish green glass, which in reducing flame becomes dark green. Fused with soda on charcoal it yields metallic lead.

Decomposes on evaporation with hydrochloric acid, with the formation of lead chlorite and molybdic oxide, the solution being green. On moistening the residue with water and adding metallic zinc it gives an intense blue colour, which does not fade on dilution of the liquid.

QUANTITATIVE ANALYSES

Sampling. The ordinary methods of sampling and preparing other ores for analysis are applicable to molybdenite ores, but particular care should be taken with the metallics or flakes of molybdenite that remain on the screen and become concentrated. These should be kept for each reserved portion of the sample and finally ground down to pass at least a 40-mesh screen, and then thoroughly mixed with the 100-mesh fines that have been retained. From the sample of about 3 pounds, samples for analysis can be taken.

Analyses. A number of methods for molybdenum analysis are used by metallurgists and chemists. Details of the methods employed by Canadian firms will be found in the accompanying pages, followed by a bibliography, referring to details of analyses as practised by some of the leading molybdenite producers and metallurgists.

One of the chief troubles in the determination of molybdenum in ores is the difficulty of getting the mineral completely into solution. Another trouble, common in low-grade ores, is that when they contain much iron its precipitation from the solution is liable to carry with it large amounts of molybdenum.

Canadian molybdenite ores contain pyrrhotite, iron pyrites, and in some cases copper pyrites, and in some British Columbia ores there are small amounts of arsenic, or bismuth, the usual gangue minerals being quartz, calcite, mica, etc.

TIVANI ELECTRIC STEEL COMPANY

The following method for the determination of molybdenum in concentrates and ferro-molybdenum was used by the Tivani Electric Steel Company, Belleville, Ont.[1] The concentrate is assayed for molybdenum and iron, and the 'ferro' for molybdenum, sulphur, carbon, and silica.

Ferro-Molybdenum: Half a gramme of ferro is treated with 50 c.c. of 1·20 s.c. nitric acid, heated till all is in solution, diluted with water, caustic soda added to precipitate the iron; the solution is brought to the boiling point, carefully stirring to prevent bumping, and is allowed to stand until the precipitate settles; it is filtered, washed with hot water, the filtrate transferred to a half-litre measuring flask, cooled to room temperature and made up to the half-litre mark. 100 c.c. of this thoroughly mixed solution is taken in a pipette, placed in a 300 c.c. flask, a small piece of litmus paper added, and hydrochloric acid until just acid; then ammonia is added until just alkaline, and acetic acid until just acid. The solution is heated to boiling, and titrated while hot with a standard solution of lead acetate using a dilute solution of tannic acid as an indicator. Standard lead acetate solution is made by dissolving 15·7 grammes of lead acetate per 1,000 c.c. water; this is standardized against a ferro of known molybdenum content. Time 17 hours.

Concentrates: Fuse one gramme of concentrate with 25 grammes potassium bisulphate in a covered fused-quartz crucible in a muffle at a temperature of between 900° and 1,000° C. When fused, place the crucible in a 600 c.c. beaker, cover with hot water and bring slowly

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[1] Trans. Can. Min. Inst., 1918, p. 160. J. W. Evans.

to boiling point. When all is in solution, rinse the crucible and cover, and precipitate iron with caustic soda; bring to boil and filter through a folded 15 cm. filter into a 600 c.c. beaker. Wash four times with hot water, transfer filtrate to a 500 c.c. measuring flask, cool and dilute to mark, shake well and withdraw 100 c.c.; transfer to a 300 c.c. flask and make slightly acid with hydrochloric acid; then slightly alkaline with ammonia, and then slightly acid with acetic acid; heat to boiling, and titrate with standard lead acetate solution, using dilute tannic acid as indicator. The colour will change from a deep orange to a colourless drop; read the last trace of colour. Dissolve the iron precipitate in hot dilute hydrochloric acid, reduce with stannous chloride, and titrate for iron with potassium dichromate solution. Time 55 minutes.

INTERNATIONAL MOLYBDENUM CO., LTD.

B. C. Lamble, metallurgist to the Orillia Molybdenum Company, Ltd., gave the following method for the determination of molybdenum in ores:[1]

Usually ten one-gramme samples are weighed out into 250 c.c. beakers, 5 c.c. concentrated hydrochloric acid added, beakers placed on hot plate and solution evaporated to dryness, 10 c.c. concentrated nitric acid added, and mass boiled, addition of nitric acid and boiling continued till all solubles are in solution, 25 c.c. distilled water added, boiled, cooled, ammonia added to precipitate iron, etc., solution again boiled, filtered, precipitate washed with a solution 20 parts water and one of ammonia. The precipitate is dissolved on filter paper with a hot 1 to 1 nitric acid solution, and received in original beaker. Iron is again precipitated with ammonia, solution boiled and filtered, receiving in beaker containing first filtrate. Each filtrate will now measure about 75 c.c. We combine five filtrates giving two final filtrates of from 350 to 400 c.c. capacity. These solutions are boiled till only a faint smell of ammonia is discernible, a small piece of blue litmus paper is dropped into the solution, and acetic acid added till solution is barely acid. This is then titrated while hot with a standard lead acetate solution, using a 1 per cent solution of tannic acid for an outside indicator. The lead acetate solution contains 15·7 grammes lead acetate per litre, and it is standardized against a known ammonium molybdate solution, the lead factor multiplied by 0·464 gives molybdenum factor. Twenty-five c.c. of the ammonia molybdate solution is measured into a flask, diluted with distilled water to 100 c.c. and boiled. The lead acetate solution is run in until a drop of this solution added to a drop of tannic acid in spot plate fails to give a yellow coloration. This is the inverse to the well-known Alexander method for lead.

The flakes are somewhat harder to get into solution. One-gramme samples are weighed out (in duplicate) into beakers, covered with concentrated hydrochloric acid, and placed on hot plates and solution taken to dryness. Treatment with the acid is continued till no sign of molybdenite is showing. About 20 c.c. of 1 to 1 ammonia is added and solution boiled. It will be seen that particles of molybdenite will now appear. This is due to the flakes becoming coated with molybdic acid, which is dissolved by the ammonia, exposing the untouched molybdenite. The precipitate and unattacked flakes are allowed to settle and solution poured through filter, the residue being washed three or four times by decantation with small amounts of hot water. The residue is treated with nitric acid, and then ammonia till all the molybdenite is in solution. Solution finally titrated as above.

The percentage of metallics to total sample, multiplied by percentage molybdenum found in metallics, equals metallic assay. This, plus fines assay, equals total assay.

For ores containing appreciable amounts of lead, copper, etc., the treatment is the same until point is reached where the ammonia is added. This is added till solution is just alkaline, a few c.c. ammonia sulphide added to precipitate iron, lead, copper, etc., and then a few c.c. in excess. The beaker containing solution set in warm place till precipitate has settled. The whole is then filtered, and precipitate washed with a weak ammonium sulphide solution. The precipitate is then rinsed into beaker and a hot mixture of equal parts nitric acid and bromine water is passed over filter paper to dissolve any adhering precipitate. The whole is boiled and then re-precipitated with ammonia and ammonium sulphide. Filter and wash precipitate with the weak ammonium sulphide. The combined filtrates will show a deep brown colour if much molybdenum is present. The solution is made just acid with hydrochloric; this theoretically will throw all the molybdenum, but it is best to pass a rapid stream of hydrogen sulphide through for 10 to 15 minutes to make sure of this. The sulphide is filtered off and washed with H_2S water.

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[1] Can. Min. Jour., April 15, 1916, p. 185. B. C. Lamble.

The precipitate is rinsed into beaker using a hot solution equal parts nitric and bromine water to cleanse filter paper. The solution is boiled with frequent additions of bromine to insure oxidation of sulphur and complete solution. The solution is then diluted somewhat if necessary with distilled water, made faintly alkaline with ammonia, barely acid with acetic, and titrated whilst hot with the lead acetate solution as above.

For the determination of molybdenum oxide and ammonia molybdate dissolve 1 gramme molybdic oxide (MoO_3) in as little ammonia as possible. When all is in solution, dilute to 100 c.c. with distilled water, measure off 10 or 15 c.c. with pipette, run into flask, dilute, make barely acid with acetic and titrate as above. Dissolve 1 gramme ammonium molybdate in 50 c.c. distilled water, add few c.c. ammonia, dilute to 100 c.c. take aliquot part and titrate as above.

VOLUMETRIC METHOD USED BY MINES BRANCH FOR THE DETERMINATION OF MOLYBDENITE IN ORES AND CONCENTRATES

Take 0·5 to 1 gramme of ore, according to richness. Place in a quartz (or platinum) crucible of 50 c.c. capacity, and add 3 or 4 c.c. of fuming nitric acid. Allow it to stand at room temperature for ten minutes, then raise the temperature gradually until all action ceases, then evaporate just to dryness. Add 25 grammes of c.p. fused potassium bisulphate to the crucible, and heat over a Bunsen burner, raising the temperature gradually until all is well melted, and finally to a dull red heat until the fusion is complete. Run the fusion well up on the sides of the crucible, and when quite cold, place with the cover in a 400 c.c. beaker containing about one inch of water. Heat until disintegration is complete. Remove and rinse the cover, then lift out the crucible on a glass rod, and wash it. When the fusion is all dissolved, remove from the hot plate and add ammonium hydrate in excess, to precipitate iron, etc., (usually about 30 c.c. is sufficient). Allow the precipitate to settle and filter on a 11½ cm. filter into a 400 c.c. Erlenmeyer flask. Wash at least six times with hot water. To the filtrate add strong sulphuric acid until neutralized and about 10 c.c. in excess; usually about 25 c.c. in all is sufficient. It is best to dilute the acid slightly before adding, to prevent spurting. The solution is then heated and passed through a reductor. This consists of a piece of glass tubing two feet in length and three-eighths of an inch internal diameter, drawn out at the lower end, in which is placed a little glass wool. The upper end is connected with rubber tubing to a four-inch funnel with short stem. The reductor is filled with amalgamated zinc, the size that will lie on a ten-mesh sieve; finer size is apt to clog the tube. The lower end of the reductor passes through a two-hole stopper far enough to reach half-way to the bottom of a one-litre gas bottle. The gas bottle is connected with a suction pump having a valve to regulate the passage through the reductor. Before making a reduction, the reductor is washed out with hot dilute sulphuric acid solution. This heats the zinc and makes the reduction more effective. After passing the sample through the reductor, wash out at least four times with hot dilute sulphuric acid solution, and then titrate (see note) at once (at about 60 to 70° C.) with potassium permanganate solution to a pink tinge.

Note:—

Instead of titrating the reduced molybdate solution direct with standard potassium permanganate, better results are obtained by allowing the solution from the reductors to run into a solution of ferric ammonium sulphate which re-oxidizes the molybdate solution, and then titrate the ferrous ammonium sulphate solution produced with standard potassium permanganate in the presence of a titrating mixture, such as is employed in the determination of iron.

Make up a stock solution of 15 per cent ferric alum solution, and add sufficient sulphuric acid to make the solution acid. Measure out 25 c.c. of this solution, together with 20 c.c. of titrating mixture, and add to the gas bottle into which the reduced solution passes. Titrate to a pink tinge with the permanganate.

Potassium permanganate solution is prepared by dissolving 2·9 grammes of permanganate in one litre of water. This is standardized against c.p. molybdic acid (Baker's 99·9 per cent special), treated in the same manner as the method for ore. The result, multiplied by $\frac{10}{9}$, gives the value of the standard in terms of molybdenite—MoS_2. This strength of permanganate solution will give about one per cent, when 0·5 gramme sample is used. A blank is run on the zinc to obtain the correction for any contained iron, and this deduction made from the burette reading in every case.

Tungsten, vanadium, and arsenic interfere. Arsenic may be removed by adding 3 c.c. of a 4 per cent solution of copper sulphate to the sulphuric acid solution before passing through the reductor. The copper is precipitated, which also precipitates the arsenic. If tungsten or vanadium is liable to be present, the procedure may be as follows: After acidifying the filtrate from the iron, transfer to a small pressure flask, and pass hydrogen sulphide into the cold solution until saturated. Close the flask and immerse in boiling water until the precipitate (Mo but no W or V) has settled. Allow it to cool and filter, then wash with very dilute sulphuric acid. Dissolve the precipitate in ammonium sulphide and receive the filtrate in a 400 c.c. Erlenmeyer flask. Add 10 c.c. of strong sulphuric acid and 3 grammes potassium sulphate, then boil until nearly all the free acid is expelled, and finally over a free flame. Dilute, add 5 to 10 c.c. of sulphuric acid, heat and pass through the reductor.

LEDOUX AND COMPANY, NEW YORK

The following method of analysis has been supplied by the courtesy of Ledoux & Company, Inc.,[1] who were the official umpires for the molybdenum industry in Canada and the United States during the war.

Method for Molybdenum in Molybdenite Concentrates

Treat 0·5 grammes of pulp with 10 c.c. strong nitric acid and when decomposition is complete add 5 c.c. strong sulphuric acid and evaporate to fumes, boiling well until the mineral is decomposed. Take up with water and boil. If arsenic is present and the iron contained in the sample is small, which is usually the case, add a solution of ferric sulphate equivalent to about 75 mg. of Fe. The precipitated iron hydrate carries the arsenic. In the presence of very large amounts of arsenic the partial separation of this element by volatilization as $AsCl_3$ (described in second method) is recommended. Make alkaline with a large excess of ammonia and filter off the iron hydrate, washing with hot water. Dissolve the iron precipitate in dilute sulphuric acid and reprecipitate it, filtering into the beaker containing the filtrate from the original precipitation. Two separations of iron may suffice but with high iron a third may be necessary to insure complete recovery of molybdenum. Add one gramme tartaric acid to the ammoniacal solution and pass a brisk current of H_2S for at least twenty minutes. Molybdenum is held in solution as ammonium

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[1] Ledoux & Company, Inc., 99 John St., New York.

molybdenum sulphide. Make just acid with dilute H_2SO_4 (1-3) added a little at a time allow to stand warm for an hour. Filter the MoS_3, precipitate and wash it with dilute H_2SO_4 (2 per cent) containing a little H_2S. Throw the filter and precipitate back into the beaker, add 8 c.c. H_2SO_4 (d. 1·84) and 15 c.c. HNO_3 (d. 1·42) and evaporate to fumes, remove heat, add 5 c.c. more HNO_3 to the hot solution and again evaporate to fumes; repeat the additions of HNO_3 and evaporations, of which two or three may be necessary, until the filter paper is completely oxidized. Finally wash down the side of the beaker and cover with a fine jet of water and again evaporate to fumes. The object of adding water and again evaporating is to insure complete removal of nitrogen compounds. This cannot be done by simple evaporation to fumes, however prolonged the heat may be, but the addition of a little water breaks up nitroso-sulphuric acid and subsequent evaporation expels all nitrogen acids. Allow the beaker to cool, add 100 c.c. of water and heat until all soluble salts are dissolved. The solution should now contain about 5 c.c. of H_2SO_4 in 100 c.c. (8 c.c. of H_2SO_4 were used but part of it vapourized in the repeated evaporations to fumes). Add about 5 grammes of granulated zinc, let stand a few minutes (well covered). Copper, if present, is thus reduced to the metal. Filter the liquid through an asbestos plug or coarse filter to remove the precipitated copper and wash with dilute H_2SO_4 (5 per cent).

(*Note:* If copper is present some or all of it will dissolve in the ammonium sulphide solution containing the molybdenum. If copper is not present the preliminary treatment with zinc should be omitted.) The molybdenum in the filtrate from the zinc treatment is partly in the reduced condition. See that the solution has a temperature of about 50° C. and pour it through a reductor tube into an excess of ferric phosphate solution (35 c.c.) contained in the receiving flask. The end of the reductor tube should dip slightly beneath the surface of the iron solution in the receiving flask so that the reduced molybdenum is oxidized wholly at the expense of the iron solution and not all by the exposure to air. The reductor is the common form illustrated in Blair's Chemical Analysis of Iron, provided with a stop-cock at the bottom of the wider part. The zinc column should be about 8 inches long and $\frac{5}{8}$ inch diameter of 30-mesh zinc which has been amalgamated by treatment with mercuric chloride.

The receiving flask is an ordinary 600 c.c. heavy glass Erlenmeyer flask with a side tubulature for connecting with suction. The stop-cock in the reductor tube (at the bottom of the zinc column) should be so regulated that at least five minutes is required for the passage of the solution. After passing the molybdenum solution, wash the reductor tube twice with dilute sulphuric acid (5 per cent) followed by three or four washings with water; do not permit it to run "dry" but add fresh water solution as soon as the liquid is down to the top of the zinc column. The reduced solution at the bottom of the zinc column should be clear green, not olive green. The solution in the reductor flask will be red owing to partial oxidation of the reduced molybdenum at the expense of the ferric iron. Titrate it immediately with standard permanganate. The red colour fades as titration progresses and the solution becomes nearly colourless, finally the characteristic pink and reaction with permanganate is obtained.

Under the foregoing conditions of reduction the change is from MoO_3 to Mo_2O_3 and not at any intermediate state. The factor for $KMNO_4$ to Mo. may therefore be calculated from standardization against pure sodium oxalate.

A blank determination should be made on the reductor, using the same strength and quantity of dilute H_2SO_4 as is used in the determination and with ferric phosphate in the receiving flask. With good zinc the blank is 0·15 to 0·2 c.c.

Ferric Phosphate Solution

100 grammes Ferric ammonium sulphate.
150 c.c. Phosphoric acid (d. 1·85).
25 c.c. Sulphuric acid (d. 1·84).
Water to make 1,000 c.c.

Very High Grade Molybdenite Concentrates.

Dissolve 0·5 grammes in HNO_3 and H_2SO_4 as above, after evaporation to fumes, cool, add 5 c.c. of water and 20 c.c. of a saturated solution of SO_2—digest on a steam plate for half an hour to reduce As_5 to As_3 and again evaporate to a volume of 10 c.c. then add 25 c.c. HCl and boil rapidly to fumes. Any arsenic present is volatilized as $AsCl_3$. Take the residue up with water, add a few drops of H_2O_2 to oxidize the Fe, boil, separate Fe twice with NH_4OH. Boil the excess of NH_3 out of the liquid and proceed as in the longer method. This omits the MoS_2 separation which is unnecessary in the known absence of V and other interfering elements.

The convenient strength of permanganate is $\frac{1}{10}$ normal. The permanganate should be standardized against pure sodium oxalate. The value in terms of $Na_2C_2O_4$ multiplied by 0·47757 = Mo.

BURMA QUEENSLAND CORPORATION, AUSTRALIA

Two methods for the estimation of molybdenite, employed by the Burma Queensland Corporation, Wolfram, North Queensland, and described by W. H. Bowater,[1] are as follows:—

Colorimetric Estimation of Molybdenite.—Weigh out 1 gramme of the finely ground ore and treat with aqua regia. The solution is repeatedly evaporated to small bulk with HNO_3, and then continuously evaporated to a pasty consistency. Add 30 c.c. water and 10 c.c. HCl, warm, stir till clear, add 15 c.c. NH_4OH, and boil for a few minutes; filter into a 250 c.c. flask, wash precipitate on filter with hot water, make the solution just acid with acetic acid, then add 10 c.c. strong acetic acid in excess; cool, make up to the mark, and mix.

The solution is now ready for comparison with a standard ammonium molybdate solution.

Standard Ammonium Molybdate Solution.—Deliver 2 c.c. of ordinary molybdate solution, as used for estimating lead (9 grm. per litre), into 250 c.c. graduated flask, also add 20 c.c. HCl and 30 c.c. NH_4OH, and boil for a few minutes, to obtain approximately the same conditions as in sample. Make just acid with acetic acid, and add 10 c.c. acetic acid in excess; cool, make up to mark, and mix. The solution is now ready for comparison with the solution.

Colour Comparison.—Make up a fresh solution of tannic acid, 0·5 gramme to 100 c.c., and fill up a burette with the standard, a second with the sample, a third with tannic acid; run 2 c.c. of standard and 2 c.c. of tannic acid into a 50 c.c. Nessler tube; dilute to mark and mix gently. To a second Nessler tube deliver 2 c.c. tannic acid, and then run in sample until the same colour is obtained.

Calculation.—The value of the standard molybdate solution is calculated as follows:—The ordinary molybdate solution is usually standardized against 0·3 grm. lead sulphate, which consumed, say, 20 c.c. of it; 0·3 grm. lead sulphate is equal to 0·1584 MoS_2; therefore, 2 c.c. = 0·01584 grm. MoS_2. This is the total value of the 250 c.c. kept as a standard. 0·01584 ÷ 125 gives the value of 2 c.c., the amount used in the Nessler tube for comparison, viz.:—0·0001267 MoS_2; thus if 8 c.c. of sample prepared from 1 grm. of ore were consumed the result would be 0·39 per cent MoS_2; 2 c.c. is chosen as giving a convenient colour, and maintained as far as possible for convenience of memory.

The following method is found to give good results on low-grade ores, battery-pulps, and tails.

Volumetric Estimation of Molybdenite.—1 gramme of the ore is weighed out and treated with HNO_3 and a little HCl, the MoS_2 being converted into molybdic acid. The solution is repeatedly evaporated to small bulk with HNO_3, and then continuously evaporated to a pasty consistency.

The residue is extracted with NH_4OH, the solution boiled, then filtered, washing the residue well with hot water. The solution is made up to 250 c.c. and mixed thoroughly; 20 c.c. of standard lead sulphate solution (measured from burette) are taken, acidified with acetic acid, diluted to 100 c.c. and boiled. This solution is then titrated with the assay solution until a faint yellow tinge is obtained, using tannic acid solution as indicator (usual volumetric method for Pb).

On the basis of 1 gramme taken, the reading obtained, less 0·2 c.c., divided into 1978·75, gives the percentage of MoS_2.

Preparation of Standard Lead Sulphate—Weigh out 7·5 grammes of pure dry $PbSO_4$; take up with 400 c.c. of ammonium acetate (slightly acid with acetic), and dilute to 1 litre.

When dealing with rich molybdenite concentrates, take 40 c.c. of $PbSO_4$ solution instead of 20 c.c.; note reading, deduct 0·2 c.c., and divide by 2 before dividing into 1978·75.

The filter paper containing $FeSiO_2$, etc., can be dried, ignited, and weighed as a rough check against the figures. The addition of percentage of insoluble and MoS_2 giving approximately 99 per cent.

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[1] Proc. Aust. I. M. M., N.S. No. 40, p. 268, Dec. 31, 1920.

DETERMINATION OF MOLYBDENUM IN THE PRESENCE OF COPPER

Owing to the fact that copper in molybdenite concentrates is injurious when they are to be used for making ferro-alloys, or steels, great care should be taken to accurately determine the quantity of copper present. The quantity of this metal allowed varies according to the subsequent nature of treatment, as some processes of roasting and extracting the molybdenum renders the copper insoluble in the residue. Generally, the maximum allowance varies from 0·2 to 0·5 per cent copper.

Molybdenum hinders the ordinary methods of determination of copper. The standard iodide method cannot be used without previously separating the molybdenum from the copper, since molybdenum liberates the iodine. In this method, metallic zinc, or aluminium, will not completely precipitate the copper in the presence of molybdenum, also hydrogen sulphide precipitates both metals as sulphides. The use of sodium hydroxide is satisfactory, but it takes a long time and the solution, after each addition of the caustic, must be boiled for half an hour to render the copper completely soluble.

In the electrolytic method considerable time must be taken to make all the necessary conditions correct and remove the interfering elements, also part of the molybdenum is precipitated, although one part of sodium chloride will prevent the precipitation of six parts of molybdenum.

Experiments on this special analysis by T. P. Bonardi and Max Shapiro[1] resulted in their finally using a modification of the thiocyanate method. This process is described in detail by the above authors, with the various chemical reactions. The method as conducted by the Mines Branch laboratories at Ottawa, which has been described in detail, entirely eliminates the interference of copper, in the molybdenum determination. The following is the Mines Branch method of analysis for copper in molybdenum ores or concentrates.

Determination of Copper in Molybdenite Concentrates.

Treat from one-half to one gramme of the sample precisely as described for the determination of molybdenum (Mines Branch, Ottawa, method) until complete solution of the fusion has been obtained.

To the warm solution add double normal sodium hydroxide solution until neutralized, and a sufficient excess to precipitate the copper and iron. Filter and wash. Dissolve the precipitate in dilute acid and evaporate the fumes. Cool, dilute, add about 3 c.c. of nitric acid, and electrolyse.

The precipitated iron and copper hydrates may be dissolved in dilute sulphuric acid, and the copper determined volumetrically by means of the iodide method with standard sodium thiosulphate described in common reference.

QUALITATIVE AND QUANTITATIVE TESTS FOR MOLYBDITE IN THE PRESENCE OF MOLYBDENITE

Owing to the fact that no reliable method has been found for the recovery of yellow ferri-molybdite, its presence with molybdenite should be carefully noted and allowed for in calculating the recovery of molybdenum in ores.

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[1] Chem. and Met. Eng., May 11, 1921, p. 847.

The following is an extract on the analysis of molybdite in the presence of molybdenite, by J. P. Bonardi.[1]

The following chemical test for molybdite in presence of molybdenite has been tried out in the laboratory of the Golden station of the U.S. Bureau of Mines, and has proved reliable for detecting molybdenum down to 0·01 per cent molybdenum on the basis of a 1-gramme sample. A complete solution away from the sulphide mineral can be effectively made by one of the three following reagents: A 10 per cent solution of hydrochloric acid, a 10 per cent solution of ammonium hydroxide, or by a 5 to 10 per cent solution of sodium carbonate. The ore is ground fine, placed in an Erlenmeyer flask, 200 c.c. of water added and then enough of one of the above reagents to make a 10 per cent solution. This is then boiled for thirty minutes, filtered and washed. Before filtering the HCl solution it is made first ammoniacal to precipitate out the bulk of the iron. Any of these three methods of solution will completely dissolve the oxide of molybdenum in a boiling solution without affecting the sulphide to the least extent. This has been thoroughly tried out and has always given reliable results. Pure molybdenite was given the same treatment, but none was found in solution in any of the three cases.

The filtered solution of any one of the above filtrates is then tested for molybdenum by the thiocyanate test as follows: The filtrate if alkaline is acidified with HCl and some H_2O_2 added to oxidize any reduced iron or molybdenum that might have passed through into the filtrate. This is boiled to drive off most of the excess H_2O_2 and is then made ammoniacal. If any iron hydroxide separates out, filter and wash. To the filtrate, which is now free from iron, aluminium and silica, make acid with HCl, add some ammonium or potassium thiocyanate and immediately follow by zinc. If any molybdenum is present, a bright cherry-red colour will develop which will disappear only on standing for a prolonged period, depending upon the amount of molybdenum present in the solution to be reduced. If hydrogen peroxide is added to the solution after the cherry-red colour has developed, the colour disappears, but will return as soon as the peroxide has been reduced. This colour reaction with thiocyanate is very definite and certain, but if the mistake is made by adding the zinc first, which reduces the molybdenum, and then later followed by the thiocyanate, scarcely any colour will be developed. When only traces or small amounts of molybdenum are present, a concentration of the cherry-red colour can be obtained if the solution is shaken with a small volume of ether, when any colour in the liquid will be extracted by the ether and intensified as a golden brown in the ether rings that form at the top of the liquid on standing. The thiocyanate colour produced when iron is present in solution soon changes colourless, by the addition of zinc, usually before the cherry-red colour of the molybdenum starts to develop.[2]

Weigh 5 to 10 grammes of the finely pulverized molybdenite ore in a 400 c.c. Erlenmeyer flask. Add 200 c.c. water and then one of the following: 20 c.c. strong ammonia, 20 c.c. concentrated HCl, or 15 grammes Na_2CO_3 and boil vigorously for 30 minutes. Wash the sides of the flasks down with water, filter and wash. To the filtrate, if alkaline digestion was made, add HCl to acid, followed by a few c.c. of hydrogen peroxide and boil. Hydrogen peroxide is also added to the HCl filtrate; this oxidizes the iron which might have been carried in solution in a reduced condition. Next, add ammonia in excess and heat. If any precipitate settles out—consisting of iron, alumina and silica—filter and wash. If large in amount, dissolve in HCl and reprecipitate, wash and filter. The molybdenum now in the form of soluble molybdate should have a volume of approximately 350 c.c. Make the solution acid with HCl, using methyl orange as an indicator, adding about 5 c.c. excess of acid. Add 5 to 10 grammes ammonium acetate—enough to decompose the free mineral acid—and 2 to 5 c.c. of acetic acid. The solution is next heated to boiling and precipitation of the molybdenum is now made in the hot solution by titrating the molybdenum content in the solution with a lead acetate solution (about 18 grammes crystallized lead acetate per liter) added slowly from a burette until a test drop taken from the solution gives no colour change with a drop of freshly made tannic acid solution (about 0·10 gramme dissolved in 20 c.c. of water) used as an outside indicator. The disappearance of the brown colour indicates when all the molybdenum has been removed from solution by precipitation. Next add 2 or 3 c.c. excess of the lead acetate solution and place the beaker back on the hot-plate and keep at or near the boiling point until the precipitate has crystallized and settled.

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[1] Chem. and Met. Eng., Aug. 4, 1920, p. 205.

[2] Treadwell, F. P., and Hall, W. T., Analytical Chemistry, Vol. I, 1912, pp. 437-438.
Kedesdy, E., Detection of Molybdenum, Chem. Abs., Vol. 7, 1913, p. 3940.
Prescott, A. B., and Johnson, O. C., Qualitative Chemistry, 1912, p. 97.
Horton, F. W., U.S., Bull. 111, 1916, p. 40.

When settled, filter hot and wash well with hot water; if precipitate is bulky, wash with a 2 to 3 per cent solution of ammonium acetate. The washed filter is placed in a fireclay annealing cup and ignited at a dull red heat. After complete ignition of the paper, cool and weigh directly. The weight of the $PbMoO_4$ times 0·2615 gives the weight of the molybdenum in the precipitate, from which the percentage can be calculated.

The size of the sample taken for an analysis should be chosen if possible as not containing over 0·15 gramme molybdenum (equivalent to 0·25 gramme MoS_2), since above this amount the precipitated lead molybdate will be too bulky to handle to the best advantage. Hydrogen peroxide can not be added in the digestion of the sample along with the alkali or acid, since in combination with these reagents a chemical action will take place on the sulphide mineral, molybdenite, and render it appreciably soluble. A large excess of lead acetate should be avoided.

The following results are typical of an analysis carried out as outlined, showing the comparison of results as obtained by the three methods on the same sample of partly oxidized molybdenite ore containing a total of 5·2 per cent molybdenum, the molybdenum content being distributed in approximately the ratio of 1:1 between molybdite and molybdenite mineral.

Weight of sample grammes	Treatment—½ hour of boiling	Weight $PbMoO_4$	Per cent Mo.
5	200 c.c. H_2O + 10 grm. Na_2CO_3........	0·4820	2·52
5	200 c.c. H_2O + 25 c.c. HCl	0·4770	2·49
5	200 c.c. H_2O + 30 c.c. NH_4OH.........	0·4800	2·51

METHOD FOR THE DETERMINATION OF SULPHUR IN FERRO-MOLYBDENUM[1]

Take 2 grammes of the sample in a 400 c.c. beaker and add to this a mixture consisting of 4 c.c. of bromine water and 6 c.c. carbon tetrachloride. Let it stand at room temperature for about ten minutes, agitating occasionally. Cover the beaker and add continuously 15 c.c. of concentrated nitric acid. Let it stand again for another ten minutes, then place on the hot plate and raise the temperature gradually; keep at this point until all is in solution, then evaporate slowly just to dryness. Add a small pinch of sodium carbonate and take up in 30 c.c. of concentrated hydrochloric acid. Again evaporate to dryness, and heat slowly from one to two hours to dehydrate the silica. Take up 20 c.c. of concentrated hydrochloric acid, or sufficient to hold all soluble salts in solution, dilute in hot water to about 85 c.c. and filter the clear solution into a one-litre beaker. Wash well with hot water. Cool the filtrate and dilute to 700 c.c. To the cold solution add slowly 15 c.c. of a 10 per cent solution of barium chloride. This is best done by dropping from a burette, taking about five minutes to add the 15 c.c. Set aside and let stand until all the barium sulphate has settled. Pour the supernatant liquid through a 11 cm. ashless filter, and then wash the filter and the precipitate still in the bottom of the beaker with a little warm dilute hydrochloric acid (one of acid to three of water). Finally, transfer the precipitate to the filter and wash well with warm water. Dry, ignite, and weigh as barium sulphate.

Caution. Make sure that all reagents used are free from sulphate.

It is not advisable to determine the sulphur from the filtrate from other determinations, as there is always a danger of contamination.

Make sure that there is always sufficient hydrochloric acid present in the solution before adding the barium chloride, in order to produce a clear solution. There should be no cloudiness from precipitated molybdic acid. On the other hand, do not have too large an excess of free hydrochloric acid present, as it interferes with the precipitation of the barium sulphate.

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[1] By H. C. Mabee, Mines Branch, Ottawa.

CHAPTER II

CONCENTRATION OF MOLYBDENUM ORES

GENERAL

One great drawback to the molybdenum industry was the difficulty of recovering molybdenite from its ores. The application of oil flotation, followed by the Thornhill patent for washing the concentrates, almost entirely eliminated this difficulty, and molybdenite, when fairly clean, is now one of the easiest minerals to concentrate. During the first three years of the war, metallurgists of the chief molybdenite-producing countries devoted much time to the study of this problem. F. W. Horton[1] gives a good description of the tests made and methods employed up to date of the publication of his report.

The first experiments in Canada were made in 1903 by J. E. Walter Wells, of Kingston,[2] who tried screening, jigging, tabling, magnetic separation, and Elmore bulk oil.

In 1905-6 tests on molybdenite ores in Messrs. Elmores' laboratories indicated the amenability of these ores to the Elmore vacuum process.[3]

A recovery as high as 98·1 per cent molybdenite with a loss in the tails of only 0·10 per cent was obtained in one of these tests.

In consideration of the results obtained from these tests it seems strange that this process was not more universally adopted, and that experiments in concentration were not conducted along the lines of this process. Several Elmore plants in operation in Norway prior to and during the early days of the war, gave satisfactory results, and when this process was adopted later by a Canadian producer, it produced a steady output of concentrates that were superior to those produced by other methods. A description of this process will be found elsewhere.

In 1916-17, the Wood water-film flotation process was the best system employed, but the best results were obtained only by expert operators. In 1918 oil flotation was adapted to the concentration of molybdenite ores and proved to be more efficient than any of the other processes.

ORE CONCENTRATION BY THE MINES BRANCH, DEPARTMENT OF MINES, OTTAWA

Although all methods of concentration employed previous to the introduction of the Callow pneumatic oil flotation process have been abandoned, an account of each process is given in order to lay before the prospective mill man all the various methods that were tried and the reasons for their failure.

HISTORICAL—VARIOUS CONCENTRATION EXPERIMENTS

The following is a historical review of the work done by the Mines Branch on the concentration of molybdenite ores.

Sizing and Jigging. The first attempts at concentration consisted in sufficient crushing to free the molybdenite, followed by careful sizing

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[1] U.S. Bur. of Mines, Bull. 111, Molybdenum: Its Ores and their Concentration, p. 91, 1916. F. W. Horton.

[2] Can. Min. Review, May 30, 1905, p. 113.

[3] Can. Min. Inst., Ann. meeting, March, 1919. Concentration of Molybdenite. H. H. Claudet.

and jigging. It was soon found that this method would not be suitable, since the heavier particles of molybdenite remained with the pyrites and pyrrhotite in the jig concentrates, and the lighter and finer flakes of molybdenite remained with the gangue minerals in the tails.

Tabling. Mica was eliminated by tables, but there was hardly any separation of the pyrite and heavy gangue from the molybdenite.

Electrostatic Separation. The electrostatic process depends upon the difference in conductivity between minerals which are relatively good conductors, such as molybdenite, pyrite, pyrrhotite, chalcopyrite, etc., and non-conductors, such as quartz, feldspar, calcite, and most silicates.

Preliminary work with this method of separation was encouraging, but it was almost impossible to make clean, high-grade commercial concentrates, as they could not be entirely freed from the other named conductors, which were deleterious.

From a commercial point of view its application is both delicate and limited. To obtain success the ore must be one in which the associated gangue minerals are non-conductors. The ore must be dry and warm and the current in the electrostatic leads carefully regulated.

Wind Machine. To take advantage of the flat flakes of molybdenite a wind machine was built, consisting of two drums over which passed an endless belt made of fine wire screen. A suction fan drew air through this belt into one of the drums. The crushed and sized ore was fed on this screen belt which moved towards the drum under suction. The larger molybdenite flakes adhering to the belt were carried away from the more rounded particles of gangue and a fair separation was made. The chief difficulty was the impossibility of reducing all particles of molybdenite into scales, thin and flaky enough to be influenced by the suction; moreover, any other flaky minerals present, such as mica, graphite, etc., remained with the molybdenite.

Magnetic Separation. Experiments in magnetic separation resulted in the removal of certain magnetic minerals only, or minerals made magnetic by preliminary roasting. Dry crushing of the ore is important, and care should be taken to pulverize the ore to a point at which the molybdenite is entirely freed from any adhering magnetic minerals.[1]

Roll Crushing and Screening. The ore was broken to one inch or less and then passed through rolls to flatten the soft molybdenite into flakes and at the same time crush the harder gangue minerals to a fine powder. This product was passed over suitable screens through which the fine gangue passed leaving the flaky minerals on the screens. The grade of concentrates obtained depended on the nature of the associated gangue and richness of the feed.

Flaky minerals, such as mica and graphite, invariably remained with the molybdenite. Feldspar also has a tendency to flatten in the rolls and the fine gangue became embedded in the flakes of molybdenite, making further concentration very difficult. It was found that there was practically no concentration of fine flake, or amorphous ores.

In applying this method, commercially, if the ore contains a high percentage of large flake, hand-cobbing, followed by a picking belt between rolls and screens may be employed advantageously.

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[1] Extracts from Sum. Rept. Dept. of Mines, 1915, p. 80. G. C. Mackenzie.

In many small properties which do not at first justify the erection of a complete milling plant, and where the ores are too low grade to ship directly to a concentrator, a roll screen equipment could be installed, to treat 10 to 25 tons per day and raise the grade of 0·5 per cent or 1 per cent ore to 15 or 20 per cent, which could then be shipped at a profit to re-treatment plants. The tailings, or fines, could be held for further treatment should a complete milling plant be erected at a later date. The accompanying sketch shows a typical machine suitable for the above purpose. (Figure 41.)

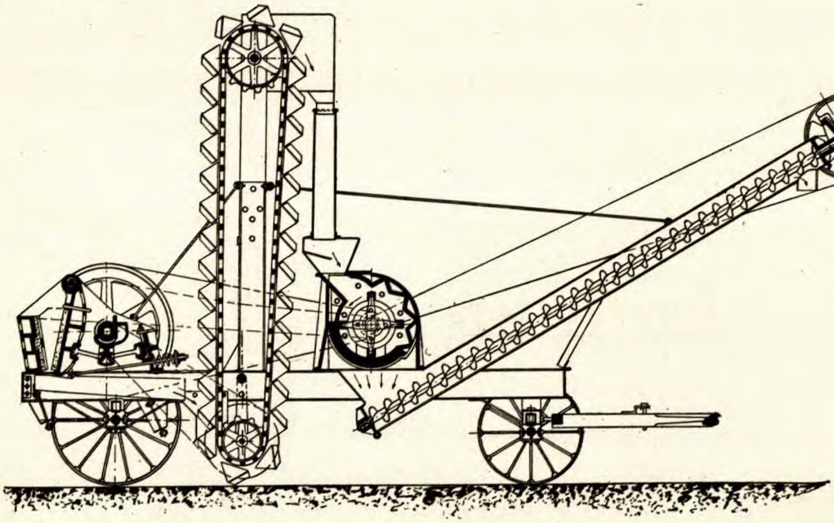

Figure 41. Complete crushing plant for small molybdenite deposit.

The results of the experimental work, done by the Mines Branch staff during the first year of the war, may be summarized as follows:—

1. Ordinary specific gravity methods of separation are not applicable to molybdenite ores, but can be applied to save other values in complex ores, after the molybdenite has been extracted.

2. Electrostatic separation is only applicable to pure molybdenite ores, containing only calcite and silicate gangues.

3. Pneumatic separation is of no practical commercial value.

4. Magnetic separation machines will only remove certain magnetic minerals, or minerals rendered magnetic by preliminary roasting. The operations in conducting the latter are delicate and costs are heavy.

5. Roll crushing and screening is only applicable to coarse flake ores free from mica. It should only be used as a preliminary to further treatment, and to reduce transportation costs.

6. A careful combination of some, or all of the above methods might result in a good separation of the molybdenite, but the flow-sheet would probably be expensive, complicated and delicate, and would require too much individual attention for commercially practical results.

FLOTATION—MINERALS SEPARATION

Numerous experiments on molybdenite ores having proved that no practical results could be obtained from the ordinary gravity, or older methods of concentration, attention then turned to oil flotation, and a small Minerals Separation plant was installed, in which the Hoover valveless apparatus was used.

The theories and principles of oil flotation[1] need not here be gone into, but briefly they are as follows:—

Certain minerals, notably sulphides when made into a pulp with water are easily coated by most oils, but the gangue and other minerals are no so affected. These oil-coated particles tend to float, but the gangue, etc., sinks. Flotation is very materially increased by means of air bubbles that automatically attach themselves to the oil-coated minerals, thereby increasing the effective surface of flotation and buoyancy. These bubbles may be produced by violent agitation of the pulp; by injection of air through a porous medium; by reduction of pressure; or by gases formed by the action of acids on the gangue.

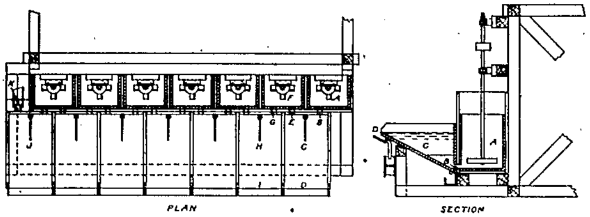

Figure 42. Hoover valveless apparatus, Minerals Separation process.

The Hoover Minerals Separation machine[2] as used in the Mines Branch tests is illustrated in Figure 42 which shows a plan and section of the apparatus.

It was found that other sulphides as well as molybdenite were recovered in the concentrates and it required repeated frothings before clean tails were produced. The concentrates were roasted at a low temperature in order to oxidize the pyrite and pyrrhotite and the whole was again refloated and yielded a fairly high-grade molybdenite concentrate.

These experiments showed a marked improvement over the old gravity methods, but at that time oil flotation was almost unknown in eastern Canada, and experience in this form of concentration was much more limited than at present, and the methods of feeding, handling the ore, and apparatus used were crude.

Detailed descriptions describing the latest developments of this and other Minerals Separation machines may be obtained from any of the numerous recent articles dealing with the process. The machine can be constructed with any number of agitators, and can have a capacity from

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[1] See "The Flotation Process," H. A. Megraw, 2nd Ed. 1918—McGraw-Hill Publishing Co., New York.
"Flotation," T. A. Rickard and O. C. Ralston.
"Concentrating Ores by Flotation," T. J. Hoover.
"Testing for the Flotation Process," A. W. Fahrenwald.
"A contribution to the study of Flotation," H. L. Sulman, Vol. XXIX, Trans. Inst. Min. & Met., London, 1919-1920, pp. 44-204.

[2] The Mining and Metallurgical Treatment of Molybdenum Ores in Canada. G. C. Mackenize.

25 tons per 24 hours upwards. Commercially the Minerals Separation process would be successful on most molybdenite ores, and good results can be expected by careful choice and quantity of oils that are necessary for differential flotation. No details of any commercial plant using this process on molybdenum ores are available, but it has been used in Norway and Australia.

WATER-FILM FLOTATION PROCESS

While the Mines Branch was experimenting with the Minerals Separation process, their attention was drawn to the good results obtained by Henry E. Wood, of Denver, Colorado, with the Wood water-film flotation machine on Colorado ores. The Department immediately stopped further experiments in oil flotation and turned to film flotation, and the results obtained warranted the installation of a full-sized unit. A full description of the Woods machine will be found in a paper read by Mr. Wood before the Canadian Mining Institute[1] annual meeting.

This method is based on the principle of surface tension, advantage being taken of the fact that molybdenite resists wetting, forming a tenacious film floating on the surface, whereas the gangue, oxidized sulphides, and other associated minerals which are more or less easily wetted, sink. In order to obtain good results, it is necessary that the ore be thoroughly dried, both to assist the flotation and to slightly oxidize the iron sulphides, care being taken not to affect the molybdenite.

Although commercial results were obtained with the original unit installed, certain alterations were subsequently made in the Wood machine and the apparatus worked more satisfactorily under all conditions. There was some trouble with the conveyer belt, which required very delicate adjustment to prevent particles of molybdenite from becoming wet and sinking at the point where the film is picked up by the belt. To prevent losses at the edges of the tank, horizontal guides had to be used. These caused compression which resulted in particles of molybdenite sliding over one another and thus becoming drowned.

The following is a description of a modified Wood film-flotation machine as used by the Mines Branch.

MINES BRANCH FILM FLOTATION

In this machine (Figure 43) the same method of feeding the ore is used, but both the conveyer belt and dewatering screen are eliminated. The machine consists of three tanks, A, B, and C. The film of mineral, on being deposited on the surface of the water in tank A is allowed to flow freely without compression, impelled by submerged water jets, directly into tank B, where it passes over a series of ripples produced by five sets of water sprays placed immediately below the surface. These ripples split up the mineral film and allow the entangled gangue particles to separate and sink. The film passes into the tank C by an inclined slide R over which the water is so regulated as to be just sufficient to carry the mineral film forward.

It is claimed that the molybdenite flakes being flat, will readily slide down this incline without turning over, even though they touch the bottom, whereas a gangue particle, on account of its shape, will be rolled over and over and become wet and sink in tank C. The wetting of the gangue is

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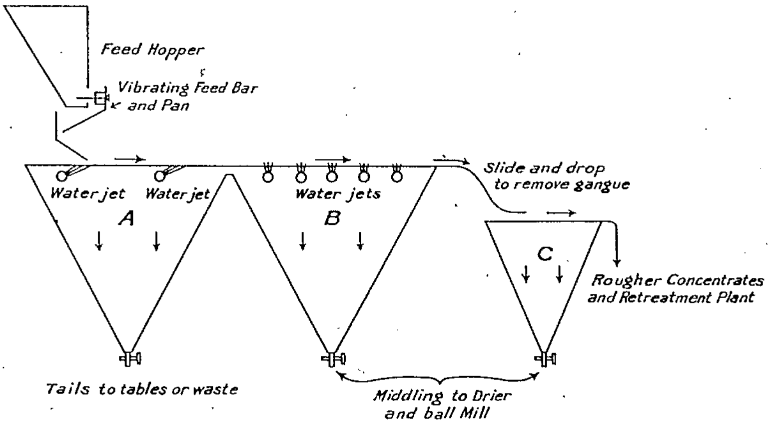
[1] Can. Min. Inst., Bull. Annual Meeting, Ottawa, 1916, by Henry E. Wood, p. 123.

helped by giving the mineral film a slight drop from the slide to the surface of water in C. In operation the machine makes a tailing from A, a middling from B and C, and a concentrate from the overflow of tank C.[1] There are three rougher flotation machines and one cleaner, the capacity of each machine being rated at about 6 tons per 24 hours. The floor space occupied by each is 6 by 5 feet.



	Average assay		Percentage of total MoS_2
Crude ore	- 2 %	MoS_2	
Tailings	0·10-0·35 %	"	15 %
B Middlings	3·00 %	"	8 %
C Middlings	10·00 %	"	
Rougher concs.	40-60 %	"	77 %

Figure 43. Detail of water-film flotation machine, Mines Branch, Department of Mines, Ottawa, Canada.

The ore after being crushed to 1½ inch in a Blake crusher is sent to a storage bin, from which it is fed to rolls set with half-inch openings. The rolled product after being automatically sampled is dried and further ground to 20 mesh in a Krupp or Traylor ball mill. The dry ground ore is then fed to the flotation machine, which makes three products—rougher concentrates, containing about 50 per cent or higher, with rich ores; middlings which are sent to a middling drier and thence back through the circuit via the ball mill; tailings that are passed over tables, giving concentrates that are sent to a middlings drier and thus returned; table tails to waste. Tails contain 0·2 per cent or less molybdenite.

The rougher concentrates, after being dried on the concentrates drier, are sized on a Keedy sizer into a number of sizes for separate treatment. There are 9 screens from 6 to 70 mesh. The plus 20 products are usually very small in proportion to quantity, but of high enough grade for a finished product; the remaining sizes are stacked and treated separately in the cleaner machine. The cleaner middlings and tails are returned to the drier

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[1] See Concentration of Canadian Molybdenite—Can. Min. Inst., Annual Meeting, 1917. Eng. and Min. Jour., May 5, 1917, p. 786. H. H. Claudet.

and ball mill. Any pyrites in the rougher machine products, or cleaner middlings, are partly oxidized in the course of re-drying and sink when re-treated. The plant was in operation from June, 1916, to December 31, 1916, treated 1,300 tons of ore (1·64 per cent MoS_2), and recovered approximately 19 tons of pure molybdenite.

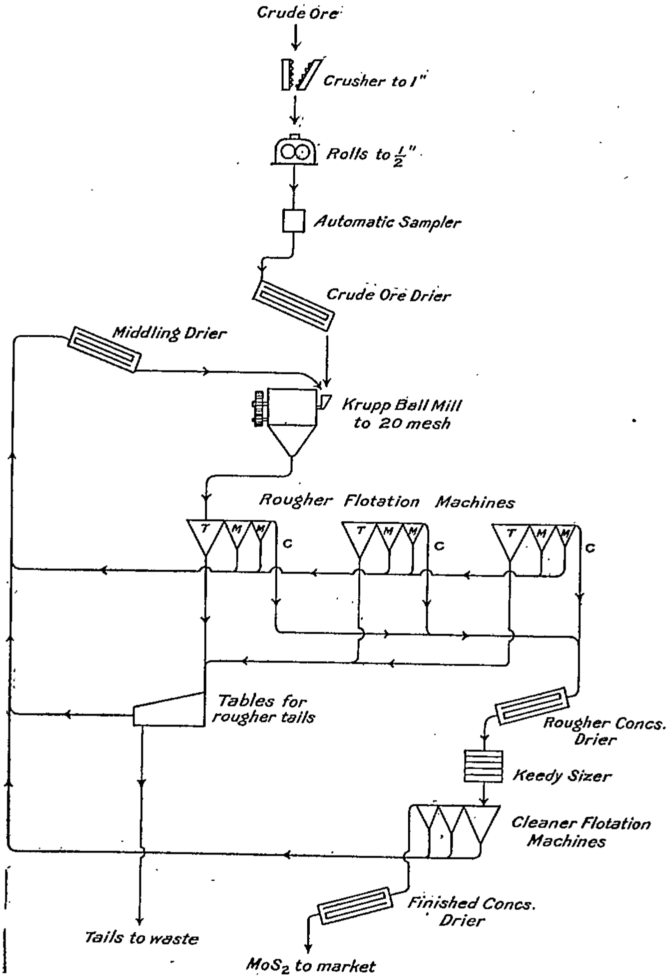

Figure 44. Flow-sheet of molybdenite concentrator using water-film flotation method, Mines Branch, Department of Mines, Ottawa, Canada.

The conclusions arrived at by the Branch, after treating a large quantity of different ores, were:—

1. By far the best grade of concentrates were produced by this method.
2. Recovery was good.

3. The flotation machines required a good deal of attention and adjusting from time to time to secure the best results, good judgment and skill in the operators being essential.

4. Owing to the repeated drying, the cost of fuel and handling is a heavy item, and unless carefully done such drying is liable to affect the flotation properties of the ore.

5. There was always a loss in slimes.

6. Fine-grained or microcrystalline molybdenite ores, such as occur in British Columbia, were not readily amenable to this form of concentration.

The flow-sheet of the Mines Branch mill at Ottawa (Figure 44) was similar to the above. The ball mill was replaced by a 4½-foot Hardinge. As there was only one rougher and one cleaner cell, the middlings, or dirty concentrates of the more complex ores, had to be re-treated in the same cells.

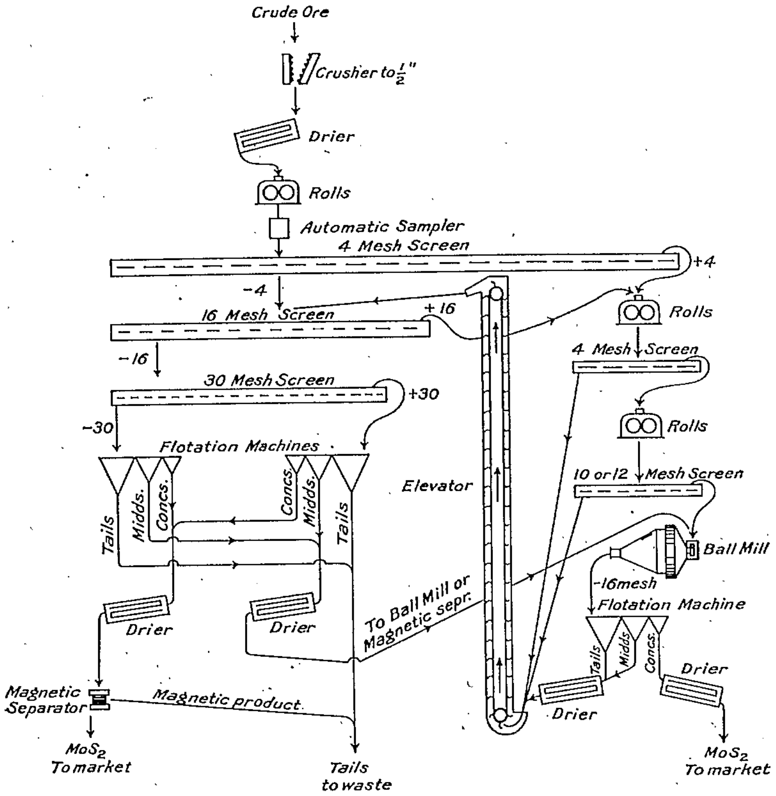

Figure 45. Flow-sheet "B," Wood water-film flotation process, as suggested by Henry E. Wood, to treat complex, coarse molybdenite ores.

WOOD PROCESS

The following are the results obtained from treating one ton of ore according to flow-sheet B.[1] (Figure 45).

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[1] Concentration of Molybdenite Ores, by H. E. Wood, Can. Min. Jour., 1916, p. 123.

TABLE XXVII

Results of Treating MoS_2 by the Wood Water-Film Process

Test No. 10—Locality of ore—Ontario, Canada.

——	Weight	Weight	MoS_2	Fe	S	Insoluble	Recoveries
	Pounds	%	%	%	%	%	%
Crude ore—16-mesh	2,000	100·00	1·73	36·4	24·48	29·9	....
1st grade 4-mesh scales	12·6	0·63	74·00	....	....	....	26·90
−16 + 30-mesh product	12·0	0·60	79·50	....	....	....	27·55
−30-mesh product	13·0	0·65	70·00	....	....	....	26·25
Total middlings for re-treatment	94·0	4·70	3·80	33·10	....	33·00	10·30
Tailings	1,725·0	86·25	trace	38·20	....	24·60	....
Overflow loss	143·4	7·17	....	....	....	....	....
	2,000·0	100·00	....	....	....	....	....

Assay of combined concentrates = 74·4 per cent molybdenite. Total recovery 80·70 per cent.

Notes: Roasting and magnetic cleaning raises the concentrate to 82·6 per cent molybdenite.

All concentrates of this test were re-floated, actual capacities are:—

25 tons per 24 hours for −16 + 30-mesh size
5 " 24 " −30 "
Average 15 tons per 24 hours.

CALLOW PNEUMATIC OIL FLOTATION

After experiments with the Callow pneumatic oil flotation process had proved successful, the Mines Branch discarded the water-film process and installed two Callow units, and in a very short time results were obtained that were in every way better than with the former system, and at the same time the process proved to be much simpler and more economical.

The principles of flotation are similar to those described under the "Minerals Separation process," except that in the Callow system aeration is the main factor, instead of agitation. The Callow machine, a detailed description of which can be found in any modern treatise on oil flotation, consists of a narrow rectangular cell with a sloping bottom that is covered with a porous blanket. This blanket is connected with a controlled system of air under pressure from some form of blower. The previously oiled pulp, diluted with water, flows slowly through the tank. The air, passing through the blanket forms minute bubbles that attach themselves to the oil-coated sulphide particles, causing them to float. This is kept up until a mineral froth of 6 to 18 inches (according to the ore) is built up, after which it overflows the sides of the tank and is caught in the concentrates launder. This froth, unlike that in Minerals Separation, is not stable, and dies down immediately the air is shut off. The gangue sinks to the bottom and gradually flows down the incline till it finds an outlet into the tails launder. The depth of froth is controlled by the rate of flow at the tails outlet.

GENERAL FLOW-SHEET FOR MOLYBDENITE

The following description of a flow-sheet, with a few modifications, or additions, can be applied to almost any kind of molybdenite ore. (Figure 46.) Complex ores will need additional units and gravity methods to recover other values.

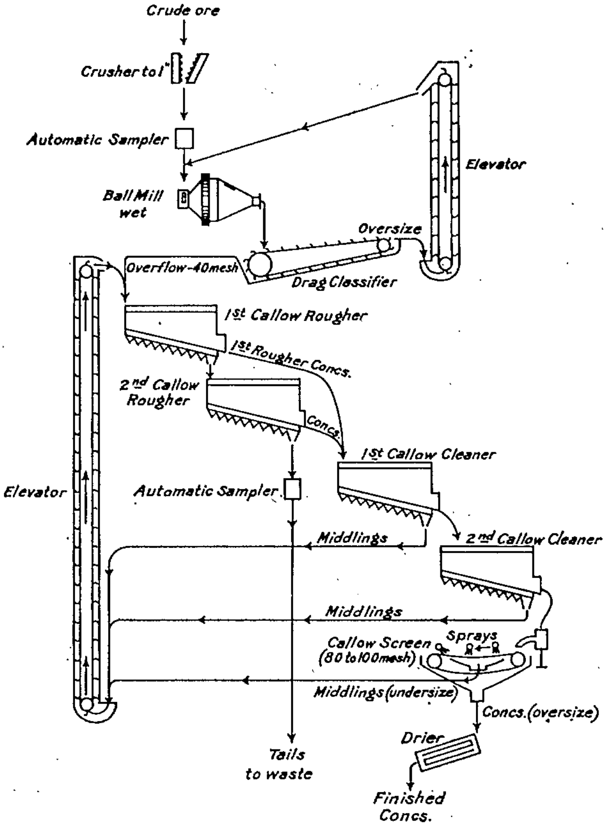

Figure 46. Flow-sheet of molybdenite concentrator using Callow pneumatic oil flotation process, Mines Branch, Department of Mines, Ottawa, Canada.

The crude ore from the mill bins is fed to a gyratory or jaw-crusher and crushed to about 1½ inch; after passing through a mechanical sampler (in order to obtain a sample of the mill feed) the ore is fed to a ball mill, preferably of the Hardinge, or Marcy type, in a closed circuit, with some form of classifier. At this point, water, flotation oils, and other reagents required, are usually added. The undersize from the classifiers, passes to the first Callow rougher cell. The first rougher tails (unless very clean) then pass through a second rougher cell, and after being sampled to check, go to waste.

The second rougher cell may be used as a safety valve when the first cell is shut down to change blankets, etc., and also is sometimes used to re-clean first rougher tails, if necessary. Concentrates from both cells then pass over a set of Callow cleaner cells where a more complete separation is made; the cleaner tails are returned to the head of first rougher, and the concentrates pass directly on to a Callow screen of about 80 or 100 mesh. The molybdenite concentrates, which are as a rule from 65 to 75 per cent, move along with this travelling screen in a flocculent condition, and the impurities, consisting of gangue, iron pyrites, etc., are washed through the screen by jets of water. The oversize, being the final clean concentrates, is dried and sacked, the undersize is sent back to the first rougher for re-treatment.

ORE TREATED BY THE MINES BRANCH, OTTAWA

During the war period the Mines Branch were acting as Customs agents, the following ores were treated; detailed statements will be found in the various Mines Branch Summary Reports.

TABLE XXVIII

—	Individual shippers	Crude ore	MoS_2	Content MoS_2	Recovered MoS_2	Recovery
Year		Pounds	Per cent	Pounds	Pounds	Per cent
1916	9	4,529,415	1·89	86,147	71,175	82·6
1917	25	3,314,802	2·37	78,664	71,966	91·4
1918	17	706,175	2·15	15,206	12,838	91·0
Total	....	8,550,492	2·01	180,017	155,979	87·0

Besides the above, 231,000 pounds of crude ore containing 1,911 pounds of molybdenite received from 31 shippers was treated for experimental purposes only.

EXPERIMENTS BY THE UNIVERSITY OF TORONTO

During 1915 and 1916, H. E. T. Haultain, F. C. Dyer, and J. T. King, of the University of Toronto, conducted a series of experiments on the concentration of molybdenite.

The method employed[1] was to crush wet and spread the pulp out sufficiently thin so that the molybdenite would work through to the surface and float. The pulp flows down an inclined sheet in waves, between the crests of which the pulp is very thin, and the film is much stretched, so that the minerals which are less easily wet break through and are picked up by the crest of the next wave until they are carried down to the still surface of the water, and float. There, a gentle air jet keeps the particles travelling towards the overflow. Concentrates were cleaned by repeating the process, but finely crushed material, or slimes, did not give good results. It was found advisable to add a small amount of oil to the ore, and results were often improved by giving the material a slight roast. One advantage over some of the other water-film flotation methods appears to be in crush-

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[1] Can. Min. Jour. Concentrating of Molybdenum Ores, July 1, 1917, p. 271.

ing the material wet, instead of dry; moreover the process and plant are simple. This was only a laboratory plant, and no commercial units were installed.

OIL FLOTATION

VARIOUS TYPES OF OIL FLOTATION MACHINES USED

The following are some of the many processes of oil flotation that have been applied to molybdenite: Callow pneumatic, Elmore vacuum, Minerals Separation, Groch, K. & K., Janney, Ruth, etc.

The Ruth is used at the R. and S. molybdenite concentrator in New Mexico. The Janney is used in conjunction with the Callow at the Climax molybdenite mill, Colorado; the K. & K. at mills in Arizona, and California; the Groch at two Canadian mills. Minerals Separation process has been used commercially in Norway, and Australia, and by the Mines Branch, Ottawa, for experimental purposes. The Elmore vacuum was successfully used in Norway, and at the Mount St. Patrick mill, in Canada.

CHOICE OF FLOTATION MACHINE

The most universally adopted process on the American continent is the Callow pneumatic oil flotation process, and almost any molybdenite ore can now be successfully concentrated by this process, a description of which will be found in the chapter dealing with the concentration of ores by the Mines Branch, Ottawa.

In a recent book on flotation processes, by Arthur F. Taggart,[1] instructive accounts are given of general flotation, and the various types of machines employed, together with a number of flow-sheets, statistical data, etc. In summing up his comparison of the different machines, Mr. Taggart concludes that the Janney is the best agitation-type machine, although its first cost is high; but that the Ruth and Groch have not been given sufficient trial to warrant a statement as to their usefulness. This writer is of the opinion that in ten years' time the agitation machine will be almost completely displaced by the machine of the pneumatic type, which is represented by the Callow. The modified Callow types, such as used at Miami and Inspiration, are more economical of floor space and cheaper in its first costs than the standard Callow type.

A brief description of the other various types of machines that have been used on Canadian molybdenite ores will be found below.

ELMORE VACUUM PROCESS

This process devised by Frank E. Elmore, one of the pioneers of oil flotation, is based on the liberation of dissolved air and gases by means of reduction of pressure. The bubbles so formed under a vacuum, greatly increase in volume and buoyancy, and are thus enabled to lift quite large masses of oil-coated minerals.

The system has been installed in several molybdenite mills in Norway. It was also used in the Renfrew Molybdenite Mines mill at Mt. St. Patrick, Renfrew, Ont., which made regular shipments to France of 95 per cent MoS_2 concentrates.

The process is as follows:[2] The ore is crushed wet to about 10 or 20 mesh and mixed with about $1\frac{1}{2}$ to 2 pounds of light flotation oil (coal oil)

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[1] Manual of Flotation Processes, 1921. Arthur F. Taggart. Published by John Wiley & Sons, Inc., New York.

[2] Eng. and Min. Jour., May 5, 1917. H. H. Claudet.

which coats the molybdenite but not the pyrite, pyrrhotite, etc. A settli tank is used to thicken the pulp and to overflow any slimes that may deleterious. The thickened, oil-coated pulp is sucked into the separating

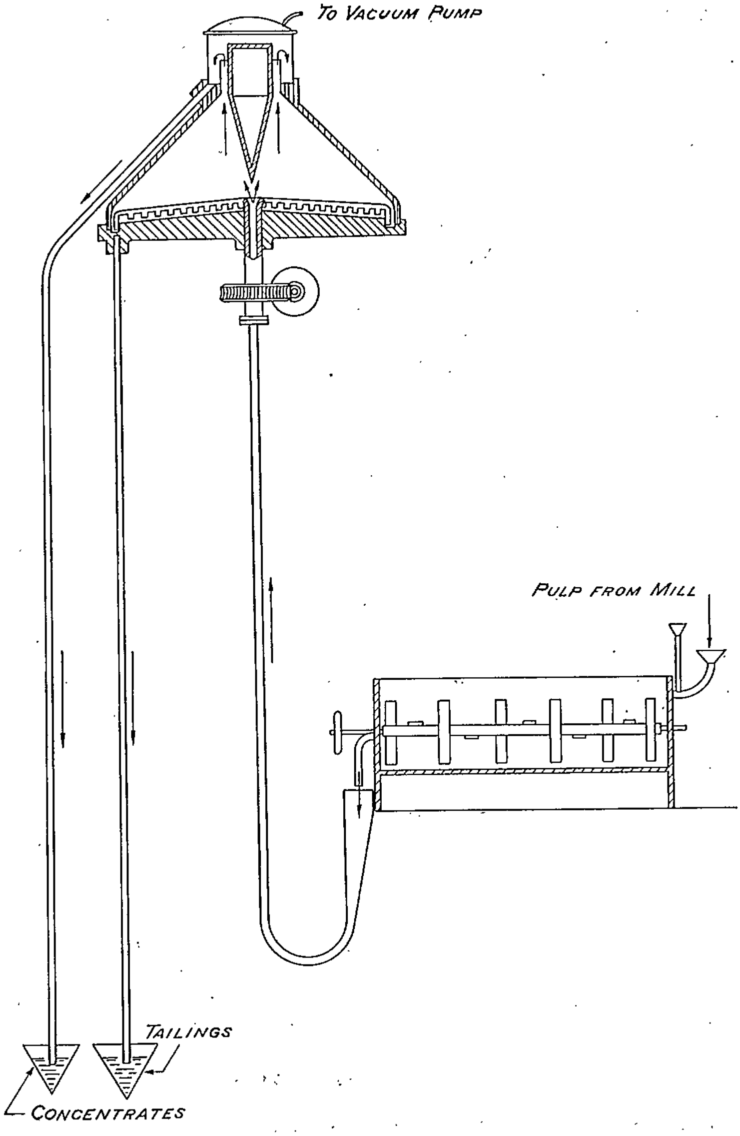

Figure 47. Section of Elmore vacuum concentrator.

machine by means of a vacuum pump. On reaching the machine, which as a rule is on the top floor, the enlarged bubbles, with their adhering molybdenite particles, rise to the neck (see sketch of apparatus, Figure 47) and overflow down the concentrates pipe. The pulp, on the sloping floor of the machine, is kept agitated by means of slowly revolving arms, and is gradually carried to the edge, where it falls down the tailing pipe. The outlets of the concentrate and tails pipes are lower than the atmospheric head of water and are water-sealed. One unit will treat about 35 tons in 24 hours. The selective action is sometimes increased by the addition of a little acid, or by warming the pulp.

The apparatus requires careful attention to preserve the correct water levels; to see that there are no leaks that would allow the entrance of air; and that the discharges into and from the concentrates and tailing pipes are regular and constant. A difference in pressure causes the floating mineral to drop, and a sudden building up of any part of the circuit might result in the concentrates being sucked into the vacuum pump. At high altitudes, because of the lower atmospheric pressure the results are not so satisfactory as those obtained when the plant is nearer sea-level. The machine should be periodically cleaned out and inspected.

The process has advantages in that it is simple, requires very little sizing of the ore, and marketable concentrates may be obtained in one treatment. On the other hand, the initial installation is costly, and the process gives poor results on slimes, so that it should not be used on ores that require fine grinding.

THE GROCH FLOTATION MACHINE

The principle employed in this machine is quite similar to that of the Ruth machine, but the apparatus is simpler. In the centre of each compartment is an impeller with a hollow shaft, that has at its lower extremity, a centrifugal runner with hollow hubs, and is subdivided horizontally by a metal disk so as to operate after the manner of a pair of centrifugal pumps.[1] The pulp is drawn in from the bottom, and air is sucked in from above through the hollow drive shaft, through which the oil is added. The impeller, which rotates from 500 to 700 r.p.m., creates a vacuum, breaks up the air, and causes the necessary frothing. (See Figure 48.) The chief advantage of the machine is its simplicity, in that emulsification, agitation, and aeration are all combined in one machine.

No practical work has been done on molybdenite ores with this machine, although the process has been installed in the Sheffield Molybdenite Company's mill (Chisholm mine) and the St. Maurice Mines Company's mill on Indian peninsula, Quebec. The 100-ton per day concentrator of the latter company was completed towards the end of 1918. When operations re-start, the ore will be fed to a Buchanan rock crusher, and then to a 5-foot ball mill in closed circuit with a Dorr classifier, passing to the Groch flotation units, and then through the usual cleaning and drying processes. (See flow-sheet Figure 49, and Plate VI.)

CONCENTRATION NOTES

INTERFERENCE TO OIL FLOTATION BY FOREIGN MINERALS

Oxidized ores, such as those exposed on the surface, old tailings dumps, etc., are as a rule difficult to float, but flotation may be assisted by preliminary washing and grinding to brighten the sulphide surfaces,

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[1] Trans. Can. Min. Inst., 1918, p. 145. Groch and Simpson.

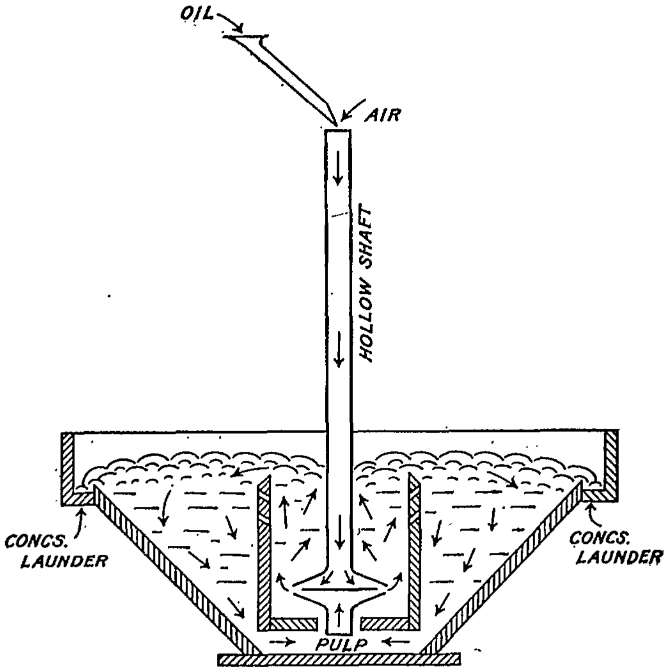

Figure 48. Diagram illustrating action of Groch flotation machine.

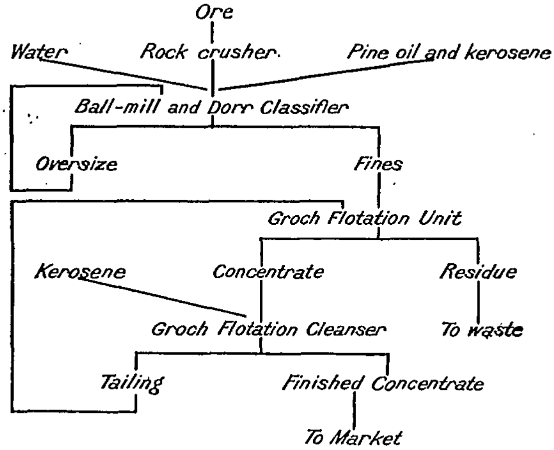

Figure 49. Flow-sheet of St. Maurice Mines Co., Ltd., Indian peninsula, Que. (Not yet in operation.)

or by the use of reagents. Molybdite or molybdic oxide, has not apparently been successfully floated, and films of it on molybdenite hinders flotation of the latter. In oxidized ores containing iron sulphate in solution, the froth is generally killed to a certain extent by the sulphate. The flotation may be aided by adding lime to neutralize the solution. (See Concentration Hints.) Experiments by the Mines Branch showed that better results were obtained by using the water-film flotation process on these ores.

Iron pyrites and pyrrhotite are separated from molybdenite by direct preferential flotation, and finally more completely by washing the concentrates over a screen, the foreign sulphides passing through, while the molybdenite is retained in flocculent masses on the screen.

Chalcopyrite has a greater tendency than other minerals to float with the molybdenite, but may be removed to a large extent by screen-washing the concentrates.

Mica gives no serious trouble, but with low-grade ores heavy in iron, rich concentrates cannot be made. However, by the use of the screen, these foreign elements can be very successfully removed.

SCREEN RESULTS FROM CLEANING CONCENTRATES

The application of the principle that molybdenite flakes, after oil flotation, tend to flocculate and remain on a fine screen, was worked out by E. B. Thornhill, and is protected by a patent application owned by the General Engineering Company. The principle has been used for many years in the concentration of molybdenite, graphite, and other similar ores.

The following extract is from the paper read before the Canadian Mining Institute by H. H. Claudet, in March, 1919.[1]

> Below are given some figures taken from laboratory tests made on different molybdenite ores to illustrate the work of the screen when treating refractory ores:

TABLE XXIX

—	By wt. per cent	Assay. MoS_2 per cent	Total per cent of contents
Low-grade Colorado ore, heavy pyrite and pyrrhotite containing 0·13 per cent MoS_2			
Flotation Concentrates—			
Before screening	4·08	3·02	96·3
Remaining on 80-mesh screen. Finished product	0·15	65·05	76·7
Passing through screen. Re-treatment product	3·93	0·64	19·6
Low-grade Canadian ore, containing 0·80 per cent MoS_2			
Flotation Concentrates—			
Before screening	2·0	12·0	80·4
Remaining on 80-mesh screen. Finished product	0·3	76·7	77·0
Passing through screen. Re-treatment product	1·7	0·6	3·4
Molybdenite tailings, Canada, containing 0·63 per cent MoS_2			
Flotation Concentrates—			
Before screening	4·66	11·9	87·2
Remaining on 80-mesh screen. Finished product	0·61	71·0	68·0
Passing through screen. Re-treatment product	4·05	3·0	19·2
Colorado ore, containing 0·74 per cent MoS_2			
Flotation Concentrates—			
Before screening	8·05	8·5	92·28
Remaining on 80-mesh screen. Finished product	0·85	72·1	82·58
Passing through screen. Re-treatment product	7·20	1·0	9·70

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[1] Trans. Can. Min. Inst., Vol. XXII, 1919, p. 72. H. H. Claudet.

CONCENTRATION HINTS

The following are some important points that should be borne in mind.

Degree of Crushing.

(*a*) The degree of crushing in the ball mill, depends on the character of the ore and size of flake present, and can only be decided by experiment. Fine-grained complex ores in which the molybdenite is intimately associated with other minerals, require much finer grinding than free-milling ores containing large flake. Coarse grinding within limits usually gives the best results, although there is probably no process to-day that gives such good results on slimes, as the Callow. Classifiers are generally better than screens for returning oversize from the ball mill, because any large flake that will float out of the classifier will float subsequently in cells, and in this manner a much coarser concentrate product will be obtained for the final cleaning, hence there will be a higher grade finished concentrate with less returns through screen as middlings.

With the eastern Canadian ores, the Mines Branch found that crushing to 40 mesh gave the best results, but with the British Columbia fine-grained ores, 80 or 100 mesh was used. The Climax Molybdenum Company, at Colorado, U.S.A., found it necessary to crush to 120 mesh.

Number of Cells.

(*b*) The number of Callow cells depends on the complexity of the ore treated. For a straight very free-milling, coarse flake ore, with clean gangue, one rougher and one cleaner may be sufficient. For more complex ores both cells may have to be duplicated.

Re-cleaning.

(*c*) In re-cleaning tails, they should be sent back through the circuit or even back to the ball mill for further treatment. By so doing the molybdenite particles have a chance of being either freed from the adherent gangue or becoming better coated with oil, and are able to float when they reach the cell on the next occasion.

Grade of Tails and Concentrates.

(*d*) It is not advisable to attempt to obtain a good concentrate in the rougher cells, but, rather, a dirty concentrate and very clean tails. All the tails should be clean enough to be discarded, or treated separately for other values. Owing to the successful method of cleaning concentrates on the Callow screen, the above remarks apply to a less extent to the cleaner concentrates. About a 70 per cent cleaner concentrate and a return of cleaner tails around the whole circuit is desirable.

Building up Froth.

(*e*) In some concentrators, the sides of the cleaner cells are higher, with small openings at the ends to build up the froth and make considerably cleaner concentrates; but the tails are liable to become dirty and the cells have to be carefully watched. Another practice sometimes employed is to place vertical boards across the cell at different heights so that the froth descends a series of cascades before it flows through the outlet; or placed in a reverse order, so that the floating mineral travels the length of the cell and back again before it escapes.

Screening the Concentrates.

(*f*) The successful recovery and grade of concentrates can be greatly increased by washing the cleaner concentrates on a Callow screen. Molybdenite (and to a certain extent graphite) has the peculiar property of flocculating; that is, the individual flakes appear to adhere to one another, but not to a foreign substance. Therefore, when minus 80 or 100 impure molybdenite concentrate is placed on an 80-mesh screen and washed by sprays of water impinging on it from above, the impurities will be released and pass through the screen, but the molybdenite flakes cling to one another forming small globules that remain upon the screen. Iron pyrites, one of the most troublesome and common impurities, is successfully removed by this means. A 60 per cent molybdenite product has been cleaned to a 95 per cent concentrate, with only a very small portion of the molybdenite passing through. The "throughs" are stored for separate treatment, or sent back through the circuit.

Oils.

(*g*) There are two kinds of oils used, frothing and collecting. One cannot be successfully used without the other. The writer has seen a froth of 8 inches without a particle of mineral, because the collecting oil had been clogged up. On the other hand, without the frother, a thin unstable scum of mineral is formed from which the ore particles constantly drop to the bottom. The kind of oil and its amount are matters of experiment, but for the average ore from eastern Canada about one-half pound of frothing oil, and one pound of collecting oil per ton of ore, is approximately correct. The Dominion Molybdenite Company used about three-quarters of a pound of each.

There is a very long list of flotation oils to choose from, and more are being put on the market all the time.[1] Although somewhat expensive, it is difficult to surpass No. 5 pine oil as a frother, and as a collector, kerosene oil is very satisfactory. Fuel oils can be used, but they are likely to lift more iron. It will be found that after running some time the system becomes impregnated with oil, so that less need be used. Poor and erratic results are obtained by using too much oil, and the circuit should be built up gradually, as too much kerosene kills the froth. The oils are generally fed to the ball mill (especially the kerosene) the feed being regulated by one of the well-known mechanical devices, the simplest being an adjustable scraper on a wheel revolving partly submerged in the oil. Some mill men add a portion of the oils to the elevator boot to liven up the froth when it reaches the cells; it is not good practice to add it directly to the flotation cells, except in an emergency.

Reagents other than Oils.

Sometimes it is necessary to use reagents such as lime, soda ash, sodium silicate, or sodium sulphide. Lime is the most useful reagent and there are very few ores which do not float better when a little is added. The lime has a tendency to hold down the iron sulphides and prevent them from floating. It is also necessary to use lime with certain ores which contain a large amount of soluble salts, such as ferrous sulphate and magnesium sulphate. These salts go into solution in the mill water very rapidly and contaminate the circuit so that the molybdenite will not

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[1] Rep. Trans. Can. Min. Inst., Bull. XX, 1917, pp. 38-51. "Canadian Wood Oils for Ore Flotation" C. S. Parsons and R. E. Gilmour.

float. The lime should be added to the ball mill in the form of milk of lime, or to the tailing pond if the water is returned from such a pond to the circuit, as long contact with the pulp is necessary.

Blankets.

(*h*) The blankets of Callow cells should be kept thoroughly clean to allow free access of air through the pores. Blankets should be periodically replaced.

Air.

(*i*) A reserve of air pressure should be maintained.

Machine Capacity.

(*j*) For the best results, the full concentrates capacity of the machines should be maintained, especially the cleaner machines. If a very small feed, or a very low-grade ore be put through a large machine, the machine will automatically endeavour to work up to its own capacity by floating gangue, mica, foreign sulphides, etc. Bad results and dirty concentrates often result from this cause, particularly in the case of ores under 0·5 per cent MoS_2. The capacity of most flotation machines can be easily reduced.

Cleanliness in the Mill.

(*k*) Oil flotation is delicate and often something goes wrong with the tails or concentrates, without apparent reason. Much trouble can be saved by having all parts of the circuit protected from foreign matter, particularly lubricating oil, or oils other than those added. The elevator boot on the ground floor in which careless mill hands shovel the dirt from the floor, or into which dirt and machine oil are liable to drain, is the worst trap.

A case can be cited in which no froth could be made for a whole day and the cause was traced to one of the mill men who had washed his hands in a basin with soap and water, and had then thrown the water into the elevator. Saponul which is an ingredient in many soaps is most detrimental to good recovery by flotation.

Cleanliness and the prevention of contamination are essential to the successful concentration and recovery of molybdenite (or any other) ores.

CONCENTRATION OF WULFENITE

Owing to the nature and high specific gravity of wulfenite, any of the gravity methods of concentration, such as are used in the concentration of lead ores, are applicable. The further separation of wulfenite from any other minerals of approximately similar specific gravity is a straight milling problem.

Details of screening, jigging, tabling, and vanning tests on the Arizona wulfenite ores are given by F. W. Horton,[1] together with the flow-sheet of Boykin and Hereford wulfenite mill at Mammoth, Arizona.

CONCENTRATION OF MOLYBDITE

Molybdenum in the form of yellow oxide, or ferri-molybdite, is not recoverable by the ordinary flotation processes but goes to waste with the tailings. Usually this loss is not serious, but the ores from some

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[1] U. S. Bull. No. 111, 1916, p. 110. F. W. Horton.

molybdenite deposits carry an appreciable quantity of the mineral. A notable instance is the ore of the Climax Molybdenum Company at Colorado, U.S.A., which is by far the world's largest producer of molybdenum. It is said that 10 to 20 per cent of the molybdenum content of this deposit is in the form of the oxide, so that in treating 1,000 tons of ore per day the loss must be considerable. This company has been conducting experiments for the recovery of this lost product.

The application of sodium sulphide (Na_2S) to a flotation charge under proper conditions has resulted in recovering a considerable part of the oxide. As this mineral is readily soluble in an alkaline solution, the sulphidizing treatment must be carried out in a solution as nearly neutral as possible.

In analysing molybdenite ores carrying molybdite, great care should be taken to determine the oxide mineral separately from the sulphide. A detailed reference to this special analysis, given by J. P. Bonardi,[1] has already been made.

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[1] Chem. Met. Engineering, p. 205, Aug. 4, 1920. J. P. Bonardi.

CHAPTER III

WORLD'S CONCENTRATORS AND THEIR FLOW-SHEETS

CANADIAN CONCENTRATORS

THE MOSS MINE, QUYON, QUE.

During 1916, when the Moss mine was first operated, the Canadian-Wood Molybdenite Company sent part of their ore to Henry E. Wood's water-film flotation concentrator at Denver; to the Mines Branch plant, Ottawa; and to the International Molybdenum Company's plant at Renfrew. The remainder was treated in their own small concentrator at the mine, and in a temporary plant at the Canada Cement Company's works at Hull, Que.

All these plants (a description of which will be found elsewhere) used the Wood water-film flotation process, or a modification of it. Owing to the abandonment of the process, a brief description of the mine concentrator only, will be given.

The flow-sheet of the mill, which was of 60-ton capacity, is as follows:—The ore was crushed in jaw-crushers to 1¼ inch, dried, and sent to a Krupp ball mill of 60 tons capacity, and to a Traylor ball mill of 20 tons capacity, both of which reduced the ore to 20 mesh. The crushed ore was elevated to bins, where it was fed to eight Wood water flotation machines. These machines were fitted with a series of baffles, to guide the flotation ore, which was impelled across the tanks by means of air jets set at certain angles. The concentrates were in some cases re-treated, and finally dried in flat trays.

In the Hull concentrator, the crushing was done by contract with the cement company, who used their own ball mills. The crushed and dried ore passed over nine Wood machines, of similar construction to the above. The recovery, however, was not very satisfactory. The Mines Branch re-treated about 50 tons of the middlings, which ran about 7·5 per cent molybdenite; and 12 tons of the concentrates that averaged 43 per cent MoS_2. There was a considerable quantity of tailings at the Hull plant, that ran over 0·5 per cent MoS_2, 28 tons being sent to Ottawa for re-treatment in the Callow cells; but it was found that the flotation properties had been destroyed by oxidation and no further attempt was made to treat them.

Satisfactory results were obtained by Mr. Wood on the ore sent to his plant at Denver; an average concentrate of 90 per cent being obtained; the ore, however, was of very much higher grade, being approximately 5 per cent molybdenite.

Dominion Molybdenite Company's Concentrator. After the property was optioned to the Dominion Molybdenite Company in 1917, exhaustive tests in concentration were made, as a result of which, it was shown that the Callow pneumatic oil flotation process gave the best all-round results;

consequently, the Wood machines were discarded, and a 150-ton mill using the Callow system was built.

After the initial difficulties were overcome, good concentration results were obtained. The concentrator gradually increased in efficiency, the maximum recovery being obtained at the time of closing down in March, 1919. (See Plate VII.)

Below is an extract from a description of the process by Charles E. Oliver, who was later in charge of milling operations.[1]

The following is a description of the milling process used by the Dominion Molybdenite Company in concentrating molybdenite ore at Quyon, Quebec. On account of the condition of the market, this company closed down its plant in March, 1919, but as excellent results were secured, the process employed will no doubt be of interest to many millmen.

The ore is mainly a quartz diorite, and the molybdenite is disseminated through the rock in flakes varying in size from minute specks to leaves an inch or more in diameter. The distribution through the rock is fairly uniform, though in spots, several hundred pounds of ore may be taken out assaying 50 per cent MoS_2 or better. However, these spots constitute only a small percentage of the total milling ore. Sorting is not done, as the ore-body is walled in on either side by barren red syenite.

The average ore assays 0·5 to 0·75 per cent MoS_2 and also carries pyrite, which is generally in excess of the MoS_2 and at times runs as high as 3 to 5 per cent. The ore contains little copper, as the concentrates carry only 0·1 per cent.

Reduction to 2-inch size is accomplished by a Blake crusher, the product going to a 6-ft. Marcy mill in closed circuit with a Dorr classifier, the overflow passing 40 mesh. A mixture of No. 5 General Naval Stores pine oil and kerosene is fed into the ball mill with the ore. As a result of grinding the oil with the ore, a large percentage of the MoS_2, as soon as freed from the gangue, floats out of the discharge in large flakes and materially aids subsequent treatment. These masses at times measure one-eighth inch in diameter.

From the ball mill the pulp is elevated to a set of Callow cells. The capacity of the mill is 150 tons in 24 hours, and four single cells are capable of handling this tonnage. The rougher concentrate assays 10 to 15 per cent MoS_2 and about the same in FeS_2, the remainder being fine gangue, which is carried over mechanically by the froth. This concentrate falls directly to the two cleaner cells.

The cleaner cells are operated differently from the usual practice. Sides are put on the cells to prevent the froth overflowing and to cause it to build up to a depth of 14 to 18 inches, and in this froth a selective action takes place. The gangue settles out of the sulphides; also, most of the pyrite falls out. The upper stratum of froth, being the richest in MoS_2, is allowed to discharge through an opening 1 inch wide in the end of the cell. The concentrate from the cleaners assays from 60 to 70 per cent MoS_2, and the particles are well flocculated, due to the quiet prevailing in the cells. The blanket bottoms must be kept well cleaned and all boiling avoided, otherwise the grade of concentrates will be reduced.

The cleaner concentrate falls to an 80-mesh Callow screen and is washed with a water spray to remove the last of the pyrite and adhering gangue. The concentrate is removed on the under side of the screen by a spray of water, and falls into a dewatering tank from which a scraper continuously removes it to a drier. This finished concentrate assays from 85 to 95 per cent MoS_2 and 2 to 3 per cent FeS_2, the remainder being gangue.

The cleaner cells operate in closed circuit; the fines from the Callow screen join the tailings from the cleaner cells and flow into the elevator boot, to be thoroughly mixed with fresh pulp. This results in a material reduction of the amount of oil necessary, and aids the recovery. The restricted overflow of the cleaner cells causes the tailings of these cells to be very high in MoS_2, and results in the building up of sulphides in the whole circuit. Consequently, careful manipulation is required in operating the rougher cells to maintain an even froth, otherwise a large loss may result in the tailings in a short time. A check is obtained on the operation by an automatic sampler placed in the tailing launder.

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[1] Eng. and Min. Jour., April 10, 1920, p. 840. Chas. E. Oliver.

The results obtained are remarkable, as the regular monthly mill sheet shows: feed, 0·7 per cent MoS_2; concentrate 90 per cent; tailings, trace. Oil consumed, 0·5 lb. pine oil and 1 lb. coal-oil per ton of ore. The recovery rarely falls below 99 per cent over a month, and temperature changes are without effect on the operation of the grade of the product.

The concentrates after being dried on flat pans were shovelled into sacks. If operations are again begun on a large scale, this method will doubtless be abandoned and mechanical driers and fillers substituted.

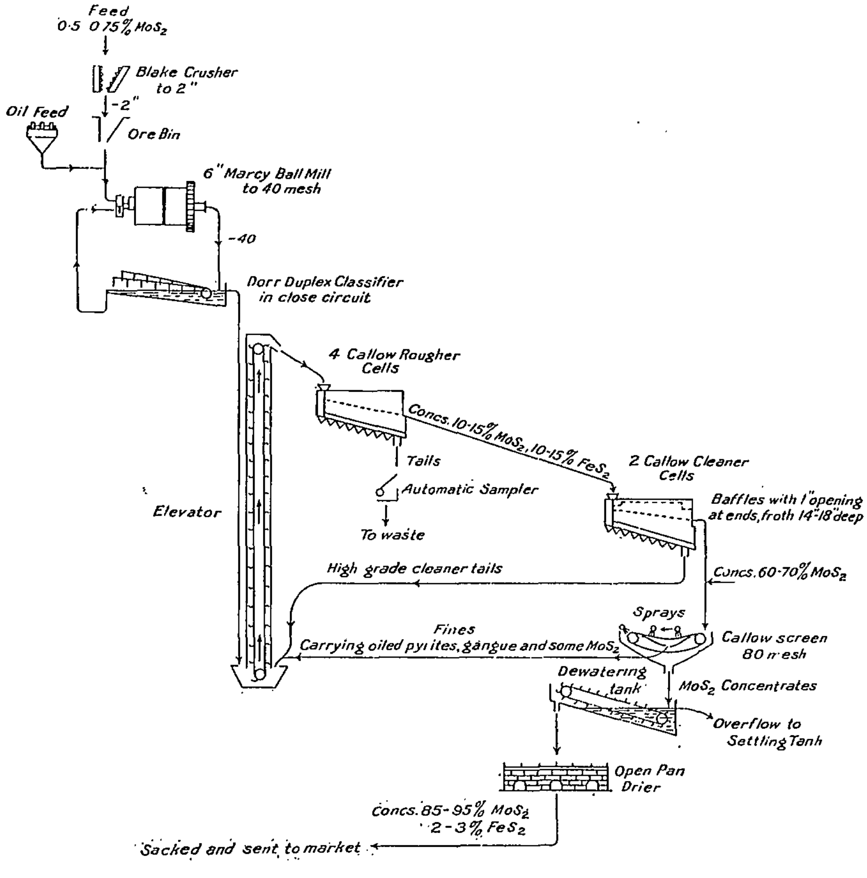

Figure 50. Flow-sheet, Dominion Molybdenite mill, Moss mine, Quyon, Que.

The accompanying flow-sheet shows the milling procedure (Figure 50), and a table shows the statistics over a period of about two years, during which the plant was operated by the Dominion Molybdenite Company. These figures show clearly the steadily increasing rate of improvement.

TABLE XXX

Milling Statistics of the Dominion Molybdenite Company's Mill, Moss Mine, Quyon, Que.

——		1917 May-Dec.	1918	1919 Jan.-Mar. 10	Totals over whole period
Ore treated in mill	tons	12,246	30,451	6,783	49,480
Average daily tonnage, actual time	"	84·30	128	126	113
Average daily tonnage, total time	"	50·00	83·7	103	77
Average per cent MoS_2 in feed		0·588	0·615	0·550	0·601
Total content pure MoS_2 in feed	lbs.	154,290	359,345	74,400	588,035
Total concentrates produced	"	193,470	384,253	79,940	658,763
Average per cent MoS_2 in concentrates	"	72·93	88·70	90·06	84·11
Total content pure MoS_2 in concs. recovered	"	141,108	340,655	72,350	554,113
Average per cent MoS_2 in tails	"	0·050	0·003	0·0015	0·016
Total content pure MoS_2 in tails	"	13,182	18,690	2,051	33,923
Total lbs. frothing oil used	"	3,692	21,672	472	25,836
Average lbs. of frothing oil per ton of ore		0·385	0·71	0·70	0·62
Total lbs. collecting oil used		9,540	22,819	525	32,884
Average lbs. collecting oil per ton of ore		0·994	0·75	0·77	0·81
Total lbs. oils used		13,232	44,491	997	58,720
Average lbs. oils per ton of ore		1·38	1·46	1·47	1·44
Pounds of balls used in mill		13,898	54,857	16,590	85,345
Average lbs. of balls used per ton of ore		1·80	1·82	2·4	1·87
Actual running time	hrs.	3489·5	5677·4	1314·2	10481·1
Running time	per cent	59·34	65·1	79·0	65·3
Actual recovery of MoS_2 in feed	"	91·45	94·8	97·2	94·3

The above table was compiled by the writer from the books of the Dominion Molybdenite Company, kindly placed at the disposal of the Department of Mines, by Mr. W. J. Boland.

INTERNATIONAL MOLYBDENUM COMPANY'S CONCENTRATOR, RENFREW, ONT.

Experiments in molybdenite ore concentration were first made at the company's plant at Orillia where a few car lots of ore were treated. After the International Company was merged with the M. J. O'Brien interests, the machinery was removed and a 100-ton per day concentrator was built at Renfrew, using a modification of the Wood water-film flotation process, a description of which is as follows:—

The ore after passing through a gyratory crusher was ground by rolls. The crushed ore was then dried and fed to a drum revolving in water at the head of a tank. Most of the sulphides and almost all the molybdenite, was floated. The stream passed down a gently inclined box, 12 feet long, until it struck a series of baffle boards placed vertically, the molybdenite being carried over the edge of the baffles by the water, the theory being that these baffles interfered very little with the molybdenite, but caused the sinking of the other minerals. In practice this was found to be only moderately satisfactory, and required very delicate adjustment of flow and careful watching. No acids or oils were used in the process.

A few alterations were made from time to time, and a large quantity of ore from all over Canada was treated. The grade of the concentrates and the recovery were apparently not very satisfactory; but no accurate information is available as all the records were destroyed when the concentrator was burned in 1919.

The following is a table showing the various ores treated (as far as can be ascertained) by the International Molybdenum Company during 1916 and 1917, after which the company ceased operations.

TABLE XXXI

Molybdenite Ores Treated by the International Molybdenum Company's Concentrators at Orillia and Renfrew

(Figures approximate)

Year	Name of Mine	Locality	Pounds ore	Approx. per cent MoS_2	Remarks
1916	Jamieson	Lyndoch tp.,	34,300	....	Ore hand-cobbed
		Ont.	25,810	18·00	
	O'Brien	Mt. St. Patrick,	253,000	1·75	
		Brougham tp., Ont.	20,760	4·00	Cobbed
	Moran	Brougham tp., Ont.	220,600	1·00	
	Chisholm	Sheffield tp., Ont.	469,740	1·00	
	Haley	Ross tp., Ont.	13,210	3·64	Cobbed
	Can. Wood Molybdenite	Quyon, Que.	3,531,050	1·23	
	Molly	Nelson, B.C.	22,610	10·36	Cobbed
	Mo. Reduction and Mill. Co.	Alice Arm, B.C.	178,740	1·60	
	Index	Texas creek, B.C.	15,980	15·70	Cobbed
	New Mexico	U.S.A.	48,920	2·70	
	Texas	U.S.A.	2,890	50·00	Concentrates
1917	O'Brien-Moran	Mt. St. Patrick, Brougham tp., Ont.	571,800	0·91	
	Chabot	Huddersfield, Que.	6,000	1·40	
	Padwell	Monmouth tp., Ont.	124,000	1·00	
	American Molybdenites, Ltd.	Monmouth tp., Ont.	54,200	0·39	
	Shipton	B.C.	2,000	1·03	
	Molly	Nelson, B.C.	181,000	3·84	
	Total	....	5,776,610	1·28	

From this 2,888 tons treated, containing 74,000 pounds MoS_2, approximately 58,000 pounds of pure molybdenite was recovered and sold.

RENFREW MOLYBDENUM MINES CONCENTRATOR

This concentrator having a capacity of 30 tons per day and using the Elmore vacuum oil flotation process, is situated on the south side of mount St. Patrick, Brougham tp., Ont.

Mr. Chas. Spearman, of Montreal, who was in charge of milling operations during 1917-18 stated that good results had been obtained in concentrating the ore which consists of a heavy pyrrhotite and pyrite. Briefly, the flow-sheet is as follows: The ore averaging 0·75 per cent molybdenite is crushed to one inch in a 10 by 15-inch Jencks jaw-crusher, then by automatic feed to 4½-foot Hardinge ball mill with a small quantity of kerosene oil; the crushed pulp next goes to an 8-foot Elmore settling cone to eliminate the surface water. The thickened pulp is discharged to an Elmore mixer, where more kerosene oil is added. A vacuum pump draws the pulp from the mixer to the Elmore vacuum concentrator. The concentrates are dried on a steam plate heated from the engine exhaust, and packed in oil barrels for shipment.

One drawback is the relatively low production per unit. Another feature that caused trouble was the discharge of gangue slimes which amounted to from 8 to 20 times the weight of the concentrates, with the concentrates. After trying several devices this trouble was finally overcome by washing out the slimes, leaving a molybdenite residue of about 95 per cent molybdenite. The tailings averaged 0·06 per cent MoS_2.

Between January, 1917, and October, 1918, about 7,270 tons of ore were treated, from which approximately 47 tons of molybdenite concentrates were produced. Almost the whole of this molybdenite, which analysed between 92 and 95 per cent MoS_2, was shipped to France.

Squaw Lake Concentrator

The flow-sheet of the small concentrator at Squaw lake, Huddersfield township, Pontiac, Quebec, is as follows:—

The crude ore was first broken in a jaw-crusher and then fed to a circular three-stamp battery with four discharges, into which a small quantity of coal-oil was put. The oil-coated pulverized ore was then run down slightly inclined glass plates onto a slowly moving surface of water in a tank. The sulphide ores floated across and were caught in a receptacle at the far end, the remainder sunk to the bottom and were regarded as tailings. The first concentrates, which ran about 40 to 50 per cent MoS_2, were re-cleaned in a second apparatus. The tails also were usually re-cleaned. The oiling of the pulp previous to floating did away with the preliminary drying of the ore.

The plant, which is of 25-ton capacity, ran for a short time and treated 500 or 600 tons of ore. Some of the concentrates (about 700 pounds) running 72 per cent MoS_2 were sent to the Mines Branch at Ottawa for re-treatment to bring them up to the required standard (86 per cent).

OTHER CANADIAN MOLYBDENITE CONCENTRATORS

The concentrator of the American Molybdenite Company, at Wilberforce, has been in intermittent operation, but no records of its output or operations are available. It is understood that the company is now making some alterations and expect to produce in the near future. (See Plate IX.)

At the mill of Spain mine at Dacre, Ont., the Steel Alloys Corporation installed a Callow pneumatic oil process after discarding the Hooper pneumatic dry process and the water-film flotation machines. The mine was closed down when only a small quantity of ore had been treated, but the mill appears to be in good condition for production. (See Plate VIII.)

No ores have been treated in the concentrators at the Chisholm mine, Ontario; on Alice Arm, B.C.; or on Indian peninsula, Quebec. (See Plate VI.)

A brief account of these plants is given in Part I, and an account of the St. Maurice Mines concentrator, Indian peninsula, accompanies the description of the Groch flotation machine.

The Canadian molybdenite concentrators will be found in the accompanying table.

TABLE XXXII

Canadian Concentrators showing Approximate Tonnage of Ores Treated, 1914-1921

Name of Company	Location of concentrator	Mill capacity tons per day	Processes employed	Approx. ore treated	Approx. MoS_2 produced	Remarks
				tons	pounds	
Canadian-Wood Molybdenite Co.	Quyon and Hull..	150	Water-film flotation.......	3,900	96,300	Tonnage of ore treated is only approximated
Dominion Molybdenite Co.	Quyon...........	150	Callow oil...............	50,000	554,100	Average 94% recovery; 84% MoS_2
Renfrew Molybdenum Mines	Mt. St. Patrick...	30–35	Elmore vacuum oil........	6,856	95,900	Includes some hand-picked flake; concentrates were exceptionally high grade
Mines Branch, Department of Mines	Ottawa...........	20	Various—mainly Callow..	4,390	156,420	Includes experimental tests, also concentrates, midds. and tailings from other mills that were re-treated by the Department
International Molybdenum Co.	Renfrew..........	100	Water-film...............	2,888	58,000	A few car lots were treated at Orillia. Quantity molybdenite produced only approximate
Steel Alloys Corp'n (Spain)	Dacre............	30	Water-film and Callow....	40	600	A Hooper pneumatic, then water-film, and finally Callow process were installed. Figures are very approximate.
Wood Molybdenite....	Squaw lake.......	25	Water film..............	550	Re-treated Ottawa	The concentrates being low grade were re-treated at Ottawa; and 457 pounds MoS_2 was recovered
American Molybdenite Co.	Wilberforce.......	125	Callow oil................	A few tons..	?	Mill ran intermittently for short periods; no records available
St. Maurice mines.....	Indian peninsula...	50	Groch flotation..........	....	....	No ore has yet been treated
Chisholm mine........	Sheffield tp.......	40	Groch flotation..........	....	....	No ore yet treated in present mill. About 5 tons of middlings was produced by a dry crushing and screening plant
Molybdenum Mining and Reduction Co.	Alice Arm, B.C...	....	....	....	....	No ores treated. Mill will be remodelled before re-starting operations

UNITED STATES CONCENTRATORS

CLIMAX COMPANY CONCENTRATOR

This is the largest molybdenite concentrator in the world. The mill, which was designed by D. F. Haley, is situated on Bartlett mountain, at an elevation of about 11,000 feet. Operations were started in July, 1917, and the first shipment of concentrates was made in February, 1918.

The method employed is as follows:—[1]

The ore is first crushed in a 10- by 20-inch crusher to about 3 inches, and fed by aerial tram into a mill storage bin of 500 tons capacity. From this bin the ore is fed by plunger feeders to a 16-inch flat conveyer belt, which delivers it to a 6- by 6-foot Allis-Chalmers ball mill, where it is crushed to about 20 mesh. It is then passed to a 6 by 10-foot Allis-Chalmers ball mill crushing to 120 mesh, and in closed circuit with a duplex Dorr classifier. The classifier overflow of minus 120 mesh goes directly to the flotation units. The flotation plant consists of five Janney machines, three Callow standard roughing cells, and two Callow half-size cleaner cells, the feed being divided between the Janney and two rougher cells, the efficiency of either for roughing purposes being about equal. The fifth Janney is used as a first cleaner for the product of the four others. The tails are discharged from the fourth Janney, the fifth Janney discharge, being middlings, is returned to circuit, and the concentrates go to the Callow first cleaner, where they are joined by the Callow rougher concentrates, the combined product passing from one Callow cleaner to the other. One of the original roughers was converted into a cleaner, and it was said to improve the product. The cleaner tails are returned to the Callow roughers.

The iron pyrites, which in amount is nearly three times that of the molybdenite, caused a great deal of trouble. In order to make the required concentrate of 65-70 per cent MoS_2 most of the iron had to be eliminated. This was partly accomplished by installing vanners to treat the concentrates, but the final product still assayed about 10 per cent iron. Another difficulty was in the proper control of the grade of concentrates from the cleaners; for, when treating, say 300 tons of ore of less than 1 per cent molybdenite per day, only about 4 pounds per minute of a 65 per cent product was recovered from the cleaner. This was partly remedied by greatly reducing the capacity of the cleaner. The finished concentrates are dewatered by means of Goldfield agitating tanks, after which the pulp passes through a Portland filter and is finally dried in a steam drier. (See flow-sheet Figure 51.)

The capacity of the mill was 350 to 400 tons per day, but the flotation system can handle 700 tons per day.

Although all molybdenum assays are on the basis of molybdenite, the feed carries from 0·25 to 0·3 per cent molybdite which is not amenable to flotation, so that the true feed is about 0·6 per cent MoS_2. Experiments are being made for the recovery of the molybdite. The recovery of the actual molybdenite is stated to be about 82 per cent.

Power is derived from a 13,000-volt line of the Colorado Power Company.[2] The design of the mill lends itself readily to the installation of additional equipment without interfering with operation.

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[1] See Trans. Am. Inst. Min. Engineers, Vol. 61, p. 74, 1919. F. D. Haley. Also: Colorado Geol. Surv., Bull. No. 14, Molybdenum Deposits of Colorado, 1919, p. 92. P. G. Worcester.

[2] Eng. and Min. Jour., May 18, 1918, p. 907. H. L. Brown and M. W. Hayward.

Each machine in the mill has its own electric motor and it is said that the mill can be handled by 4 or 5 men, including the tram tender, per shift.[1]

The Climax concentrator has recently been enlarged to treat 1,000 tons of ore per day, but the results obtained by the new plant are not available.

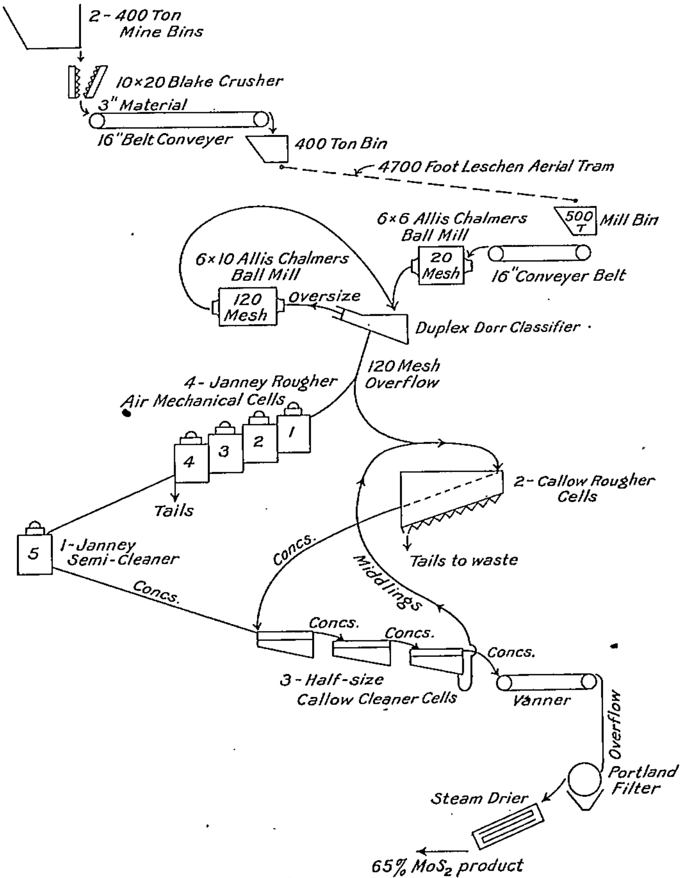

Figure 51. Flow-sheet of Climax Molybdenum Company's mill, Colorado, U.S.A. (After D. F. Haley.)

SAN DIEGO CONCENTRATOR[2]

In 1916, Shinn and Shinn, of Sacramento, California, erected a 50-ton mill to treat their ores, which as a rule ran less than 1 per cent MoS_2. The ore is crushed in a Dodge crusher to three-quarter inch, then in a Herman screen discharge ball mill to 50 mesh, after which the pulp passes through a 3-cell K & K flotation battery. The concentrates go to a filtration and drying plant.

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[1] Bull. No. 14, op. cit. p. 93. P. G. Worcester.
[2] Salt Lake Mining Review, June 15, 1918. H. E. Davis.

THE STANDARD MINERALS COMPANY, KINGMAN, ARIZONA

The company installed a 50-ton per day concentrator, using two K & K flotation units.

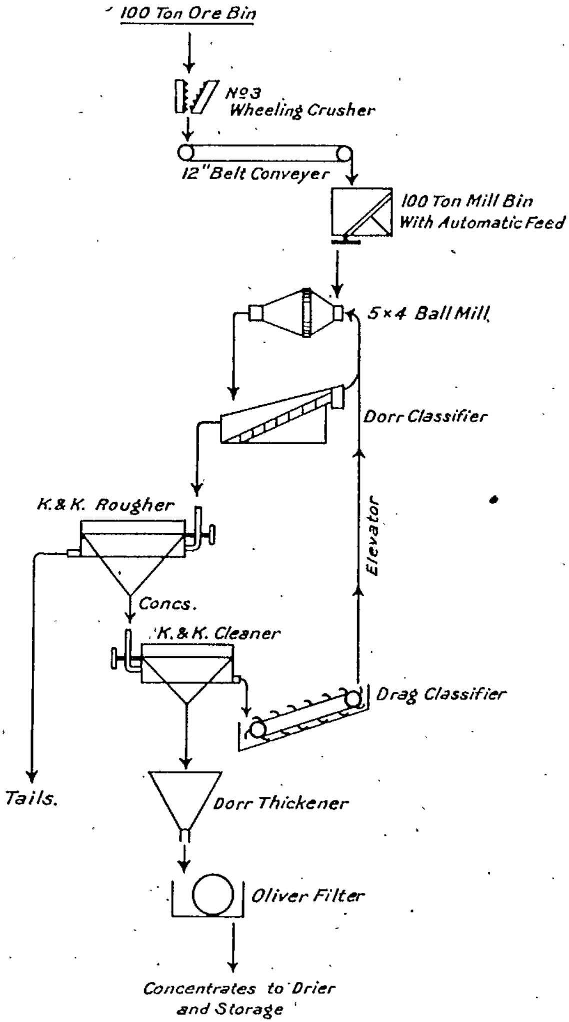

Figure 52. Flow-sheet of the Standard Minerals Company, Kingman, Arizona, U.S.A., 50-ton molybdenite mill using K. & K. flotation machines.

The accompanying sketch shows the flow-sheet of the company (Figure 52). The mill which was built early in 1919, was designed and erected by the Wellman Lewis Company, the flow-sheet being devised by the resident engineer, R. L. Cornell.[1] The average run of the ore is 1 per cent molybdenum. The mill is driven by a 120 h.p. oil engine.

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[1] Min. and Scientific Press, March 1, 1919, p. 306.

R. AND S. MOLYBDENITE CONCENTRATOR, NEW MEXICO

This company's property is situated about 8 miles northeast of Questa, Taos county, New Mexico. The concentrator erected by the owners, Messrs. M. B. Rapp and C. W. Savery, has a 50-ton per day capacity and uses the Ruth flotation process.

The ore is loaded into a 5-ton White motor truck at the mine and hauled five miles to the mill, where it is crushed in a jaw-crusher, and then fed into a ball mill, in closed circuit with a classifier. After the material is ground to about 80 mesh it is fed directly to a Ruth flotation unit. The concentrates are recovered, cleaned and dried in the usual way, and shipped in 100-pound sacks. The concentrates are said to have averaged 85-90 per cent MoS_2 with a recovery of 85 to 90 per cent.[1]

AUSTRALIAN CONCENTRATORS

BURMA QUEENSLAND CORPORATION, WOLFRAM, NORTH QUEENSLAND

The concentration of complex molybdenite-wolfram-bismuth ores of the Burma district was described in a paper read before the Australasian Institute of Mining and Metallurgy, by W. H. Bowater, in December, 1920.[2]

This mill was the first plant to successfully treat mixed ores of wolfram, bismuth, and molybdenum, producing separate commercial concentrates of each mineral.

A summary of the procedure, taken from the Chemical Engineering and Mining Review,[3] is as follows:—(Flow-sheets Figures 53 and 54.)

> The ore from the various mines of the company is delivered by aerial ropeway into the crusher bins, from which it is fed to two grizzlies and rock-breakers in series, reducing it to a maximum size of 1½ inches. The crushed ore passes to the mill supply bins.
>
> The mill consists of two units of 20 head of stamps (1,250 lb.), each complete with its own set of concentrating tables, classifiers, settlers, etc., flotation plant, and a magnetic separation plant in common The second mill unit has not yet been put into commission.
>
> The battery pulp is classified, the overflow going to slime treatment and the spigot-product being treated on Wilfley and Boss tables, which produce wolfram-bismuth concentrates, tails (containing the molybdenite) to the flotation plant, and middlings which are ground in Wheeler pans. The re-ground pulp is classified, the overflow going to slime treatment and the spigot product being treated on Krupp tables and Isbell vanners, which produce wolfram-bismuth concentrates, middlings which are returned to the Wilfley tables, and tails which go to the flotation plant. The various slime overflows from the classifiers are dewatered and treated on slime tables, which produce tails, which go to the flotation plant, heads and middles which are treated on buddles. The buddles produce tails to waste and heads to Luhrig vanners. The vanners produce wolfram-bismuth concentrate and tails to waste.
>
> Wolfram-bismuth concentrates are dried and screened into three through sizes, and an oversize, which latter is ground and re-sized. The three through sizes are separately treated on magnetic separators giving bismuth concentrates, wolfram concentrates, and an iron-wolfram product, which latter is treated on a Wilfley table, giving wolfram concentrates and an iron residue to waste.
>
> The various tailing products which are sent to the flotation plant are settled, the overflow going to the buddles and the spigot product passing to another set of cone settlers, giving a coarse spigot product and an overflow product which are treated in separate sets of flotation vessels. The dewatered pulp is sent to mixers, where it is mixed with kerosene liquor, and then passes to several sets of flotation vessels placed two in series. The

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[1] Eng. and Min. Jour., Dec. 13, 1919, p. 923.
[2] Proc. Aust. Inst. Min. and Met., Bull. No. 40, Dec. 31, 1920, p. 259.
[3] Chem. Eng. and Min. Rev., April 5, 1921, p. 229.

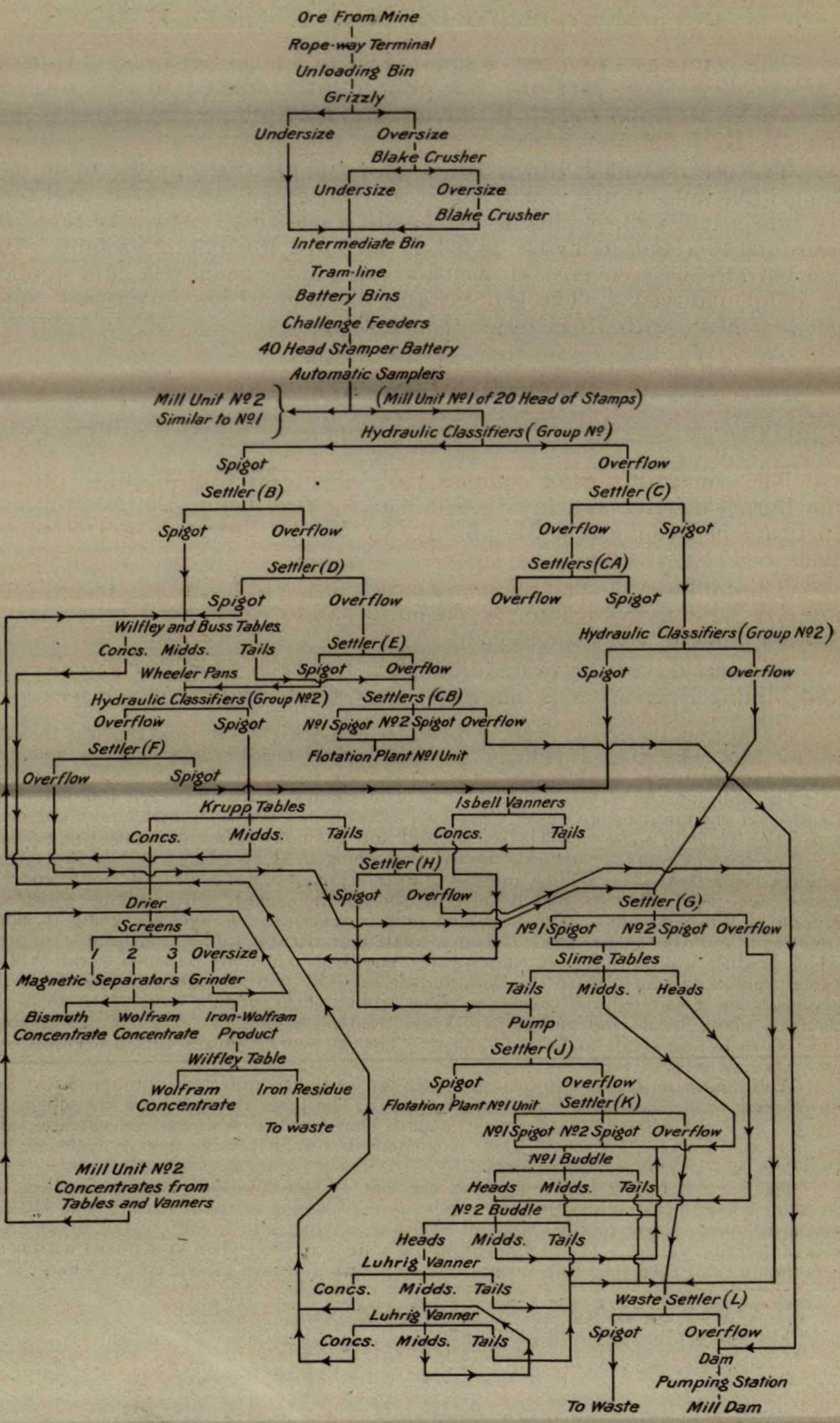

Figure 53. Complete flow-sheet of Burma Queensland Corporation mill, Wolfram, North Queensland, Australia.

flotation vessels are inverted cones in shape, the pulp fed on to conical distributors at the centre. The overflow passes over the periphery of the cones, and carries the floated molybdenite. The spigot of the first vessel delivers to the second vessel. The final spigot products are dewatered, the liquor being returned to the flotation liquor supply tank, while the dewatered pulp is sent to waste. The overflow products of the flotation vessels pass to a shaking screen giving an oversize which is sent to the kieves. The undersize is passed through large three-compartment settling boxes, the settled product from the first compartment being sent to the kieves and that from the other two compartments being returned to the mixers. The kieves give skimmings which are returned to the mixers, and molybdenite concentrates which are dried and bagged for market.

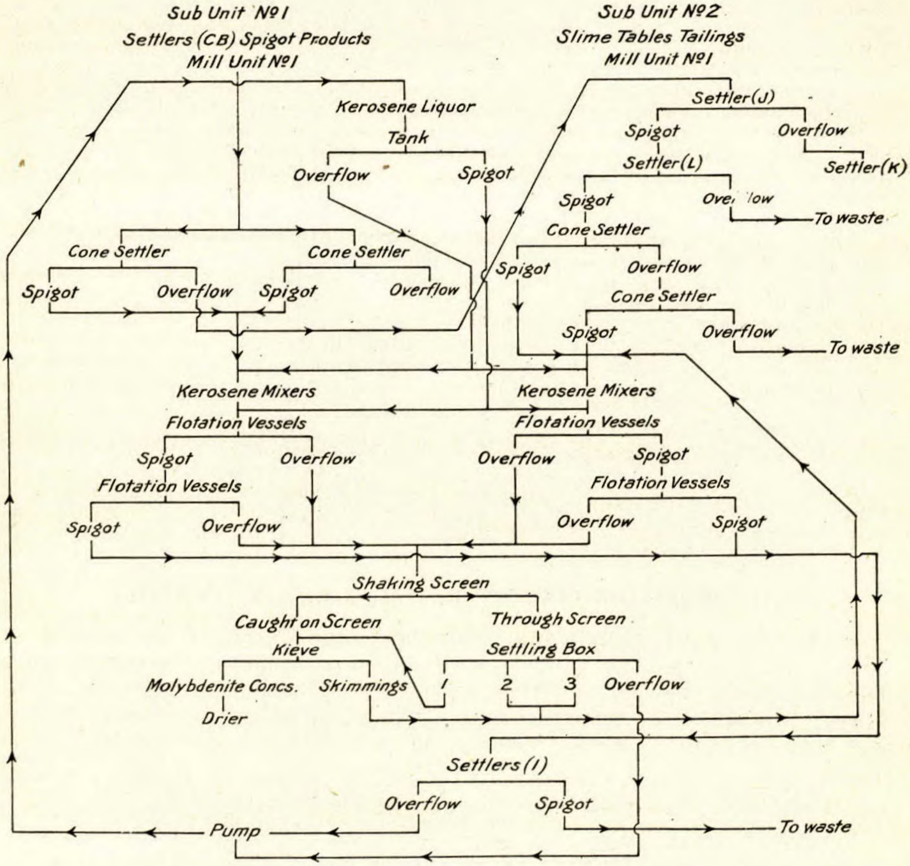

Figure 54. Flow-sheet of Molybdenite Flotation Unit No. 1, Burma Queensland Corporation mill, Wolfram, North Queensland, Australia.

THE WONBAH CONCENTRATOR, MOUNT PERRY, QUEENSLAND

The following is a description of the Wonbah mill, by J. H. Reid,[1] which is a typical Australian example of a modern stamp battery and oil flotation process adapted to a clean-milling molybdenite ore.

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[1] Eng. and Min. Jour., Nov. 13, 1920, p. 947. J. H. Reid.

The ore consists of white milky quartz with coarse and fine flakes, and also masses of molybdenite. The base sulphides mentioned occur as small segregations, which are discarded in mining, leaving quartz and a little calcite as the only gangue to be eliminated in the flotation treatment. The ore going to the mill averages 0·8 per cent MoS_2.

The mill comprises a battery of ten head of heavy quartz stamps in conjunction with a 12-inch unit oil flotation plant (Minerals Separation Co. and DeBavay's patent). The flotation machine is driven by a 33 h.p. Crossley suction gas engine with open hearth generator. Recently thirty to forty tons of ore have been treated per day (three shifts). The crude ore is broken to 1½ inch and passes to a plant storage bin (capacity fifty tons) on a slow conveyer belt which permits boys to hand-pick the material, all solid ore being thrown on to a dump, from which it is bagged and shipped direct.

The 1,000-pound stamps, with ninety-eight drops per minute, crush the ore to pass woven wire screens with 625 holes per square inch. The pulp is elevated to a Callow settling spitz, which feeds the coarser particles to the stirrer boxes while the slime overflow is carried by launder to a Dorr thickener (capacity 100 tons). The thickened slimes are laundered to a 4-inch elevator having a speed of 200 feet per minute, and elevated to meet the feed from the Callow settler.

The flotation machine is a 12-inch six-stirrer unit, and consists of six stirrer boxes at the back of the machine and six flotation boxes at the front. The stirrers, or mixers, have a speed of 450 r.p.m. The pulp from the Callow settler and Dorr thickener is introduced into the first stirrer box with four parts of water to one part of pulp, and eucalyptus oil is automatically added, one half pound of oil to one ton of crushed ore. Extremely small quantities of kerosene, of unfixed amount, are also added periodically to assist frothing.

The comminuted ore is forced into the flotation box, where the floated MoS_2 overflows and is carried by launder to two concentrate bins 10 by 5 by 4 ft. 6 in. each. The non-floating gangue, with up to 10 per cent of unrecovered molybdenite, is passed through the remaining five flotation units, and from the last box the residues go to the tailing dump. The initial treatment gives a concentrate of 70 per cent MoS_2, but at the end of the month the whole of the concentrates are re-treated, bringing the grade up to 90 per cent.

The concentrates are dried on a small open hearth furnace and bagged. The following give the output of the mine and the value of the concentrates for 1918 and 1919:—

Year	Crude ore, long tons	MoS_2 concentrates, 90 per cent, long tons	Value £
1918..........................	2,435	13·95	6,052
1919..........................	6,026	41·75	18,100

THE STANDARD CONCENTRATOR, EVERTON, VICTORIA

The Standard Molybdenite Company, in March, 1920, erected a 25-ton per day mill, in which was installed a Minerals Separation and DeBavay process of oil flotation, and when operations were resumed in May, 250 tons of ore from the dump, which ran about 4 per cent MoS_2, was treated, from which 8½ tons of 85 per cent concentrates was produced.

The following is a description of the plant and flow-sheet:—[1]

A tramway has been laid down from the mine workings to the concentration mill, and the ore is trucked to the crude ore bin, from the floor of which it is fed to the stone crusher. The latter is a jaw-crusher, with feed opening 16 by 9 inches set to break to about 1 inch. The product falls into a mill service ore bin, which has a capacity of about 25 tons. A Challange ore feeder delivers the ore from mill service bin to crushing rolls of 21 inch diameter by 12 inch face, the roll product gravitating to a trommel screen of 2 feet 10 inches in diameter and 6 feet long, fitted with punched steel plate screen, aperture approximately 2 mm. Oversize material is returned to the rolls, while undersize flows by gravity to No. 1 conical spitz classifier, of 6 feet diameter, which thickens the pulp. The classifier underflow—spigot discharge—gravitates to the grinding pan. The overflow —fine pulp—flows to No. 2 elevator. The Forwood Down grinding pan, 5 feet diameter,

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[1] Chem. Eng. and Min. Rev., Sept. 5, 1920, p. 448.

is fitted with Freeman classifier discharge. The pan product is returned by gravity to No. 1 elevator. No 2 bucket elevator, mentioned above, delivers to No. 2 conical spitz, 6 feet diameter, which further thickens the pulp. The underflow—spigot discharge—gravitates to No. 4 conical spitz. The overflow—slime and water—runs into No. 3 conical spitz, 8 feet diameter, which dewaters the slimes. The underflow of thickened slime discharged from spigot is carried to No. 4 conical spitz. The overflow—water—is returned to the mill water service supply. No. 4 conical spitz (balance spitz) is 3 feet in diameter. The underflow is fed into No. 1 mixer box of the 6-compartment 9 inch stirrer standard flotation machine. The primary concentrates, which are floated off boxes 1 to 4 of this machine are carried to primary concentrate storage boxes. The overflow from Nos. 5 and 6 boxes is returned to the grinding pan. Residues gravitate to the tailings storage dam.

The primary concentrates are re-treated in a single 6 inch stirrer sub-aeration flotation machine, and the final grade concentrates produced flow into storage boxes, thence to hot drying plates, where the moisture is evaporated prior to bagging for transport to buyers. The unfloated material discharged from the flotation machine is returned to the grinding pan.

NORWEGIAN CONCENTRATORS

According to Mr. E. R. Woakes,[1] nearly all the successful molybdenite concentrators in Norway use the Elmore vacuum process, and all the mills are of similar design. The ore from the mines is first crushed in Blake type rock breakers, then passed through a ball mill (Grondal type). After the requisite sizing and return of the oversize to the ball mill, the ore passes on to the Elmore units. Mica and copper are the impurities which cause most trouble; and, where these do not occur in large amount, a fairly good extraction is obtained, and the concentrate runs from 75 to 80 per cent MoS_2.

During 1916, H. H. Claudet, of Ottawa, erected a 60-ton mill at the Ornehommen mine, with a flow-sheet as follows: The ore was crushed in a jaw-crusher, and sent to a ball mill of the Ferraris type; the pulp being elevated to a corrugated 20-mesh screen. The throughs of this screen went to two Elmore units in series.

The Lilleknaben mine installed a Minerals Separation process, but there is no record of the results obtained.

The Gursli mine erected a German process during the war, but it proving a failure they then installed an Elmore unit.

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[1] Trans. Inst. of Min. and Met., 1918. Molybdenum in Norway. E. R. Woakes.

PART III

METALLURGY

CHAPTER I

ALLOY STEELS

The use of alloy steels for structural purposes is rapidly increasing and in this connexion statistics from the United States are of interest.[1]

In 1905, the United States produced a little over 20,000,000 tons of steel and less than 100,000 tons of alloy steel, a ratio in excess of 200 to one. In 1910, the ratio was reduced to less than 50 to one; and, in 1919, to less than 25 to one. In 1920, the output of alloy steels is stated to have reached 1,660,292 tons.

The question of suitable alloys and their availability for tonnage production is therefore of greater importance to the manufacturer than ever before.

Besides carbon, silicon, and manganese, which are almost always present in alloy steels, a very large number of elements have been tried in combination, and about ten have proved of value in steel-making. Four of the ten have been found to benefit steels sufficiently to warrant their adoption. These metals are nickel, chromium, vanadium, and molybdenum, in various combinations.

The part played by molybdenum in these combinations will be dealt with in this report, together with its economic, manufacturing and commercial possibilities.

GENERAL SCOPE OF MOLYBDENUM STEELS

The range of application of molybdenum steels appears wider than that of any of the other types of alloy steels. This range can be roughly divided into two parts: (1) high molybdenum steels that contain over one per cent of the metal and which are used for high-speed tools, permanent magnets, self-hardening steels, rustless steels, stainless cutlery, etc.; (2) low molybdenum steels, containing less than one per cent of the metal and classed as structural steels. The greater part is used in automotive forgings, pressed metal parts, railway forgings and track bolts, armour plate, air-flasks, pneumatic hammers, agricultural implements, shovels, machinery forgings, piston rods, chains, pierced tubes, rolls, etc. From a commercial and tonnage point of view the low molybdenum steels are by far the most important.

Brief History

Until quite recently the use of molybdenum in steels was regarded with suspicion by many metallurgists, and early experimenters of 30 years ago were almost unanimous in condemning it. The main causes of failure were that the molybdenum powder, or ferro-molybdenum used in making the steels was generally very impure, and contained an excess of

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[1] Am. Iron and Steel Inst., May 27, 1921. A. H. Hunter.

many deleterious substances such as sulphur and metallic oxides. Moreover, those molybdenum steels that were free from objectionable impurities were generally ruined by improper heat treatment.

Investigations were confined, mainly, to alloy tool steels using a high percentage of molybdenum. Since molybdenum and tungsten have similar alloying qualities with steel, it was hoped that the former metal could be used instead of tungsten, especially as it was found that less than half the amount of molybdenum was needed to produce the same result. Although the high-speed molybdenum tool steels were often superior to the tungsten steels, especially when alloyed with other metals such as chromium or manganese, etc., they were found to be erratic in behaviour. On this account experiments in making them were discontinued, and investigations were confined to structural and commercial steels. At first these steels were not very successful, but by diminishing the amount of molybdenum, and by a careful selecting of other metal as alloys, the earlier difficulties were overcome.

As a result of careful experiments on a series of molybdenum alloy steels of variable content, Léon Guillet of France[1] pointed out in 1904, that the commercial molybdenum steel, which is used for structural purposes should not contain more than one per cent molybdenum.

War requirements caused intense activity in various alloy steels, and molybdenum steels were proved to be superior to many of the older alloy steels. These molybdenum steels, which usually contain 0·2 to 0·5 per cent molybdenum, in conjunction with varying quantities of other metals, are generally known as low molybdenum alloy steels, and are being used to-day to the almost entire exclusion of the high molybdenum steels. According to recent information it appears that the United States metallurgists believe that the trend seems to be toward the lower molybdenum content, say about 0·25 per cent. Such steel has the advantage of being cheaper to manufacture.

HIGH MOLYBDENUM STEELS

TOOL STEELS

Prior to the development of the Taylor-White process and the modern high-speed steels, air-hardening steels were in general use. These were high in carbon and usually contained tungsten and chromium, the latter having replaced the manganese of the original Mushet air-hardening steels. Later, tungsten was frequently replaced by molybdenum. An air-hardening molybdenum steel largely used, contained: carbon 1·75 to 2 per cent; molybdenum 3·75 to 4·25 per cent; chromium 3·75 to 4·25 per cent.

In the earlier years of the twentieth century, high-speed steels quickly displaced the air-hardening steels. The efforts of most manufacturers were confined to tungsten-chromium combinations; but, in America, determined efforts were made to use molybdenum instead of tungsten. Dr. J. A. Mathews, president of the Crucible Steel Company of America[2] states that although one European metallurgist claimed that steel containing over 6 per cent molybdenum could not be rolled, large quantities containing

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[1] Paper in the Jour. Iron and Steel Inst., 1906.

[2] The Iron Age, Vol. 107, Feb. 27, 1921, p. 505. John A. Mathews.

9 per cent were being commercially rolled in America and steel containing up to 15 per cent had been successfully rolled. The steels containing over 6 per cent molybdenum came under the old Halcomb patent[1] now expired.

Although chrome-molybdenum-vanadium and molybdenum-vanadium steels were abandoned for high-speed purposes over twenty years ago, experiments on these steels have been conducted from time to time since then. Occasionally, these steels have given extraordinarily good service, but they are as a rule erratic.

One of the principal difficulties with molybdenum in high-speed steel is its tendency to volatilize at the somewhat high temperatures necessary in the working and hardening of steel. It is said by some metallurgists, that after prolonged, or excessive heating, a well-defined zone entirely different from the interior in structure is formed on the outside of the bars or tools; and, as a result, finished tools, such as drills and cutters, that cannot be given the grinding permissible with lathe tools, are not satisfactory. The zone is believed to be caused by the molybdenum on the surface becoming oxidized,[2] and in turn, volatilized, since the trioxide is much more volatile than the metal. H. D. Hibbard[3] suggests that for this waste of metal to extend to any considerable depth implies either that molybdenum moves through the heated steel to reach the oxygen of the air, or, as is more likely, that the oxygen penetrates the steel, reaching the molybdenum and oxidizing it, the volatile oxide escaping. The same author states that among the complaints that have been received by some of the early individual manufacturers regarding these molybdenum tool steels are; that molybdenum is liable to cause tools to crack in quenching, and that the steel was apt to be seamy and to contain physical imperfections. Some of these objectionable features were due to the use of impure ingredients in the manufacture of the steel, or to improper heat treatment. However, because of these undesirable characteristics, investigations have followed the line of endeavouring to discover some element, or elements, which in combination with molybdenum would act as a stabilizer for the latter.

A. H. Hunter[4] states that, in 1919, Arnold and Ibbotson[5] reported on an extensive research embracing several types of high-speed steel (described later). The chromium content was kept constant, the content of tungsten, molybdenum and vanadium being varied. The steels were rated in the following order in cutting efficiency: (1) molybdenum-vanadium, (2) tungsten-vanadium, (3) tungsten-molybdenum-vanadium, (4) tungsten-molybdenum, (5) tungsten, (6) molybdenum. These authors also state that with about 1·25 per cent vanadium present, the ratio of the hardening power becomes 2·7 to 1.

Although it may be inferred from these tests that the presence of vanadium had overcome the tendency of molybdenum to show erratic results, it is not stated that surface volatilization had been eliminated by this means, since the steel used had metal ground from the cutting edge before testing.

It has been reported that cobalt, especially in conjunction with vanadium, or tungsten, is a stabilizer for molybdenum. This is said to have been discovered by P. R. Kuehnrich, of Sheffield, who patented a formula

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[1] C. H. Halcomb. U. S. Pat. 722504, March 10, 1903.

[2] Molybdenum oxidizes at about 600° C.

[3] U. S. Bur. of Mines Bull. 100, p. 959, 1916.

[4] Am. Iron and Steel Inst., New York, May 27, 1921. A. H. Hunter.

[5] Journal (British) Iron and Steel Inst., Vol. 99, Nov. 1, 1919.

to this effect. Some hundreds of tons of this steel under the name of Como brand molybdenum high-speed steel was made and distributed by several Sheffield firms.[1]

One type of steel of lower molybdenum content contained 0·25 to 1·5 per cent molybdenum, 4 to 5·5 per cent cobalt, and 16 to 18 per cent tungsten, and is said to have given good results.

On the other hand, molybdenum in amounts less than one per cent, is used in conjunction with tungsten, cobalt, chromium, and vanadium, in a high-speed tool steel called iridium steel. This steel is reported to do 60 per cent more work than the best tungsten steel.

Dr. Mathews,[2] however, asserts that cobalt and vanadium, alone and separately, were thoroughly investigated in the United States previous to the war, without success; and that recent tests of the Halcomb Steel Company had shown that molybdenum could not be stabilized in this way.

A. H. Hunter[3] states that it can be confidently said that the commercially successful molybdenum high-speed steel has not yet been produced.

Arnold Steel.—In the latter part of 1918, John A. Arnold, of Sheffield University, England,[4] patented a high-speed steel which added certain percentages of molybdenum and vanadium to the usual constituent elements, but eliminated tungsten, the composition being as follows:—

—	Range	Preferred proportions
	Per cent	Per cent
Carbon	0·5 to 0·8	0·65
Manganese	0·1 0·3	0·20
Silicon	0·2 0·5	0·35
Sulphur	0·05 0·15	0·10
Phosphorus	0·01 0·03	0·02
Chromium	2·75 3·75	3·25
Vanadium	0·5 2·0	1·25
Molybdenum	5·0 10·0	7·50
Aluminium	....	Trace
Iron	Difference	86·68
		100·00

It is claimed that it is 10 per cent more efficient than any other high-speed steel; that the hardening temperature is about 1,300° C.; and that vanadium, when present in the specified quantities, nullifies the erratic influence of molybdenum when it is used in very considerable percentages; and that vanadium also renders water-quenching possible, without the danger of causing the tool to crack.

It would appear that this steel was not new since high-speed steels in which vanadium, or molybdenum in similar proportion and in which tungsten was eliminated, were experimented with, and even patented, some years previously.[5]

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[1] Metal Bulletin, Jan. 2, 1920, p. 5.

[2] Trans. Am. Inst. of Min. and Met. Eng., Feb., 1921.

[3] Am. Iron and Steel Inst., Loc. cit.

[4] Br. Pat. 132082, Dec. 12, 1918, and Sept. 11, 1919.

[5] Criticisms by various steel makers on The New British Super High Speed Steel—Iron Age, Jan. 8, 1920, p. 150.

About the same time that the Arnold patent was published, a large Rheinish steel works in Germany[1] appears to have also succeeded in discovering a process in which tungsten was discarded altogether in favour of molybdenum. The patented alloy, which is very similar to the Arnold formula, is as follows: For medium cuts; carbon 0·5 to 0·8 per cent; manganese 0·2 to 0·4 per cent; silica 0·2 to 0·4 per cent; molybdenum 6·0 to 10 per cent; chromium 3·0 to 6·0 per cent. For heavier cuts; the same as above with the addition of 1·0 to 2·0 per cent vanadium. The proportion of vanadium may be decreased to 0·75 per cent if from 2·0 to 3·5 per cent of cobalt is added. Vanadium is said to improve all steel alloys, as it refines the grain and thereby increases the toughness, and cobalt increases the range of hardening temperature. The patentees claim that without the cobalt, the regulation of the temperature for hardening requires a very high degree of skill and experience. The cobalt should always be in fixed proportion to the vanadium.

PERMANENT MAGNET STEELS

The permanent magnet steels investigated by Madame Curie in 1898 contained 3·36 to 4·05 per cent molybdenum. In 1902, Dr. G. L. French and Dr. J. A. Mathews thoroughly tested magnet steels containing 2 to 4 per cent molybdenum. These steels were satisfactory for permanence, but were found to be low in residual density, and more sensitive to hardening than the corresponding tungsten products, so that work on them was discontinued.[2] After hardening, however, they are said to retain their magnetism longer than hardened carbon steel, and to be superior to tungsten magnet steels. These magnet steels usually contain 0·5 to 0·7 per cent carbon and 0·5 per cent chromium, and sometimes up to 6 per cent molybdenum.

STAINLESS AND ACID PROOF ALLOYS AND STEELS

The main constituent of stainless steel is chromium, which should be at least 12 per cent. A very good stainless steel may be made combining 15 to 18 per cent chromium with a carbon content ranging as high as 0·8 per cent.[3]

Besides iron, chromium, and carbon, these steels are as a rule improved by the addition of small amounts of various other metals, such as manganese, molybdenum, tungsten, silicon, etc.

When these steels are rolled or hammered into a bar and afterwards properly heat-treated and polished, they show remarkable resistance to atmospheric influences, sea water, etc. They may be boiled in nitric acid without losing their lustre, dipped into sal ammoniac, or ammonium chloride solution, and afterwards exposed, without washing, to the atmosphere for an indefinite time without change. These steels are immune to vinegar and to the action of citric acid. If the chromium be raised to 40 per cent or over, and a small amount of molybdenum added, the steel will resist a boiling concentrated solution of salt and citric acid.

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[1] Mining Journal, Dec. 20, 1919.

[2] Ref. The Iron Age, Vol. 107, Feb. 27, 1921, p. 505. John A. Mathews.

[3] The Iron Trade Rev. "Stainless Steel offers Wide Use." June 2, 1921, p. 1516. Elwood Haynes.

Acid proof steels have been made containing 60 per cent chromium; 3 per cent molybdenum; and 35 per cent iron, which are said to have even resisted aqua regia.[1] Alloys containing 10 per cent chromium and 3 per cent molybdenum are practically acid proof. The heat treatment of these alloys has a great effect on their acid resisting qualities. By proper heat treatment and quenching they can be rendered extremely hard, and by proper annealing can be made sufficiently soft to be worked on the lathe. Their machining and forging qualities are good, and they show practically no scale during the hammering process.

A steel with about 15 per cent chromium has an elastic limit of 115,000 pounds per square inch; tensile strength, 200,000 pounds per square inch; elongation 2½ per cent; hardness 80. The manufacture of these steels is quite simple, though the best results are obtained by means of the crucible or electric furnace.

NON-FERROUS MOLYBDENUM ALLOYS

There are many types of non-ferrous molybdenum alloys which are very hard and acid proof. E. Haynes the inventor of "Stellite" says:[2]

> When molybdenum is added to a 15 per cent cobalt-chromium alloy, the alloy rapidly hardens as the molybdenum content increases, until the content of the latter metal reaches 40 per cent when the alloy becomes exceedingly hard and brittle. It cuts keenly and deeply into glass, and scratches quartz crystal with ease. It takes a beautiful polish, which it retains under all conditions, and on account of its extreme hardness, its surface is not readily scratched. When 25 per cent of molybdenum is added to a 15 per cent chromium alloy, a fine-grained metal results, which scratches glass somewhat readily, and takes a strong, keen edge. Its colour and luster are magnificent, and it will doubtless find a wide application for fine, hard cutlery. It cannot be forged, but casts readily and its melting point is not abnormally high.

These non-ferrous stellite alloys are silver white, are insoluble in nitric acid and only slowly attacked by hydrochloric acid. They are also said to possess remarkable qualities when used for high-speed cutting tools. The following is an analysis of a typical molybdenum stellite.[3]

Mo 22·50, Co 59·50, Cr 10·71, Fe 3·11, Mn 2·04, C 0·87, Si, S and P, balance.

Chrome-Molybdenum usually contains about 50 per cent each of molybdenum and chromium.

Nickel-Molybdenum contains 50 to 70 per cent molybdenum and the balance nickel, but usually carries some iron and carbon as impurities.

There are several other molybdenum alloys such as ferro-molybdenum-tungsten and copper-nickel-molybdenum.

Prof. S. W. Parr[4] produced an alloy called "Illium" having the following composition: Cu 6·42, Mn 0·98, Si 1·04, W 2·13, Ni 60·65, Al 1·09, Fe 0·76, Cr 27·07, Mo 4·67.

It is said to have been used with considerable success in the construction of combustion chambers of calorimeters and as a substitute for platinum. It is practically unattacked by 25 per cent nitric acid. It may be cast and machined, although with difficulty, and has a tensile strength of 50,000 pounds per square inch.

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[1] Recent Advances in Industrial Chemistry. Min. and Scientific Press, Vol. 105, 1912, p. 629. R. C. Benner.
[2] Alloys of Cobalt with Chromium and other Metals. Am. Inst. Min. Eng. Vol. XLIV, 1912, p. 576. E. Haynes.
[3] Manufacture and Use of Alloy Steels, Bull. 100, Bureau of Mines, 1915, p. 61. H. D. Hibbard.
[4] Trans. Am. Inst., Metals, Vol. 9, p. 211, 1915.

LOW MOLYBDENUM STEELS

DEVELOPMENTS

Molybdenum steels of to-day contain less than one per cent of molybdenum, alloyed with varying proportions of other metals. The superiority of these alloy steels, containing less than one per cent molybdenum, was pointed out in 1904 by Léon Guillet, of France,[1] who stated that "they have high elongation and good twisting strength". Previous to this John A. Mathews[2] experimented on these steels with varying results, which he attributed rather to the quality of the alloy used in manufacturing the steels, than to the presence of molybdenum.

Gustave Gin[3], in 1907, states that "molybdenum increases largely the ductility and elasticity of hard steels, for 0·25 per cent molybdenum will increase the extension to the point of rupture 40 per cent, and the addition of 1 per cent molybdenum to chrome steels of great hardness permits of their being worked rather easily". This metallurgist, as well as E. Schaaf-Regelman,[4] predicted that technical difficulties could be overcome if a constant supply of raw material could be assured, and that the consumption of molybdenum would then be very much greater.

Thomas Swinden conducted experiments on molybdenum alloy steel over a period of several years and found that one per cent gave a most excellent case-hardening steel.[5] His further study in 1913[6] included steels from 0·45 to 0·96 per cent molybdenum, together with varying proportions of the following metals: carbon, manganese, phosphorus and silicon with the addition of either nickel, chromium or vanadium.

Giolitti, in 1915, published a table giving the effects of various elements on the rate of carbonization, and it is interesting to note that molybdenum is as effective an aid to carbonizing as tungsten, chromium and manganese,[7] thus showing that molybdenum, when alloyed with straight carbon, chromium, nickel, nickel-chromium or other alloy steels, imparted to them a further increase of strength and toughness, thus making them very desirable commercial steels. Dr. Sargent states that:

> Their adoption, however, has been held back on account of the relatively high cost of molybdenum alloys, and the uncertainty of the supply, together with the quality of the same. These latter features have now been eliminated and molybdenum steels should be even more generally used than nickel or low-grade nickel-chromium steels.

During recent years much has been published regarding the physical properties, types, and uses of molybdenum alloy steels.[8]

The modern development of low molybdenum steels is largely due to the research work of C. Harold Wills, of Marysville, Mich., who was long associated with Henry Ford. During 1918, he was granted patents[9] for certain steel alloys in which molybdenum is the important factor. Mr. Wills classifies the various well-known alloys of steel according to their defects and disadvantages, among which are: vanadium, for "its liability to crystallization above certain narrow temperature ranges"; nickel,

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[1] Ref. "Molybdenum as an alloying element in Structural Steels," Proc. Am. Soc. for Testing Materials, June 22, 1920. G. W. Sargent.

[2] Journal Iron and Steel Inst., 1902, p. 182, "A Comparative study of some Low Carbon Steel Alloys." J. A. Mathews.

[3] "The Electrometallurgy of Rare Metals," Am. Electro-Chemical Soc., 1907.

[4] Engineering Magazine, Vol. XXXIII, 1907.

[5] Journal Iron and Steel Inst., 1911. Carnegie Scholarship Memoirs, Vol. III.

[6] Journal Iron and Steel Inst., 1913. Carnegie Scholarship Memoirs, Vol. V.

[7] For table see G. W. Sargent's paper. Op. cit., p. 9.

[8] See bibliography.

[9] U. S. Pats. 1278082; 1288344; 1288345. Sept. 3 and Dec. 17, 1918.

"although having non-crystallizing characteristics superior to those of vanadium steel, is very hard to machine after heat treatment"; manganese steels although possessing "super-excellent properties, such, for example, as exceedingly high tensile strength and high elastic limit, are unworkable and most difficult, if not impossible to machine"; and chrome falls short in some respects "particularly as to crystallization and narrow range of heat treatment". Mr. Wills goes on to say that molybdenum in percentages less than one per cent, when added to alloy steels, imparts all the characteristics necessary to bring the steel within the commercial class, as well as the super-excellent qualities of certain special steels. In other words, molybdenum in small percentages, when added to an alloy, acts as a stabilizer, or corrective against the undesirable qualities of the other elements present in that alloy.

EXPERIMENTS BY U. S. BUREAU OF MINES, ITHACA, N.Y.

Among the most recent experiments on the properties of molybdenum steels are those carried out by Dr. H. W. Gillett, Chief Alloy Chemist, Department of the Interior, at the Ithaca, N.Y., field office of the U. S. Bureau of Mines.[1]

The conclusions concerning molybdenum in steel are as follows: better control over the hardening operations; consecutive heats produce more uniform results; higher drawing temperatures, producing less internal stress; and that molybdenum is one of the most powerful and useful alloying elements in steel. The Bureau of Mines considers that the value of molybdenum as a steel alloy is only beginning to be appreciated and that it is destined to be widely used. As far as failure from fatigue and resistance to vibration are concerned, it has been shown that although molybdenum steels have slight advantage in some cases, they do not stand out above certain other alloy steels.

Another point that the work of the Bureau has brought out is the effect of non-metallic inclusions on endurance. Dirty steel is erratic and unsafe where repeated vibration must be endured. It may give either the same results as a clean steel, or far poorer results, depending on whether the stressed spot happens to be clean or otherwise.

It is more than probable, therefore, that the unreliability of some molybdenum alloy steels may be due to the above cause rather than to the presence of molybdenum.

PHYSICAL PROPERTIES OF LOW MOLYBDENUM STEEL

Molybdenum steels as a class, when compared with alloy steels in the same category from a commercial standpoint and subjected to the same tests of tensile strength, show[2]:—

1. A slightly higher elastic limit, hence a somewhat higher elastic ratio.
2. A higher elongation, hence greater ductility.
3. A much higher reduction of area, hence appreciably greater toughness.

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[1] Trans. Am. Electrochem. Soc. Experiments with some of the Rarer Elements in Steel, 1923.
[2] Am. Iron and Steel Inst., May 27, 1921. A. H. Hunter.

The last property is probably the most pronounced individual physical result of the addition of molybdenum to steel. Considerable data has been published dealing with the above points, in which a variety of alloy steels have been compared and properties tabulated.[1]

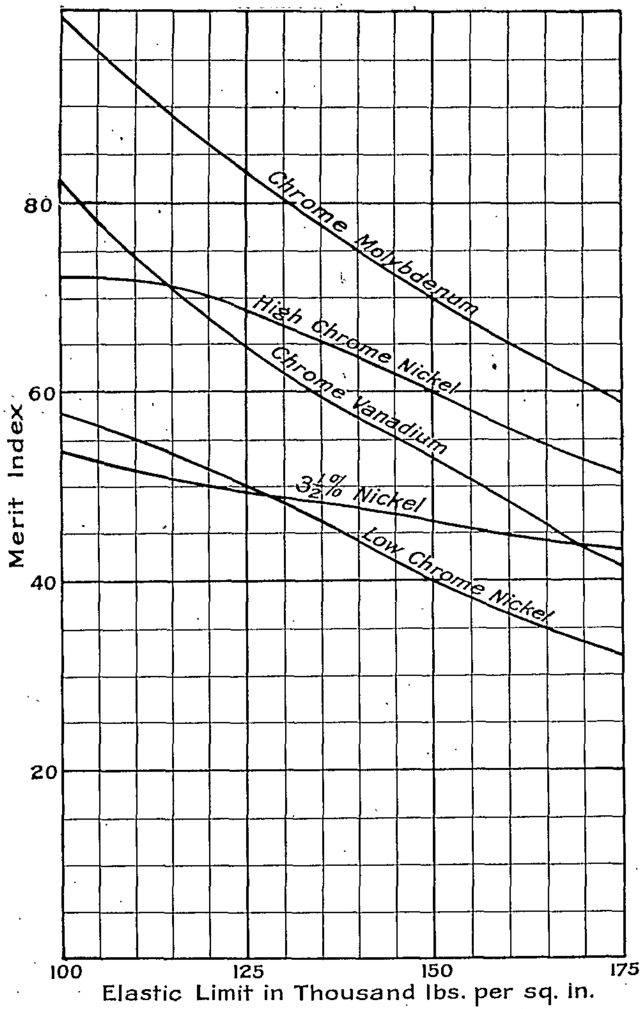

Figure 55. Merit Index curve, illustrating the properties of alloy steel.

Merit Index.—The physical merit of a steel depends upon the relation of all its properties, and it is the cumulative effect of the increase of each that gives to the molybdenum steels their superior merit. The use of a merit index, developed by H. T. Chandler, was referred to in a paper by

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[1] See bibliography, also tables dealing with molybdenum steels.

J. D. Cutter.[1] In the following formula the four static properties of different steels are compared:—

$$I = \tfrac{1}{2} e (E + S) \div (100 - R)$$

Where I = The merit index.
e = The percentage of elongation in 2 inches.
E = The elastic limit in terms of 1,000 pounds per square inch; in tests it is taken as the yield point.
R = The percentage of reduction of area.
S = The ultimate strength in terms of 1,000 pounds per square inch.

In making comparisons by utilizing the above formula the quenching and drawing temperatures for each series of tests should be constant.[2] (See Figure 55 and Tables XXXIX and XL.)

Under certain treatment conditions the all-round properties of molybdenum steel have been shown to be progressively better as the molybdenum content is increased up to one per cent.[3] (See Table XXXVII.)

TYPES OF LOW MOLYBDENUM ALLOY STEELS

By referring to recent bibliography dealing with molybdenum alloy steels, it will be found that a large number of these steels are enumerated and discussed in detail. It appears that only a few metallurgists, mainly in the United States, have experimented on and produced these steels commercially. These metallurgists, however, stand so high in their profession, and the data of the results obtained and the statements in their reports are so convincing that there appears to be no doubt that low molybdenum commercial steels have all the good qualities claimed for them.

Owing to the variable elements contained in each type of these steels as given by different authorities, representative formulas with their different qualities would be almost impossible, so that they can only be generalized.

Among the prominent types of these commercial alloy steels are the following:—

Carbon-molybdenum steel
Chrome-molybdenum steel
Chrome-nickel-molybdenum steel
Chrome-vanadium-molybdenum steel
Nickel-molybdenum steel

In all these steels molybdenum is substituted for a proportion of the other elements present in the standard alloy steels. It is claimed that by this substitution, the tensile strength and elastic ratio are strikingly increased. An important feature too, is that the reduction of area is increased, which is pointed to as an index of the toughness and the machinability of the steels. These steels almost invariably contain, in addition, small percentages of carbon and silicon, and in many cases manganese.

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[1] Trans. Am. Soc. for Steel Treating, 1920, p. 188.
[2] "Chrome and Nickel-Molybdenum Steels," The Iron Age, Mar. 16, 1922, p. 725. C. N. Dawe.
[3] Am. Iron and Steel Inst., May 27, 1921, p. 14. A. H. Hunter.

STRAIGHT CARBON-MOLYBDENUM

These steels contain variable amounts of carbon from 0·20 to 1·00 per cent, and molybdenum 0·60 to 0·80 per cent. These particular steels are not very extensively used because the benefits of molybdenum are to a large extent lost if not augmented by some other alloy, such as chrome and nickel.

The comparison of the mechanical properties of carbon-molybdenum steels, treated under different temperatures and with different heat treatment, has been very fully dealt with and tabulated in a recent paper by H. J. French,[1] of the Bureau of Standards, Washington. (See Table XXXIII.)

CHROME-MOLYBDENUM STEELS

By the addition of about 0·3 per cent of molybdenum to a chrome steel, the elastic limit and tensile strength are increased, and the brittleness decreased, the greater toughness being shown by the higher elongation and reduction of area. Molybdenum, particularly in conjunction with chromium, seems to impart the property of very deep hardening. There are three classes of this type of steel, of which the first contains 0·25 to 0·40 per cent molybdenum, the second 0·50 to 0·75 per cent molybdenum, and the third 0·75 to 1·00 per cent molybdenum. The last two classes are now only used in exceptional cases.

The chrome-molybdenum type appears to be at present the most universal of all the types of molybdenum alloy steels. In the United States it has been adopted by automobile and tractor manufacturers, agricultural implement makers, and the machinery manufacturing trade in general.

This steel, which is used in various parts of the car made by the Studebaker Corporation,[2] was found to forge entirely satisfactorily, with the particular advantage that the forgings scale very easily. It shears cold as readily as the other grades of commercial alloy steels, responds very readily to heat treatment, the percentage of forgings falling outside of the Brinell hardness being very small. Although no figures of the machining qualities are given, the Studebaker Corporation are satisfied that this special steel machines as well as the best of other alloy steels.

When chrome-molybdenum steel is to be case-hardened, the carbon content should be increased to about 0·19 per cent, in order to lower the quenching temperatures required. For special parts, used in transmission systems, rear axle gears, and drive pinions, this steel is hardly tough enough unless the part be specially treated by prolonged heating above the critical temperature of the core. It is claimed that this steel will take on the required case-depth in 10 per cent less time than chrome-nickel steels, with an average increase in Shore hardness of 5 to 7 points.

Chrome-molybdenum steel as used in the automobile trade is being gradually standardized and used as a universal steel—*i.e.*, ordering a certain amount of carbon and using the high temperatures for oil-quenching, and the low heats for case-hardening.

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[1] Am. Soc. for Steel Treating, Vol. II, No. 9, June, 1922, pp. 169-198. "Effect of heat treatment on mechanical properties of a carbon-molybdenum and a chrome-molybdenum Steel." H. J. French.

[2] For details, tables and analyses see The Iron Age, March 16, 1922, p. 723. C. N. Dawe.

The mechanical and physical properties of chrome-molybdenum steel at various temperatures have been thoroughly investigated and reported upon by H. J. French in a recent paper before the American Society for Steel Treating.[1] (See Table XXXIV.)

The advantages of this steel in fabrication such as forging, machinability, etc., have resulted in its rapidly increased use during the last two or three years. The consumer of alloy steel in the United States can buy chrome-molybdenum steel at the same or less initial cost for given strength or toughness than other alloy steels, and net a further saving in fabrication.[2]

CHROME-NICKEL-MOLYBDENUM STEEL

By adding 0·3 and 0·5 per cent molybdenum to an alloy containing about 3·0 per cent nickel and 0·8 per cent chromium, all the increased qualities of the chrome-molybdenum steel were observed. A permissible drawing temperature from 1150° to 1200° F. tends to remove quenching and forging strains, and eliminates straightening operations during machining.

Tests have shown that the addition of one-half of one per cent molybdenum, with lower nickel and slightly lower chromium produces an increase of 13,000 pounds per square inch in the elastic limit and of 7,000 pounds per square inch in the ultimate tensile strength, at the same time raising the elongation about one per cent and the reduction of area about 8 per cent.

This steel was made by the United Alloy Steel Corporation, Canton, Ohio, for the crankshafts and connecting rods of the Liberty motor. The steel showed high machining and workable qualities, exceptional range in heat treatment and anti-fatigue qualities. Dynamic, or impact tests made on several hundred crankshafts showed an average Izod value, more than 50 per cent in excess of the requirements, and considerably greater than could be obtained in chrome-nickel steels without molybdenum.[3] (For analyses and properties see Table XXXVIII.)

CHROME-VANADIUM-MOLYBDENUM STEEL

According to tests furnished by the Crucible Steel Company of America, when 0·85 per cent molybdenum is added to an alloy containing 1·06 per cent chromium and 0·17 per cent vanadium, the elongation and reduction of area is increased, but there is a slight decrease in elastic limit, tensile strength, and hardness. When this steel was specially toughened however, there was a considerable increase in the above qualities. In general, this steel appears to have all the advantages of the chrome-molybdenum with the added qualities conferred by vanadium. (See Table XXXVIII.)

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[1] Loc. cit.
[2] Mineral Industry, 1922. Molybdenum. W. Norman Bratton.
[3] Raw Material, April, 1921, p. 118. "Achievements in the realm of Molybdenum Steels," by Ch. McKnight, Jr.

NICKEL-MOLYBDENUM STEEL

The addition of molybdenum to nickel steel results in remarkably increasing the elastic limit, also the toughness, and ductility for given elastic limits as measured by reduction of area and elongation. (See Tables XXXV and XXXVI.) The effect is particularly pronounced when the steel is drawn at high temperatures. The Carbon Steel Company, Pittsburgh, conducted a series of tests that showed the superiority of such steel over straight nickel steel. It is claimed that finished products can be made from these steels with great ease, that they have a wide temperature range for heat treatment, and that they are exceptionally homogeneous, and free from fibres and flakes. This nickel-molybdenum steel, which contains approximately 0·58 per cent molybdenum and 3·50 to 4·50 per cent nickel, was used in the manufacture of parts of the Renault baby tanks, and was found to have very high armour-piercing resisting qualities. It is claimed that the steel can be effectively used in aeroplane, automobile, truck and tractor parts, and all working parts subjected to live loads, including crankshafts, connecting rods, pinions, axles, etc.; and, in view of its exceptional ductility for given elastic limits, it is also recommended for engine crank cases, brake drums, axle housings, and other deep drawn parts.

Nickle-molybdenum steel, containing nickel 1·58 per cent and molybdenum 0·20 per cent, is now being used for case-hardened parts, including the gears and knuckle pins of certain automobiles.[1] This steel is believed to be even more satisfactory than chrome-molybdenum steel for these purposes, because of its ability in the hot-rolled condition, to harden in oil after carbonizing, thus eliminating a certain percentage of loss due to straightening, after water-hardening, which is necessary with other types of alloy steels.

Practical tests have shown that, for carbonizing purposes, chrome-molybdenum should prove entirely satisfactory for parts in which hardness alone is the chief requirement, but less satisfactory for important parts in which combined toughness and hardness are requisite. According to at least one observer[2] nickel-molybdenum steel is better for these parts than any other alloy steel.

ANALYSES, COMPARISONS AND PHYSICAL PROPERTIES OF VARIOUS MOLYBDENUM STEELS

Wide Range of Heat Treatment. The following examples taken at random show that over a wide range for heat treatment there is practically no change in the properties of the finished steel.

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[1] For details see "Chrome and Nickel Molybdenum Steels," Iron Age, March 16, 1922, p. 728. C. N. Dawe, metallurgist to Studebaker Corporation of America.

[2] C. N. Dawo. Loc. cit.

TABLE XXXIII

(a) A straight carbon-molybdenum steel consisting of: carbon 0·20 per cent; molybdenum 0·70 per cent; quenched in oil and drawn at 1,000°.[1]

Quenching temperature	Elastic limit	Ultimate strength	Elongation	Reduction of area
Degrees F.			per cent	per cent
1600	90,400	101,600	22·0	64·2
1700	88,440	102,000	22·5	62·9
1800	89,040	103,500	24·0	65·4
1900	88,630	100,600	23·0	64·2
2000	88,800	103,700	22·0	62·3

TABLE XXXIV

(b) A chrome-molybdenum steel used for automobile forgings, shaftings, etc., and general machinery parts is as follows: carbon 0·27; manganese 0·66; sulphur 0·036; phosphorus 0·018; silicon 0·08; chromium 0·83; molybdenum 0·42. The size treated was $\frac{7}{8}$-inch round and all tests were drawn at 1,050° F., after quenching in water at the temperatures indicated.[2]

Quenching temperature	Elastic limit	Tensile strength	Elongation	Reduction of area	Brinell	Izod
Degrees F.	Lbs. per sq. in.	Lbs. per sq. in.	Per cent	Per cent		Ft. lbs.
1500	140,000	163,500	18·5	62·7	319	58
1600	139,500	161,700	17·0	63·1	321	62
1700	138,400	160,400	17·5	61·7	321	60
1800	138,300	158,500	18·0	61·5	319	61
1900	139,600	159,600	16·8	57·9	317	56
2000	140,000	157,000	17·0	59·0	317	55

TABLE XXXV

(c) A nickel-molybdenum steel is as follows: carbon 0·33; manganese 0·25; silicon 0·18; nickel 4·50; molybdenum 0·58.

All tests are drawn at 1,000° F.; Brinell and Scleroscope hardness 364 and 57 respectively in each case.[3]

Oil quench.	Elastic limit	Tensile strength	Elongation	Reduction of area
Degrees F.			Per cent	Per cent
1450	164,600	173,800	16·0	53·4
1500	166,500	176,000	15·5	55·3
1550	165,100	175,000	15·5	54·0
1600	164,900	173,300	15·5	55·6
1650	166,000	174,400	15·0	55·0

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[1] Raw material. April, 1921, p. 120. Ch. McKnight, Jr.
[2] Trans. Am. Soc. for Steel Treating, Vol. I, p. 503, 1921. M. H. Schmid.
[3] Book issued by Climax Molybdenum Company, "Molybdenum Commercial Steels," 1919, p. 56.

The following table gives the effect of drawing temperatures on the same type of steel 2 inches round after quenching in oil at 1,450° F.

TABLE XXXVI

Drawing temperature	Elastic limit	Ultimate	Elongation	Reduction of area	Brinell	Scleroscope
	Lbs. per sq. in.	Lbs. per sq. in.	per cent	per cent		
Degrees F.						
500	233,000	249,800	14·0	46·8	455	54
900	170,000	189,200	16·0	51·6	363	45
1000	161,000	180,700	18·5	58·3	344	43
1100	149,000	166,800	18·5	60·0	328	41

These results show that there is little change in physical characteristics when the steel is drawn between 900° and 1,100° F.

TABLE XXXVII

Progressive Effect of Molybdenum Steels

Sections $1\frac{1}{4}$-inch round and $1\frac{1}{4}$-inch square, quenched in water from 1,550° F. to 1,600° F. Drawn to show a tensile strength of 175,000 pounds per sq. in.[1]

Analysis range: carbon 0·28 to 0·36; manganese 0·44 to 0·64; chromium 0·70 to 1·04.

—	Mo. 0·02%	Mo. 0·40%	Mo. 0·76%
Elastic limit	167,000	164,000	162,000
Elongation per cent in two inches	13·5	16·6	19·5
Reduction of area, per cent	52·0	58·4	61·0

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[1] Trans. Am. Iron. and Steel Inst., May 27, 1921, "Molybdenum." A. H. Hunter.

TABLE XXXVIII

Effect of adding Molybdenum to Chrome, Chrome-nickel, and Chrome-vanadium Steels[1]

	Analyses, per cent							Physical Properties					
	C.	Mn.	Si.	Cr.	Ni.	Va.	Mo.	Elastic limit	Tensile strength	Elongation	Red. of area	Izod	Brinell
										per cent	per cent		
Chrome	0·27	0·63	....	0·99	....	....	Nil.	130,000	139,000	16·5	58·0	....	....
Chrome-molybdenum	0·26	0·64	....	0·76	....	....	0·31	142,000	151,000	18·5	62·0	....	....
Chrome-nickel (*a*)	0·35—0·45	0·50—0·80	0·10—0·20	0·70—0·90	1·75—2·25	....	Nil.	129,760	144,460	12·2	53·7	46	307
Chrome-nickel-molybdenum (*a*)	0·24—0·31	0·50—0·69	0·08—0·52	0·74—0·98	2·85—3·05	....	0·32—0·54	130,000	142,000	20·5	65·0	67	303
Chrome-vanadium	0·32—0·40	0·40—0·60	....	0·80—1·00	....	over 0·16	Nil.	146,500	167,500	16·0	54·5	....	340
Chrome-vanadium-molybdenum (*b*)	0·39	0·48	....	1·06	....	0·17	0·85	144,000	155,000	23·0	63·5	....	310–330
(*c*)	0·39	0·48	....	1·06	....	0·17	0·85	170,000	190,000	19·0	60·0	....	364–420

(*a*) Liberty motor crank-shafts. (*b*) Semi-toughened. (*c*) Toughened.

[1] Book issued by Climax Molybdenum Company, "Molybdenum Commercial Steels."

Physical Properties of Molybdenum Steels with Comparisons

General Efficiency—Merit Index[1] (*See also Fig. 55*)

The following are the analyses of the various steels tested:—

TABLE XXXIX

Chemical Analyses of various types of Steels tested

—	Chrome molybdenum	Chrome vanadium	Chrome	Chrome nickel
Carbon	0·260	0·320	0·310	0·280
Manganese	0·570	0·750	0·850	0·720
Sulphur	0·020	0·033	0·012	0·012
Phosphorus	0·025	0·025	0·020	0·020
Chromium	0·800	1·030	0·910	0·580
Molybdenum	0·360	....	....	....
Vanadium	....	0·160	....	....
Nickel	....	....	....	1·270

TABLE XL

Results of Tests of 1½-inch round Steel of the above Analyses

Grade of steel	Temperature deg. Fahr.		Yield-point as elastic limit	Ultimate strength	Elongation in 2 in.	Reduction of area	No. of tests made	Merit index
	Quenching	Drawing	lb. per sq. in.	lb. per sq. in.	%	%		
Chrome molybdenum	1,550 to 1,650	1,000	147,900	157,600	20·3	57·0	9	72·2
Chrome vanadium	1,550 " 1,650	1,000	129,800	140,200	20·9	57·6	9	66·6
Chrome	1,550 " 1,650	1,000	101,370	122,178	18·1	60·8	9	51·6
Chrome nickel	1,475 " 1,575	1,000	103,360	123,036	18·7	61·1	9	54·1
Chrome molybdenum	1,550 " 1,650	1,100	118,500	131,900	24·0	64·4	9	84·3
Chrome vanadium	1,550 " 1,650	1,100	117,800	134,900	23·5	61·0	9	76·1
Chrome	1,550 " 1,650	1,100	86,770	109,710	21·9	65·0	9	61·4
Chrome nickel	1,475 " 1,575	1,100	87,720	110,492	22·3	65·5	9	64·0
Chrome molybdenum	1,550 " 1,650	1,200	92,900	112,400	26·9	68·8	9	88·7
Chrome vanadium	1,550 " 1,650	1,200	102,400	118,500	26·5	67·0	9	88·8
Chrome	1,550 " 1,650	1,200	78,250	103,453	23·7	67·2	9	65·6
Chrome nickel	1,475 " 1,575	1,200	80,417	103,577	24·6	67·8	9	70·3

Each group of the above test pieces was quenched from a production furnace in the same manner as small forgings would be handled in receiving similar treatment.

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[1] The Iron Age, March 16, 1922, p. 727. C. N. Dawe.

GENERAL COMMERCIAL USES OF LOW MOLYBDENUM ALLOY STEELS

General

Small percentages of molybdenum, as a rule alloyed with chromium, nickel, or vanadium, constitute different types of steels that have been used for a wide variety of purposes. The list includes automobile parts, aeroplane motor and fuselage parts, section steel for reapers and other agricultural implements such as shovels, etc., armour plate, battering tools such as machinists' hammers, edge tools such as chisels and hatchets, gears, large and small, springs of all kinds, shafting for heavy and light machinery, balls for ball-bearings, rifle barrels, rivet sets, pierced tubes, pressed metal parts, chains, etc., and recently for heavy and light rolls.

Automobiles

There is probably no mechanism that is subject to such hard and variable usage as the working parts of an automobile, and combined with this is the insistent demand that the weight be kept down. The steel employed must have the combined qualities of hardness, toughness, resiliency, and ability to withstand sudden and great reversals of stress and a continued succession of shocks of the heaviest character. It is claimed by some automobile manufacturers, who have devoted much time to investigating its merits, that molybdenum steel meets all these exacting demands and permits of a reduction in the sectional weight of certain parts to a degree impossible with any other known steel.

It is probably in the manufacture of automobile parts that molybdenum steels find their greatest application, particularly in the production of rear axle shafts, transmission gears and shafts, steering knuckles and pins, ring gears, drive pinions, etc.[1]

The chrome-molybdenum steels used contain about 0·8 per cent chromium and 0·36 per cent molybdenum.

Clifford Taylor[2] of the Molybdenum Corporation of America, Pittsburgh, stated that:—

"Half of the steels for automobile business, etc., will be molybdenum steels, estimating two million tons of alloy steels, which would mean about one million tons of molybdenum steel."

Springs

The high elastic limit combined with the dynamic toughness of chrome-molybdenum and nickel-molybdenum steel has led to its use in the manufacture of spring steels. It is said that, amongst others, the Fifth Avenue busses in New York use this type of steel in their springs.

Molybdenum Steel Rolls

One of the most recent forms of use for molybdenum steels is molybdenum steel rolls. One company in the United States produced to date (July 1922) about 750 tons of cast steel molybdenum chrome rolls and 350 tons of molybdenum iron rolls, and use approximately 3,000 pounds of ferro-molybdenum per month.

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[1] For details, tables, and analyses, see "The Iron Age," March 16, 1922, p. 723. C. N. Dawe. Also Scientific American, July 23, 1921, p. 62.

[2] Hearings on general tariff revision before the Committee on Ways and Means, House of Representatives, 1921, Part II, Schedule C, p. 746.

The Blast Furnace and Steel Plant Journal gives a detailed description of these special steel rolls, pointing out their uses and excellent qualities.[1]

WAR USES

General.

Authentic statements as to the exact uses to which molybdenum was put during the great war are almost entirely lacking; but there is no doubt that the metal was used in the manufacture of chemicals and some tool and machine steels.

In the earlier stages, reports were common that the great German howitzers used against Liege and Namur owed their endurance to a lining of molybdenum steel. The metal of two of these guns, which were captured, was analysed by the American government, and Henry M. Howe[2] found that in the portions analysed neither of them contained any of the relatively infusible elements, tungsten, vanadium, or molybdenum, the main alloy metals being nickel 2·7 to 2·9 per cent and chromium 1·3 per cent. Experiments were also conducted by the Japanese metallurgists, M. Okochy, M. Majima, and N. Stato,[3] to determine the resisting power of molybdenum steel against gun erosion. These chemists found no trace of the metal in specimens from captured German guns.

It is claimed that towards the end of the war, molybdenum was used in the manufacture of fighting tanks, gun shields, steel helmets, parts of aeroplane and automobile engines, armour plating, etc. Many of these were produced by United States steel makers but it is doubtful if they saw actual war service.

Renault Baby Tanks. The first baby tanks that were used in France during the war were protected by heavy cast manganese steel plate over 3 inches thick, but were easily penetrated by the high-powered German armour-piercing projectiles. These were later supplemented by nickel-molybdenum plates less than three-fourths of an inch thick, and apparently effectively withstood severe tests by armour-piercing bullets. The steel contained molybdenum 0·30 to 0·70 per cent, nickel 3·0 to 5·0 per cent, manganese 0·30 to 0·50 per cent, carbon 0·20 to 0·40 per cent, and silicon 0·10 to 0·20 per cent.

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[1] The Blast Furnace and Steel Plant, June, 1922, p. 358.

[2] Trans. Am. Inst of Min. Eng., "The Erosion of Guns," Feb., 1918, p. 386. H. M. Howe.

[3] Jour. Soc. Mech. Engrs., Tokyo, Vol. 22, No. 4, Nov. 1918, pp. 1 to 44; also, Jour. Col. of Eng. Tokyo Imp. Univ., Vol. 9, No. 5, Oct. 15, 1918, p. 193.

CHAPTER II

MANUFACTURE OF FERRO-MOLYBDENUM, METALLIC MOLYBDENUM, AND MOLYBDENUM STEELS

MANUFACTURE OF FERRO-MOLYBDENUM

Formerly ferro-molybdenum was produced by first roasting the molybdenite concentrates and then treating them by the crucible process, but in most cases it is now made in the electric furnace by fusing the concentrates with varying proportions of coke, lime, scrap iron, etc. Detailed descriptions of the processes employed in Canada will be found under the headings International Molybdenum Company, and the Tivani Electric Company.

Ferro-Molybdenum from Wulfenite.

By treating the ore with soda-ash in a lead furnace, a sodium-molybdate slag and lead bullion are produced. The slag is crushed and smelted with a lime flux in a magnesite-lined electric furnace. Iron ore is added to obtain the required grade of ferro-molybdenum.[1]

MANUFACTURE OF METALLIC MOLYBDENUM

There are several methods by which molybdenum is produced from its ores.

For molybdenite concentrates, the following is a brief outline of the methods employed.

Alumino-thermic Process. The metal is obtained by igniting a mixture of the concentrate and finely divided metallic aluminium. The metal so obtained is compact, but, as a rule, contains some iron and small quantities of silicon, as impurities.

Electric Fusion Process. The molybdenite concentrates are heated in a carbon tube by a current of about 350 amperes at 60 volts. Sulphur dioxide is at first evolved, and the sulphur is finally expelled by increasing the amperage to 900 at 50 volts. The molybdenum thus obtained contains a considerable percentage of carbon, but this can be removed by heating with molybdic oxide.

The methods employed for treating wulfenite concentrates will be found in the chapter dealing with the metallurgy of wulfenite.

Further brief descriptions of several patents for the manufacture of molybdenum, or its salts, are outlined under the Direct Reduction of Ores and Concentrates.

The ordinary methods of reducing molybdenite by carbon in the electric furnace, produce a metal which contains carbon or carbides and in order to obtain pure molybdenum the concentrates are first converted into either molybdic oxide, or ammonium molybdate.

The Fansteel Products Company converts the molybdenite into molybdic acid by roasting on a cast iron base. A description of the method of producing pure molybdenum as carried out by this company is as follows:[2]

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[1] Trans. Am. Inst. Min. & Met., 1920, pp. 28-82. R. M. Keeney.
[2] Chem. and Met. Eng., Oct. 27, 1920, p. 837.

The product of roasting is dissolved in ammonia, filtered and precipitated with nitric acid. This gives a relatively pure molybdic acid which is then ignited at a temperature below 1,000° C. to molybdic oxide, a pale yellow-brown material.

It is necessary in the purification process to be sure that copper and all the alkali earth metals are eliminated. Their presence in the actual metal is of little consequence except that they retard seriously the reducing of the oxide to metal by preventing the removal of oxygen.

Molybdenum is reduced from the ignited oxide in nickel or nichrome trays placed in iron tubes. A stream of hydrogen previously dried and purified is run through the tubes, which are subjected to temperatures approximately 1,000° C. Reduction of molybdenum is extremely difficult as compared with tungsten; it is frequently necessary to run a furnace containing trays of the oxide for forty hours before reduction is complete enough to make a workable metal.

The metal powder is removed from the boats, screened and pressed into bars in a hydraulic press, the process varying from that of tungsten only in minor details.

The pressed sticks of metal are placed between electrodes of an electric furnace and brought up to approximately 2,400° C. by passing an electric current through them. This operation is, of course, performed in an atmosphere of hydrogen. The molybdenum shrinks very considerably and the follow-up on the electrodes must be unusually long in order to develop sufficient grain growth in one operation. The ingots must not show any cracks except very slight ones at the end, unavoidable because of the cooling effect of the electrode.

The material is then rolled into sheets, or may be swaged round in ordinary swaging machines. The drawing operation in the manufacture of molybdenum wire may begin as large as 0·100 inch. A piece $\frac{3}{16}$ inch in diameter may be bent cold in a radius of approximately 3 inches. The material is machinable and is highly resistant to most alkalis and acids. It takes a very high polish.

During 1912 and 1913 W. D. Coolidge took out a number of patents embodying the purification of molybdenum and tungsten, and their manufacture into lamp filaments.[1]

MANUFACTURE OF MOLYBDENUM STEELS

Molybdenum can be introduced into steel as easily as any other alloys and with ordinary precaution the metal does not volatilize or oxidize out of the bath. The production of many thousands of tons of molybdenum steel has served to place melting practice on a firm basis. Molybdenum may be added to the electric or open-hearth bath either as ferro-molybdenum, or calcium molybdate but greater care must be taken in the open-hearth with the latter than with the former.

Open-hearth Practice

When using ferro-molybdenum in the open-hearth furnace, the metal may be introduced at any of the following points during manufacture.[2]

1. *In the bath.*
   (a) The ferro-molybdenum is thrown in, containers and all, just after the charge becomes plastic and a little before the melt becomes level—*i.e.*, just before the lime begins to come up. It should not be added with the charge because of possible loss in the furnace bottom.
   (b) The ferro-molybdenum is thrown in just after the final additions of the ferro-manganese, ferro-chrome, etc., have been made, *i.e.*, about 10 to 15 minutes before the furnace is tapped.

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[1] U. S. Pats.: 1,026,384; 1,026,428 May 14, 1912; 1,082,933 Dec. 30, 1913.

[2] Molybdenum Commercial Steels—issued by Climax Molybdenum Company.

2. *In the ladle.*

When the alloy is added in the ladle it should be first melted and poured into the molten steel stream as the furnace is tapped. The alloy is sometimes added partly in the furnace and partly in the ladle. This method of adding in the ladle was employed in the first production of molybdenum steel during the war, but is now believed to have been abandoned.

There is little choice betweeen either method, both of which are used by various steel works. The United Alloy Steel Corporation, however, have adopted the first method as standard practice because of the better diffusion and higher degree of uniformity in the finished product, together with higher efficiency and minimized loss of the alloy.[1]

The average loss of metal added by this method should not exceed 5 to 10 per cent, the loss being cancelled where the same furnace or furnaces are used on successive heats, thereby reducing the purely mechanical loss. A slight mechanical loss of, probably, between 2 and 4 per cent is inevitable. The small balance of the loss is at present unaccounted for, but is probably due to oxidation and volatilization.

Calcium Molybdate. When calcium molybdate is used in the open-hearth, it should be added in the early stage of the heat, not with the charge because of possible loss in the furnace bottom, but, preferably, as the scrap charge is melting down, and a little before the melt becomes level. The molybdate is added, container and all, and is placed so as to permit the partly molten scrap to cover or envelop the salt; it being borne in mind that the molybdate must come in direct contact with the molten iron. As a rule the gases are shut off during the actual addition.

Whenever possible, because of its purity, the salt is added in preference to the ferro-molybdenum, but greater care is necessary with the former in order to prevent the draft of the furnace from blowing off part of the powdered molybdate and carrying it to the furnace walls, ports, and checker chambers.[2]

According to a German patent[3] briquettes of calcium molybdate are made by mixing molybdenum trioxide and calcium chloride with water, pressing the mix into shapes, and drying, thereby eliminating the loss from furnace draft.

Molybdenum is sometimes added to the furnace in the form of molybdenum powder. The results obtained and precautions to be taken are similar to those when the salt is used.

Steel Scrap. Molybdenum steel scrap can be re-melted without appreciable loss of the metal, and, in continuous operations, little more than the actual amount need be added. This fact is, of great economic importance from the standpoint of recoveries and cost. In general practice, the total alloy efficiency is well over ninety per cent.[4]

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[1] Molybdenum Steel and its application. Am. Soc. for Steel Treating, April 22, 1921. M. H. Schmid.

[2] The rights to this process are covered by the U.S. Pat. 1300279 owned by The Steel Alloys Company.

[3] German Pat. 337961, March 3, 1920.

[4] "Molybdenum." Am. Iron and Steel Inst., May 27, 1921. A. H. Hunter, Atlas Crucible Company.

Electric Furnace

With the strong reducing action and concentrated heat of the electric furnace, the time of addition of calcium molybdate is of little importance, but the best results have been secured from its introduction just after skimming off the first, or phosphorus slag, the final or white slag indicating that reduction has been completed. The addition of ferro-molybdenum may be made as above or at any time after the final slag has been formed.

No comment is, therefore, necessary regarding the charges, as conditions are under absolute control. Practically one hundred per cent alloy efficiency is said to be possible.[1]

Crucible Process

When the crucible process is employed the ferro-molybdenum is placed in the crucible with the last two-thirds of the charge. Molybdenum powder may be used; but, on account of its high melting point (about 2520° C.) and the impurities usually present, the amount of molybdenum in the finished steel is less than when ferro-molybdenum is used, which has a melting point around 1550° C. for 50 to 60 per cent molybdenum content. Calcium molybdate should never be used in the crucible process. By using ferro-molybdenum practically all the molybdenum added to the melt will be present in the ingot metal, and this is true of either the basic, or acid open-hearth practice.

FORMS IN WHICH THE MOLYBDENUM IS ADDED TO THE STEEL

Ferro-molybdenum. Formerly a ferro containing from 75 to 80 per cent molybdenum was generally specified. Because of the difficulty of securing an ore suitable for manufacturing such a high-grade alloy, and because of the high-melting point of the metal, with attendant difficulties of production the cost of this alloy was necessarily high. More recent practice has been to produce a ferro containing approximately 50 per cent molybdenum. This grade besides being less costly to produce, is perhaps the principal factor in the success of its direct addition to steel. Its lower melting point is responsible for less segregation and eliminates the necessity of pre-melting, or fine crushing.[2]

Calcium Molybdate. High-grade calcium molybdate containing practically nothing but the oxide of molybdenum and calcium can be made easily and comparatively inexpensively. It contains approximately 40 per cent metallic molybdenum, and is free from impurities detrimental to good steel manufacture. This salt is easily reduced and the lime apparently prevents loss by volatilization of the molybdenum trioxide. The lime merely serves as a small added source of material upon the reduction of the molybdenum by the carbon or silicon in the steel.

The almost complete recovery of the molybdenum used has proved that molybdenum in this form may be successfully and very efficiently introduced into the steel. Furthermore, this introduction involves no complication, it being only necessary to add the salt at the stages already mentioned.

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[1] M. H. Schmid. Loc. cit.

[2] Calcium Molybdate as an addition agent in Steel making. Chem. and Met. Eng., June 2, 1920, p. 1018. Alan Kissock.

The production of calcium molybdate offers a further advantage in that the equipment for its manufacture does not involve great cost, nor is special skill required in the operation; whereas the electric production of ferro necessitates both large expenditure and considerable skill and experience.

A carbon-free molybdenum agent can be offered to the steel manufacturer at a price that should permit the competition of the metal with those at present in more general use.[1]

From the standpoint of the mine owner the production of calcium molybdate has the advantage that neither copper nor iron interferes. It, therefore, becomes unnecessary for the producer of the raw material to make a high-grade concentrate, or to separate any copper, or iron sulphides present. Many molybdenite properties have in the past been unable to operate because of the high copper values present, as such ores were too heavily penalized, or else were unmarketable.

Molybdenite Concentrates. Attempts have been made to introduce molybdenite concentrates direct into the steel.

All concentrates unless extremely high grade, contain a certain proportion of silica, and in basic furnace practice it is desirable to avoid, as far as possible, any introduction of silica into the bath. The most serious objection, however, is the 25 to 30 per cent sulphur content of the high-grade concentrates. Although a considerable proportion of the molybdenum will enter into the steel, sulphur, with its great affinity for iron, will also be introduced. Tests by the Southern California Iron and Steel Company in making a 0·4 per cent molybdenum steel direct from concentrates found 0·25 per cent of sulphur absorbed. The sulphur content might have been lowered by long treatment in the furnace with manganese and lime additions, but general conditions would make this impracticable.[2]

On addition of the concentrate to steel at least a portion of the mineral would be converted into trioxide, and as such would readily volatilize and be lost. The tendency to volatilize, as well as the cost, makes a preliminary roast of the concentrate inadvisable.

Dr. G. W. Sargent has compiled tables showing the basic open-hearth practice followed in producing 6,000 tons of chrome-molybdenum steel.[3]

It has been shown in actual practice that molybdenum does not go into the slag when molybdenum steel scrap is re-melted, as chromium and vanadium do, but that it behaves as does nickel.

Dr. Sargent further states that the yield, through the various stages of manufacturing to the finished bars, averaged as follows: ingot yield in melting 87 per cent; billets yield in blooming 80 per cent; bars in rolling 94·4 per cent. In other words 66 per cent of the metal charged into the furnace was obtained in finished bars.

In using the acid open-hearth, similar results were obtained by employing the same practice as was followed in the basic open-hearth.

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[1] Loc. cit.
[2] Chem. and Met. Eng., June 2, 1920, p. 1018. Alan Kissock.
[3] Proc. Am. Soc. for Testing Materials, June 22, 1920. "Molybdenum as an alloying element in Structural Steel." G. W. Sargent.

Pouring and Rolling. No special precautions need to be taken in pouring or rolling, except those which would be taken with any alloy steel, and it will be found in most cases that the percentage of product will be greater, and the rejections for seams, segregations, or piping, less with molybdenum steel than with corresponding grades of other alloy steels.[1]

THE ADAPTABILITY OF MOLYBDENUM STEEL TO FABRICATION

In the making of an article from steel there are three fundamental operations:[2] (1) forging, or cold pressing; (2) heat treating; (3) machining.

Forging. Good forgeability is determined by three factors: (a) the manner in which the steel flows; (b) permissible range in forging temperatures; (c) the extent to which the scale adheres to the steel.

Molybdenum steels flow readily under the dies and possess a wide, safe forging range. Their chief advantage in forging lies in the ability that is claimed for them to "throw the scale", so that not only do they show a comparatively smooth surface after hot working, thus considerably reducing the time of pickling and hand cleaning, but also forging rejections are minimized, because the adhesion of scale during working naturally increases the prevalence of pits and other surface defects. Forging companies report that chrome-molybdenum steels flow better in dies than do other types, this owing, probably, to a large extent, to the higher working temperatures to which these steels may be subjected.

In discussing the forging qualities of molybdenum steels, Martin H. Schmid[3] states that:—

> Wide temperature ranges are available for rolling and forging, and while there is no appreciable difference in the amount of scaleage, there is a marked advantage in the texture of the scale over that of nickel steels. The scale is, however, a loose non-tenacious one, freely flaking from the steel, showing no tendency to roll into surface and result in pitting.

Molybdenum steels as a class are more free from seams than nickel and chrome-nickel steels of corresponding grades. Such defects in billets do not, however, heal up or roll out in finishing mill operations. Molybdenum evidently has no deoxidizing, or scavenging effect, neither has it any deleterious effects on the working of the steel.

Cold-Pressing. In sheet form, straight carbon-molybdenum steel has proved, because of its great ductility, especially adaptable for parts which require difficult forming operations. Also, because of its high strength it has a much wider application of heat treatment to sheet metal parts than has heretofore been possible. Partly because of these qualities molybdenum steel is used by manufacturers of automobile frames, and of implements such as shovels.[4]

Heat Treating. The outstanding advantage claimed for the heat treatment of molybdenum steels are: extremely wide quenching ranges available for practical heat treatment; the excellent penetrative effect of such treatment on large sizes; and the broad drawing range, causing but slight modification and reversion to normal state upon heat application after quenching.[5] For hardening, the heat treatment range allows for a temperature variation of 200° F. The high drawing temperatures mean greater

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[1] "Molybdenum Steels." Trans. Am. Soc. Steel Treat., March, 1921. C. H. McKnight, Jr.

[2] Am. Iron and Steel Inst., May 27, 1921. A. H. Hunter.

[3] "Molybdenum Steel and its Application." Trans. Am. Soc., Steel Treat., April 22, 1921. M. H. Schmid.

[4] A. H. Hunter, Op. cit. p. 17.

[5] Am. Soc. for Steel Treating, April 22, 1921. M. H. Schmid.

ease in furnace regulation, and the adaptability of the steel to heat treatment results in greater uniformity and fewer rejections. A great deal of data[1] has been published to show that the static physical properties of molybdenum steel are practically constant over a wide range of temperature for quenching. (See tables on heat treatment.)

For case hardened parts, molybdenum has the effect of greatly toughening and of adding hardness and wearing qualities to the case. The penetration of carbon, in the carburizing process, is high,[2] being almost twice as great as nickel.[3]

A recent paper published by H. J. French, of the Bureau of Standards, Washington,[4] gives a comparison of different heat treatments for production of high resistance to impact, and the best combinations of strength and ductility of carbon-molybdenum and chrome-molybdenum steels.

Machining. Corroborative evidence collected from a large number of commercial plants, and results of careful tests, show that molybdenum steels have, for a specified elastic limit, or Brinell hardness, better machining qualities than other alloy steels of equal physical properties, such as chrome-nickel and the nickel steels, etc. The superior machining qualities of molybdenum steel is illustrated by the following:—[5]

> This has been established by the production results obtained on several thousand tons processed into rear axle drive shafts and on which no machining difficulties were experienced on shafts heat treated to conform to a 300-340 Brinell specification. On a heat made by the United Alloy Steel Corporation for one of the large automobile companies and put into steering knuckles and front axles, we received a report to the effect that tool grinding costs were but one-third as high as on 3½ per cent nickel steel of the same hardness and with corresponding shop production. Front axles with Brinells up to 340 maximum machined as well as chrome-nickel steel axles of 302 Brinell.

Molybdenum Cast Iron

Molybdenum introduced into cast iron improves the texture of the iron very much, making it tougher and finer, and increasing its tensile strength.

The following table shows the superior qualities of molybdenum over ordinary cast iron:—[6]

TABLE XLI

Addition of Molybdenum to Cast Iron

—	Brinell hardness	Tensile strength pounds per sq. in.
(*a*) Cast iron containing no molybdenum	236	32,500
(*b*) Cast iron containing 2 per cent Mo	277	36,300
(*c*) Cast iron containing 4 per cent Mo	311	38,400

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[1] Data by Crucible Steel Company; The Carbon Steel Company; United Alloy Steel Corporation, etc.
[2] Trans. Am. Iron and Steel Inst., May 17, 1921, p. 18. A. H. Hunter.
[3] Tables of penetration by Dr. Frederico Giolitti.
[4] Am. Soc. for Steel Treating, "Effect of heat treatment on Mechanical Properties of a Carbon-molybdenum and a Chromium-molybdenum Steel," Vol. II, No. 9, June, 1922. H. J. French.
[5] Am. Soc., Steel Treat. M. H. Schmid. Op. cit.
[6] Proc. Am. Soc. for Test. Mat., Vol. XX, Part II, 1920. G. W. Sargent.

The machining properties of both these molybdenum cast irons were very markedly superior to those of ordinary cast iron.

Although experience in the use of malleable castings containing molybdenum is very limited, it would seem that there is an increase in toughness and tensile strength over ordinary castings especially when they are subjected to heat treatment.

STATE IN WHICH MOLYBDENUM EXISTS IN STEEL

The state in which molybdenum exists in steel does not yet appear to have been definitely ascertained. T. Swinden, in his earlier investigations in 1911, considered that the metal is distributed throughout the ferrite with which it first combines, somewhat like a solid colloidal solution in an iron-molybdenum compound, and does not exist as a double carbide, nor is it in solid solution in the iron.

Tests made by Arnold and Read[1] on the other hand, on high molybdenum steels led these authors to conclude that molybdenum formed a double carbide with iron, which completely replaced the cementite structure in the presence of about 18·25 per cent molybdenum. With low carbon, and less than one per cent molybdenum, French did not find any evidence of special carbides under the microscope, when using ordinary etching re-agents and magnification of 500 to 1,000 diameters.

Special investigations on the constituents found in tungsten and molybdenum steels which were carried out by A. M. Portevin[2], led him to believe that the needle clusters disclosed by etching with sodium picrate may be an iron-molybdenum, or an iron-carbon-molybdenum compound, and that their presence indicates a state of equilibrium more stable than previously encountered.

COMPARATIVE COSTS OF MOLYBDENUM STEELS

It is beyond the scope of this report to deal with the comparative manufacturing costs of various steels. It is, however, an erroneous assumption to judge the cost of a steel by that of its alloys. Many users are apt to give too much consideration to the actual cost per pound of the alloying metal, rather than the all-round efficiency of the steel.

The manufacturing advantages of molybdenum steels make possible both increased production and decreased cost of the finished article. There have been, and still are, a great variety of types of molybdenum steels, but these are gradually being worked down to certain standards. For instance, the automobile requires in its construction, steels having a wider range of physical properties than probably any other manufactured unit. It is obvious that the fewer the kinds of steels that will meet the requirements, the greater the efficiency in production, purchasing, inspection, etc., and the lower the cost. Certain automobile manufacturers who have carefully studied this problem, found that chrome-molybdenum steel, of a single type in two or three carbon grades, develops under suitable heat treatment, a sufficient variation in physical properties to meet all the demands of motor car construction. It is claimed that the adoption of molybdenum steel for the manufacture of all vital parts of the automobile

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[1] Proc. Inst. Mech. Engs., 1915, No. 2, p. 629.
[2] Engineering, Sept. 9, 1921, p. 372.

is tending to lead to a standardization of molybdenum steels that will have the two-fold benefit of simplifying purchasing and inspection, and of increasing manufacturing economy.

It must be borne in mind, however, that although these are the opinions of some of the leaders in the automotive and allied industries in the United States, there are only a few steel makers, or manufacturers throughout the world, who have adopted this kind of steel. This, however, is not due to any inferiority of the metal, but, probably, to the causes outlined in previous chapters.

In the most recent reports concerning new mixtures, the trend seems to be toward an even lower molybdenum content, that is one about 0·25 per cent. Such a steel is considerably cheaper to manufacture and therefore meets the objection so often urged, that although molybdenum steel gives remarkable results, its cost is too high to allow of commercial competition with other alloy steels.

CHAPTER III

DIRECT REDUCTION OF ORES AND CONCENTRATES

Patents

Several patents have been taken out for the direct reduction of molybdenite ores, or concentrates, amongst which are the following:—

F. M. Becket and J. A. Holladay of Niagara Falls, N.Y.,[1] patented a process by which molybdenum can be recovered from ores or concentrates, by leaching with an alkaline sodium compound in sufficient proportion to secure a commercially complete extraction of the metal, while leaving undissolved a substantial proportion of the impurities in the ore. The molybdenum is precipitated as calcium molybdate, which is then smelted or otherwise utilized.

H. A. Doerner[2], of Meriden, Conn., has a process in which the molybdenum content of ores, or concentrates, is recovered by forming briquettes of the ore and sodium chloride mixed with a sulphur-bearing material, if the ore itself does not contain sufficient sulphur. The briquettes are heated in a vertical kiln to volatilize chlorides or oxychlorides of molybdenum. The briquettes are made of small size so that the reaction may penetrate through their entire mass.[3]

In another patent by Doerner,[4] the author recovers molybdenum from its ores by heating to about 500°C., in a stream of chlorine gas. The molybdenum is volatilized as chlorides or oxychlorides, and these may be condensed, or may be decomposed by steam or water into oxides and hydrochloric acid. By maintaining the condenser at a temperature of 200°C., the hydrochloric acid may be separated from the oxides and recovered in a separate condenser.

In the process of E. M. Hamilton,[5] of San Francisco, the ore or concentrate is ground, mixed with water and with a non-volatile alkali metal to form an alkaline pulp, and the pulp is treated to convert the molybdenum into a soluble compound. The pulp is then filtered and the molybdenum recovered.

A. Kissock, of Tucson, Ariz.,[6] has a process for recovering molybdenum as a salt, by dissolving the ore in a sulphide of an alkali metal.

G. W. Sargent, of Pittsburgh, and J. W. Weitzenkorn, of Washington,[7] have patented several processes for special molybdenum alloy steels and for the recovery of molybdenum from its ores. The principle employed in the latter is to cause either oxide of manganese or oxide of iron to react with the molybdenite.

Briefly the following reaction takes place:—

$$MoS_2 + 2\ MnO_2 + 4C = Mo + 2\,MnS + 4\,CO$$

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[1] U. S. Pat. 1403477, Jan. 17, 1922, p. 449.

[2] U. S. Pat. 1299560, April 8, 1919.

[3] Chem. Abstracts, Vol. 13, No. 16, Aug. 20, 1919, p. 1816.

[4] U. S. Pat. 1329380, Feb. 3, 1920.

[5] Eng. and Min. Jour., Vol. 112, No. 26, Dec. 24, 1921, p. 1025.

[6] U. S. Pat., 1403035, Jan. 10, 1922, p. 298.

[7] U. S. Pats., 1401926, 1401924, 1401927, Dec. 27, p. 818.

The powdered reagents (with or without iron filings) are mixed, heated to 2000° F., whereupon a button of substantially pure molybdenum, or ferromolybdenum, is formed, containing less than 0·10 per cent sulphur, overlain by a clean fluid slag. If carbon is not added to the mix, the end product is a reducible manganese-molybdenum-sulphur compound, or the complete reaction may be effected during steel-making operations, with the resultant formation of excellent alloy steel.

T. R. Forland, of Haugesund, Norway,[1] has an electrolytic process by which the metal can be obtained from molybdenum chloride by electrolyzing a fused salt mixture, comprising chlorides of molybdenum, sodium, and aluminium.

In another process, by T. R. Forland[2], a current of chlorine gas, at a temperature above 268° C., is brought into contact with the dried and pulverized ore or concentrate. Molybdenum chloride distills over and is separated from the pure sulphur, and any metallic chloride having a lower boiling point, by fractional condensation. In case the ore contains metals whose chlorides have a higher boiling point than that of molybdenum, the temperature may be so controlled that these chlorides remain in the tailings, from which they are recovered by leaching.[3]

F. D. S. Robertson, of Toronto, Canada, has taken out a patent[4] under which molybdenum ores can be treated for the production of the trioxide (MoO_3) by a direct process of volatilizing-roasting, in a highly oxidizing atmosphere of about 800° C.

The process is hastened by the addition of steam, according to the equation: $2MoS_2 + O_2 + 2H_2O = 2MoO_3 + 4H_2S$

$$4H_2S + 6O_2 = 4H_2O + 4SO_2 = 4H_2SO_3$$

After cooling, the trioxide of molybdenum, in the form of fine silky crystals, is drawn off from the dust-collecting towers by means of a fan, into a bag-house which is fitted with cotton, or woollen bags, about 30 feet long and 2 feet diameter. The trioxide collects in these bags, while the permanent gases, sulphur dioxide, etc., pass through the meshes of the bags and are drawn off by means of another fan to an open stack, or may be recovered to form sulphuric acid and other compounds. It is important to keep the heat up to 800° C. all the time, otherwise oxides other than the trioxide of molybdenum are apt to be formed. The temperature of the bag-house should not exceed 120°C., with woollen bags, or 90°C., with cotton bags. The resulting product is said to be very pure.

METALLURGY OF WULFENITE

Although only about 10 per cent of the world's supplies of molybdenum are derived from wulfenite, nevertheless, owing to the probable recovery of lead and precious metals as by-products, the special treatment of this mineral is of some importance.

J. P. Bonardi,[5] who has made a detailed report on this subject, states:—

> The principal methods may be classed under three general heads:—
> (1) An acid leach.
> (2) An alkaline leach.

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[1] U. S. Pat., 1305350, June 3, 1919, p. 23.

[2] U. S. Pat. 1308735, July 1, 1919, and Can. Pat. 207832, Jan. 25, 1921.

[3] Chem. and Met. Eng., Vol. 21, No. 5, Sept. 1, 1919, p. 256.

[4] U. S. Pat. 1118150, Nov. 24, 1914. Also, Ref: Met. and Chem. Eng., Jan., 1915, p. 64.

[5] Chem. and Met. Eng., Sept. 15, 1919, p. 364, "Notes on the Metallurgy of Wulfenite." J. P. Bonardi.

(3) Fusing the ore with some material that will give the lead in metallic form, carrying the gold and silver, and the molybdenum as a soluble compound in the slag which can be extracted by solution methods, or may be used directly in the electric furnace for the preparation of ferro-molybdenum.

(1). *Acid Leach Method.* Wulfenite is only soluble in a considerable excess of acid, and the cost of alkali to neutralize such a solution to obtain the proper working conditions is prohibitive. Lead also occurs both in solution and in the residues, and requires further treatment to extract, and arsenic, phosphorus, etc., interfere to such an extent that this method is not practised.

(2) *Alkaline Leach Method.* The solubility of wulfenite in sodium sulphate is fairly complete in boiling solution, and after the elimination of impurities, such as arsenic and phosphorus, the molybdenum can be recovered as calcium molybdate."[1]

In this method the lead, together with the precious metals, will be found in the residue as sulphides in a concentrated form, which can be shipped to the smelters for further treatment. The molybdenum goes into solution as sodium molybdate, and is precipitated as calcium molybdate.

At least one company in the United States is using this method of treating wulfenite concentrates, in which a high-grade calcium molybdate is produced of about 60 per cent, practically free from sulphur, phosphorus, and arsenic. The high-grade calcium molybdate thus produced can be used for the manufacture of ammonium molybdate, ferro-molybdenum, or added direct to molten steel in the manufacture of special alloys.[2]

For the precipitation of molybdenum as calcium molybdate Bonardi tried several methods. Slaked lime emulsion with prolonged agitation gave at the best less than 9 per cent precipitation of molybdenum; calcium chloride solution at ordinary temperature did not completely precipitate the molybdenum. In any case the solution must be in large excess and the best results only converted 60 per cent of the molybdenum. Boiling solution, with bromine as an oxidizer, followed by excess of calcium chloride, however, completely precipitated the metal as calcium molybdate. The solution must be completely neutral.

(3) *Fusion Process.* The main feature of this process is that the ore must be fused with compounds that will reduce the lead and permit the molybdenum to pass into the slag. It was found that the best results were obtained by fusing the concentrates with a combination of soda ash and caustic soda. The precious metals reported with the metallic lead and all were recovered, while the molybdenum remained in the slag as soluble sodium molybdate. By neutralizing with calcium chloride and boiling, calcium molybdate was precipitated.

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[1] Loc. cit.

[2] Pat. 1300279, April 15, 1919. "Process of making Alloy Steel." A. Kissock.

SELECTED BIBLIOGRAPHY ON MOLYBDENUM AND ITS ORES

Occurrences and Deposits

(*a*) *Canadian*—

Adams, F. D. and Barlow, A. E. Geology of the Haliburton and Bancroft Areas, Ont. Geol. Surv., Can., Mem. 6, 1910, p. 87.

Bancroft, J. A. Mineral Resources of Kewagama Lake Region, Timiskaming, Que. Quebec Dept. of Mines Rept., 1911, pp. 186-201, and 1912, pp. 230-6.

Molybdenite Deposits in Vicinity of Big Squaw Lake, Que. Quebec Dept. of Mines Rept. 1917, pp. 35-40.

Bruce, E. L. Molybdenite near Falcon Lake, Manitoba. Geol. Surv., Can., Sum. Rept. 1917, p. 22D.

Camsell, C. Molybdenite Deposits of the Moss Mine, Quyon, Que. Geol. Surv., Can., Sum. Rept. 1916, p. 207; Tulameen district, B.C., Geol. Surv., Can., Mem. 26, 1913, pp. 170-1.

DeLury, J. S. Molybdenite in Falcon Lake District. Manitoba Pub. Serv. Bull., 1917; also Can. Min. Jour., vol. 38, No. 23, 1917, pp. 460-2.

Dresser, J. A. The Moss Molybdenite Mine, Quyon, Que. Eng. and Min. Jour., vol. 103, No. 12, Mar. 24, 1917, p. 484. Also Can. Min. Inst., Bull. 59, Mar. 1917, p. 206.

Drysdale, C. W. Molly Molybdenite Mine, Lost Creek, Nelson, B.C. Can. Min. Inst. Bull. 43, 1915, pp. 877-880.

Geology and Ore Deposits of Rossland, B.C. Geol. Surv., Can., Mem. 77, 1915, pp. 70-90. Also "Index Molybdenite Mine, B.C." Geol. Surv., Can., Sum. Rept. 1916, p. 54.

Evans, H. F. A description of the Gnawed Mountain Molybdenite Deposit, B.C. The Mining World, Oct. 21, 1905, p. 443.

Evans, J. W. Ferro-molybdenum in Canada. Trans. Can. Min. Inst., 1918, pp. 154-61. Tivani Steel Company's operations at Belleville, Ont., describes furnace and method of analysis. See also Can. Chem. Jour., Aug. 1918, p. 208.

Molybdenum Resources in Southwest Ontario. Cement Mill and Quarry, Feb. 5, 1921, pp. 35-6.

Faribault, E. R.
(See Hayes, A. O.).

Galloway, J. D. Various Ann. Repts. Minister of Mines, B.C. (For references see text).

Graham, R. P. D. Pseudomorph of Bismuthenite after Molybdenite. Trans. Roy. Soc. of Can., Ser. 111, vol. XII, 1918, pp. 191-3. Specimens from Height of Land Company, northern Quebec.

Gwillim, J. C. Molybdenite in Canada. Mun. Res. Comm. Can., 1920, pp. 104-133. Final report. Description of the main molybdenite occurrences in Canada.

Hagen, E. A. Occurrences, Ores, Tests, Geology, Uses and Production of the Molybdenum Minerals. Min. and Eng. Record, B.C. Continuous series from Nov. 1916 to Dec. 1917. A very complete review. April, 1912, p. 262. Ore deposits around Vancouver.

Hayes, A. O., and Faribault, E. R. Investigations in Nova Scotia. Geol. Surv., Can., Sum. Rept. 1917, Pt. F., pp. 19 and 28; 1919 Pt. F., p. 6.

Johnston, R. A. A., and Willimott, C. W. Molybdenum and Tungsten. Geol. Surv., Can., Bull. 872, 1904. Describes various Canadian occurrences, 16 pages.

Mailhiot, A. Molybdenite Deposits of LaCorne township, Abitibi, Que. Quebec Dept. of Mines Rept. 1919, pp. 40-6; also Can. Min. Jour., Feb. 18, 1920, p. 135.

McConnell, R. G. Portland Canal and Skeena Mining Division, B.C., Geol. Surv., Can., Mem. 32, No. 25, 1913, p. 93.

McLeish, John. Various Mines Branch, Dept. of Mines, publications.

Mills, S. D. Molybdenite. Ont. Bur. of Mines, 1902, pp. 45-8. Describes various deposits in Haliburton county, (Harcourt mine).

Obalski, J. Molybdenite deposits in Quebec. Min. Prod. Quebec, 1899, pp. 15-17.

O'Neill, J. J. Economic Geology of Hazelton District, B.C., Geol. Surv., Can., Mem. 110, 1919, pp. 12, 20-23.

Parsons, A. L. Molybdenite Deposits of Ontario. Full detailed report, Ont. Bur. of Mines, 1917, pp. 275-313.

Puyjalon, H. de. Rept. Com. Colon., Quebec, 1898, pp. 264-276. Detailed account of the Saguenay Coast occurrences (reproduced by T. L. Walker, p. 24).

Reinecke, L. A description of the Lac La Hache Molybdenite Deposit in British Columbia. Trans. Can. Min. Inst., vol. 22, 1919, pp. 357-360; Mineral Deposits between Lillooet and Prince George, B.C., Geol. Surv., Can., Mem. 118, 1920, pp. 91-95.

Smith, W. H. Geology, Occurrences and Mining of Molybdenite in British Columbia, Ontario and Quebec. Eng. and Min. Jour., Feb. 6, 1915, p. 271.

Sweezey, R. O. Molybdenite Deposit at Turnback Lake, Que. Can. Min. Jour., vol. 34, 1913, pp. 190-1.

Tyrrell, J. B. Molybdenite in Ontario—Kirkland Lake Area. Trans. Inst. Min. and Met., vol. 23, 1913-14, pp. 153-6, 158-9.

Thomson, E. Pegmatitic Origin for Molybdenite Ores. "Economic Geology," vol. 13, No. 4, June 1918, p. 302.

Walker, T. L. Molybdenum Ores of Canada. Mines Br. Rept. No. 93, 1911, 64 pp. monograph.

Wilson, M. E. Molybdenite in the Lower Ottawa Valley. Geol. Surv., Can., Sum. Rept. 1919, Part E., pp. 35-43. Geology of the Mount St. Patrick and Spain Mines, with plans and sections; also Trans. Can. Min. Inst., vol. 23, 1920, pp. 418-25.

Molybdenite deposits of Quyon District, Quebec. Can. Min. Jour. Mar. 1, 1918, pp. 78-80.

Temiskaming County, Que. Geol. Surv., Can., Mem. 103, No. 86, 1918, pp. 155-8.

(b) *United States—*

Brown, H. L., and Hayward, M. W. Molybdenum Mining at Climax, Colo.; Eng. and Min. Jour., May 18, 1918, pp. 905-907. An excellent description of the molybdenite mine and mill of the Climax Molybdenum Co., by engineers connected with the company.

Calkins, F. C. Molybdenite near Ramona, San Diego county, Cal.; U.S. Geol. Surv., Bull. 640, 1916, pp. 73-76.

Chapin, I. "Mineral Resources of Alaska in 1917," U.S. Geol. Surv., Bull. 692, 1919.

Crook, A. R. Molybdenite at Crown Point, Wash., Geol. Soc. Am., vol. 15, pp. 283-288, 1904. Describes the occurrence, relations to surrounding rocks, and character of molybdenite-bearing veins at Crown Point, Wash.

Davis, H. E. Molybdenite in San Diego, Calif., U.S.A. Salt Lake Mining Review, June 15, 1918.

Emmons, W. H. Ore Deposits in Maine and the Milan Mine, New Hampshire, U.S.A. U.S. Geol. Surv., Bull. 432, 1910, pp. 21, 42, 47-49.

Guild, F. N. The Composition of Moybdite from Arizona. Am. Jour. Sci., ser. 4, vol. 23, 1907, pp. 455-6. Analysis of Molybdenite from Santa Rita; also West. Chemist & Met., vol. 3, 1907, pp 218-9.

Haley, D. F. Description of Climax Molybdenum Company's deposit. Eng. and Min. Jour., Aug. 31, 1918; also The Mining Jour., Sept. 14, 1918, Geology and description of mining and milling; also Trans. Am. Inst. Min. Met. Eng., 1919, pp. 71-76.

Hess, F. L. U.S.A. Mineral Resources Bulletins: 1906, 1907, pp. 527-529; 1908, 1909, pp. 745-47; 1915, pp. 807-812; 1916, pp. 777-779; 1917, pp. 907-915; 1918, pp. 795-805; 1919, pp. 713-714; 1920, p. 403. Molybdenite Deposits of Maine, Utah, and California, U.S. Geol. Surv., Bull. 340, 1908, pp. 231-240; Bull. 666, 1917, pp. 9-11; Bull. 530, 1913, p. 151.

Molybdenum during 1917-1919, Chem. & Met. Eng., Nov. 24, 1920; pp. 1029-30.

Hills, B. W. The Molybdenite Deposits of Tunk Pond, Maine, Min. World, vol. 31, 1909, pp. 323-4; also describes knightite (molybdenum phosphate).

Holland, L. F. S. Recent Developments in Molybdenum. Min. and Sci. Press, Oct. 19, 1918, pp. 529-31. Describes the Climax Molybdenite deposits, Colo.

Horton, F. W. Molybdenum: its Ores and their Concentrates with a Discussion of Markets, Prices and Uses. U.S. Bur. of Mines, Bull. 111, 1916. A detailed monograph of 127 pages. Also U.S. Geol. Surv., 666, U., 1917. Molybdenite deposits in U.S.A.; also Min. and Sci. Press, Feb. 24, 1917, p. 276. The ores of molybdenum, concentration, etc.

Joseph, P. E. Molybdenum. Univ. of Arizona, Bull. 5, No. 3, 1915-16, 15 pages. General report with special reference to the Arizona mines.

Larson, E. S. and Ross, C. S. R. and S. Molybdenite Mine, New Mexico. Econ. Geol., vol. 5, 1920, pp. 567-73.

Livingston, D. C. Tungsten, Molybdenum and Tin Deposits of Idaho. Bull. Univ., Idaho School of Mines, No. 14, pp. 5-67.

McPherson, J. L. Alaska's Mineral Development During 1918. Min. and Sci. Press, Jan. 11, 1918, p. 45, Shakan molybdenite mine.

Mertie, J. B. The Shakan Molybdenite Lode, Alaska, U.S. Geol. Surv., Bull. 714, 1921, pp. 118-9.

Schrader, F. C., and Hill, J. M. Molybdenite in Arizona. U.S. Bull. 582, p. 373, 1910, Detailed description of molybdenite deposits in Santa Rita and Patagonia mountains; also Bull. 430, 1910, pp. 154-63.

Wickes, Webster L. Molybdenite at the Hualpai Mts., Arizona. Min. and Sci. Press, May 19, 1917, p. 699. Method of analysis also given.

(c) *Australian*—

Andrews, E. C. The Yetholme and other Molybdenite Deposits. Ann. Rept. Dept. Min., New South Wales, 1915, p. 176; also 1917, pp. 159-166; 171-2.

Deepwater District. Ann. Rept. Dept. Min., N.S.W., 1918, pp. 152-55.

Ball, L. C. Numerous reports in the Queensland Govt. Min. Jour., Oct., 1911, pp. 504-8; Nov., pp. 564-5; Jan., 1913, pp. 4-7; April, June, p. 300, Oct., pp. 503-5, 1915. Geol. Surv., Pub. No. 248, 1915, 78 pages; Bamford, etc., 1918, pp. 304-6, Connors Range.

Baragwanath, W. Molybdenite at the Northern Hope Mine, and Mount Moliggul, Australia. Government Repts., June, 1916, and Feb., 1917, pp. 225-229.

Blatchford, T. Molybdenite Occurrences at Mount Mulgine, Yalgoo Goldfield. Geol. Surv. Perth, W. Australia, Ann. Prog. Rept., 1918, pp. 77-8.

Cameron, W. E. Wolfram and Molybdenite Mining. Queens. Govt. Min. Jour., vol. 5, 1904, pp. 62-5.

Clarke, A. H. Kitchener Blocks Molybdenite Company Mines. Queensland Govt. Min. Jour., 1919, pp. 176, 184, 272.

Fry, S. Molybdenite in New Zealand. N.Z. Mines Rec. No. 9, April 17, 1905.

Herman, H. Molybdenite in Victoria. Aust. Min. Standard, Sept. 23, 1915, also Aust. Govt. Reports, Sept. 1915, July 1915, Aug. 1915.

Hills, Loftus. Tungsten and Molybdenum in North Eastern Tasmania, No. 1, Part I, 1916, 35 pages.

Tungsten and Molybdenum in Middlesex and Mt. Claude, No. 1, Part II, 1916, 16 pages.

Jensen, H. I. Some Wolfram and Molybdenum Occurrences, Stanhope Dist., Australia. Queens. Govt. Min. Jour., Oct. 15, 1918, pp. 458-461.

Kenny, P. T. L. Molybdenite at Everton, Victoria, Australia; also Australian production. Indust. Aust. & Min. Stand., May 1, 1919. Also Aust. Govt. Reports, April 11, 1919, June 6, 1918, June 18, 1918. Also Rec. Geol. Surv., Victoria, Pt. 3, 1921, p. 296; also "The Standard Mine," Chem. Eng. and Min. Rev., Sept. 5, 1920, p. 448.

Laun, E. J. The Kitchener Mine, Australia. Queens. Govt. Min. Jour., vol. 1, June 1916, p. 297.

Maitland, A. Gibb. "Molybdenite Deposits in Western Australia." The Mining Handbook, Geol. Surv., Mem. 1, ch. 2, Econ. Geol., pt. 3, sec. 7, 1919.

Morrison, M. Molybdenite Deposits 40 miles east of Hillgrove. Dept. of Mines, New South Wales Ann. Rept., 1914, p. 208. Deposits near Manildra. Dept. Mines, N.S.W., 1916, p. 211.

"Mount Booroolong Molybdenite Mine. Ann. Rep. Dept. Min., N.S.W., 1920, pp. 109-111.

Plummer, J. Molybdenite Deposits in Australia. Min. World, Mar. 30, 1907, pp. 421-2. Description of deposits, mining and preparation in N.S.W.

Reid, McIntosh A. The mining fields of Moina, Mt. Claude and Lorinna. Tasmania Geol. Surv., Bull. 29, 1919, pp. 100-122; also Bull. 30, p. 46.

Saint-Smith, E. C. Various reports in Queensland Govt. Min. Jour. Molybdenite in Stanthorpe Dist., vol. 15, April, 1914, pp. 184-9. Dreadnought Molybdenite Claim, vol. 15, May, 1914, pp. 246-7.

Tin Kettle and Wolfram Claims, Dalveen, vol. 15, July, 1914, pp. 358-9.

Kidston District, vol. 16, Aug., 1915, pp. 415-7.

Kitchener mine, Khartoum, vol. 18, Mar. 15, 1917, pp. 226-30; also May, pp. 226-8; also July, pp. 345-9.

Ohlsen Claim, Lappa, June, 1917, pp. 272-3.

Thomas, J. A. Wonbah molybdenite mine: Queens. Govt. Min. Jour., Nov., 1917, pp. 569-70.

Waterhouse, L. L. Tungsten and Molybdenum. Tasmania, Geol. Surv., No. 1. Pt. III, 1916. King island, 50 pages.

(d) *General—*

Campbell, J. M. The Ore Minerals of Tavoy, India. Min. Mag., Feb., 1919, p. 85.

du Toit, A. L. Unique Occurrence of Molybdenite in Natal, S. African Jour. Sci., Nov., 1916, p. 153. Chem. News Abstr., 1917, pp. 257-9.

Falkenberg, E. O. Norwegian Molybdenite mines. Eng. and Min. Jour., June 18, 1921, pp. 1021-1023; also Chem. Trade Jour., and Chem. Eng., April 2, 1921, p. 452.

Hall, T. C. F. Lead Ores—Wulfenite in Jugo-Slavia. Imp. Inst. Monograph, 1921, p. 78.

Holland, T. H., Fermor, L. L., and Hayden, H. H. Mineral Production of India, Geol. Surv., India, 1915, p. 284; 1921, pp. 305-6.

Johnson, J. P. Molybdenum and Other Minerals near Potgietersrust, S. Africa. Trans. Geol. Soc. S. Africa, 1907, p 115; also Min. Ind. Rhodesia, 1911, p. 39.

Jones, W. R. Tin and Tungsten Deposits in China, Inst. Min. and Met., Bull. 186, Mar., 1920.

Kinahan, G. H. Notes on Mining in Ireland. Trans. Inst. Min. Eng., 1904, vol. 26, p. 265; also Jour. Gro. Soc., Ireland, vol. 8, p. 55.

Lloyd, G. C. Sources of Ores used in Iron and Steel Industry. Dept. of Sci. and Ind. Research, 2nd Ed. Advisory Council, 1918, pp. 142-9; also brief treatment of ferro-molybdenum.

Miller, B. L., and Singewald, J. T. The Mineral Deposits of South America. New York and London, 1919. Describes molybdenite deposits in Chile.

Smith, F. J. Eng. and Min. Jour., July-Dec., 1918, p. 1054. General review of world occurrences.

Stephens, F. J. Occurrences in Newfoundland. Trans. Inst. Min. and Met., 1917-18, vol. 27.

Ting, V. K. and Wong, W. H. Mining Industry in China. Special Rept. of the Geol. Surv. of China, Peking, No. 1, 1921, p. 33.

Umpleby, J. B. U.S. Geol. Surv., Bull. 528, 1913, p. 73. Ore deposits of Lemhi, Idaho.

Versfeld, Wm. Molybdenum in South Africa. Mem. No. 1, Dept. of Mines, Industries Union of South Africa, 1919, pp. 59-66. Uses, world's occurrences, concentration, production, etc.

Wagner, P. A. The Geology and Mineral Industry of S.W. Africa. Geol. Surv., U. of S. Africa, Mem. 7, 1916, p. 111.

Wilson, Otto. Molybdenite in Peru. Chem. and Met. Eng., April 12, 1922, p. 700.

Woakes, E. R. Molybdenum in Norway. Inst. of Min. and Met., Jan. 17, 1918. A detailed description of the Norwegian mines.

Wray, D. A. Geology and Min. Res. of the Serb-Croat-Slovene State, Dept. of Overseas Trade, 1921, p. 63. Describes wulfenite in the old lead mines of Jugo-Slavia.

Concentration

Andrews, E. C. Method of Concentrating Molybdenite Ore in New South Wales. Austr. Min. Stand., Mar. 2, 1916.

Bonardi, J. P., and Coghill, W. H. Flotation of Molybdenite at Empire, Colorado. Eng. and Min. Jour., 1920, pp. 1210-1214.

Bowater, W. H. Treatment of Wolfram, Bismuth and Molybdenite Ores at Burma, Queensland Corporation Mill, Australia. Proc. Austral. Inst. Min. and Met., Dec. 31, 1921, pp. 259-270, flow-sheets given; also Chem. Eng. and Min. Rev., April 5, 1921, p. 229; also Min and Sci. Press, Dec. 10, 1921, pp. 821-4; also Eng. and Min. Jour., Nov. 26, 1921, p. 865.

Callow, J. M. Notes on Flotation. Trans. Am. Inst. of Min. Eng., vol. 54, 1916, pp. 3-25; also Can. Min. Inst., Bull. 51, 1916, pp. 609-16.

Claudet, H. H. The Concentration and Marketing of Canadian Molybdenite (with discussions). Trans. Can. Min. Inst., vol. XX, 1917, pp. 121-34.

Recent Improvements in the Concentration of Molybdenite. Trans. Can. Min. Inst., vol. XXII, 1919, pp. 68-75.

Cunningham, J. Bibliography of Concentration by Flotation, including Patents. Bull. Missouri School of Mines, Feb., 1916.

Elmore, F. E. Treatment of Molybdenite by the Elmore Vacuum Process. Eng. and Min. Jour., May 11, 1907, pp. 908-909.

Grant, E. P. International Molybdenum Co., Trans. Can. Min. Inst., Bull. 20, 1917. p. 131. The concentrator at Renfrew and refinery at Orillia.

Haultain, H. E. T., Dyer, F. C., and King, J. T. The Concentration of Molybdenite ores. Can. Min. Jour., July 1, 1917, pp. 270-1. Experiments at the University of Toronto.

Mackenzie, G. C. The Mining and Metallurgical Treatment of Molybdenum Ores in Canada. Trans. Can. Min. Inst., vol. II, part 2, No. 26, 1916, pp. 269-287. See also Met. and Chem. Eng., July 1, 1917, p. 39; also Iron Trade Review, Mar. 15, 1917, p. 631. See also Mines Br. Sum. Repts., 1913-19. Tests, flow-sheets and descriptions of molybdenite properties.

Oliver, C. E. Milling practice of the Dominion Molybdenite Co., Quyon, Que., Eng. and Min. Jour., April 10, 1920, p. 840

Parsons, C. S., and Gilmour, R. E. Canadian Wood Oils for Ore flotation. Trans. Can. Min. Inst., Bull. 20, 1917, pp. 38-51.

Reid, J. H. The Wonbah Molybdenite Mine and Mill, Queensland, Aust., Eng. and Min. Jour., Nov. 13, 1920, p. 947; also Eng. and Min. Jour., Nov. 15, 1919.

Robertson, A. J. Tungsten, Molybdenum Ore Concentration. Eng. and Min. Jour., July 15, 1916, pp. 126-7.

Concentration Tests of a Tungsten-Molybdenum Ore from Callie Soak, Poona. Geol. Surv., Perth, W. Australia, Bull. 64, series 4, Nos. 52-60, 1915, pp. 55-63.

Timm, W. B. Ores Tested by the Mines Branch: Sum. Rept., Mines Branch, Dept. of Mines, Can., 1919-21.

Wells, W. J. Experiments on Canadian Molybdenite Concentration. Can. Min. Rev., May 30, 1903, pp. 113-118.

Wood, Henry E. Separation of Sulphides by Water Flotation. Am. Inst. Min. Eng., Bull. 71, 1912, pp. 1227-1244; also Mining Science, Dec. 19, 1912, p. 392; Dec. 26, 1912, p. 412.

The Concentration of Canadian Molybdenite. Trans. Can. Min. Inst., vol. 19, 1916, pp. 106-123. Detailed description of the Wood water-film process, flow-sheets and photographs.

Metallurgy

Aitchison, L. The Corrosion of Molybdenite Steel. Trans. Chem. Soc., 1915, vol. 107, pp. 1551-8; The New High-Speed Steel; Autocar, Jan. 10, 1920, pp. 56-7. Examination and special references to J. O. Arnold's steel.

Anderson, R. J. Metallurgical Disposal of flotation concentrates, Min. and Eng. World, July 8, 1916, pp. 57-9.

The Ferro-Alloy Industries in 1919. Eng. and Min. Jour., Jan. 17, 1920, pp. 204-8. General review.

Armstrong, G. S. Modern Tool Steels and High-speed Tool Alloys. Engineering (3 articles), Sept., Oct., Nov., 1913.

Arnold, J. O., and Read, A. A. The Chemical and Mechanical Relations of Iron, Molybdenum, Carbon and Nickel. Jour. Inst. of Mech. Engrs. (London), Nov., 1915, pp. 629-51; also Mar.-May, 1914, pp. 223-279.

Arnold, J. O., and Ibbotson. Molybdenum and Tungsten Steels: Proc. Inst. and Mech. Eng. (London), Nov., 1915.

High Speed Steels: Jour. Iron and Steel Inst. (London), vol. 99, No. 1, 1919: Vanadium-molybdenum High-speed Steel, Engineer, 1920, p. 480.

Barnitz, H. L. Manufacture of Molybdenum. Sci. Amer., April, 1921, p. 347. Hydrogen method.

Baughman, W. Manufacture of Molybdenum. Salt Lake Min. Rev., Nov. 30, 1917, p. 29. A detailed account of various fusion and leaching processes.

Bradley-Stoughton. The Metallurgy of Iron and Steel. Molybdenite steel, pp. 396, 409-13.

Brandt, W. V. High-speed Tool Steels—manufacture and heat treatment. Iron Age, Nov. 3, 1910.

Bratton, W. N. Latest Word in Steel. Sci. Am., Mar. 27, 1920, pp. 336, 351. Uses of Molybdenum Steels, Eng. and Min. Jour., Jan. 23, 1921.

Criticisms of J. O. Arnold's steels: Use in automotive industry.

Chaudron, G. Reversible Reaction of Water on Molybdenum. Compt. Rend., vol. 170, No. 3, Jan. 19, 1920, pp. 182-5.

Clarke, C. H., and Browne, D. Molybdenum in the Steel Industry. Iron Age, March 15, 1917, p. 667.

Climax Molybdenum Company. Molybdenum Commercial Steels. A 70 page illustrated book giving details of tests, properties, manufacture, uses, etc., of molybdenum alloy steels. Abstracts in Iron Age, Feb. 5, 1920, pp. 407-9: Ry. Mech. Engr., April, 1920, pp. 205-7.

Coblentz, W. W., and Kahler, H. Some Optical and Photoelectric Properties of Molybdenite. U.S. Bur. Standards, Sci. paper No. 338, pp. 121-62.

Coolidge, W. D. Some applications of Wrought Tungsten and Molybdenum. Jour. Ind. and Eng. Chem., vol. 4, 1912, pp. 2-4. Describes uses of molybdenum for electrical contacts and winding electrical-resistance furnaces, etc.

Cutter, J. D. Suggested method for Determining comparative Efficiency of certain Combinations of Alloy steels. Trans. Am. Soc. Steel Treat., 1920, p. 188. Use of the merit index.

Use of Molybdenum steel in the Automotive industry. Jour. Soc. Automotive Engrs., May, 1922, pp. 340-7 (with discussions).

Dawe, C. N. Chrome-molybdenum Steel; applications from the consumers viewpoint. Jour. Soc. Auto. Eng., Jan., 1922. See also Iron Age, Mar. 16, 1922, pp. 725-28; The Mining Journal, Feb. 18, 1922, pp. 145-7; Raw Mat., Mar., 1922, pp. 53-7; Chem. and Met. Eng., Feb. 22, 1922, pp. 369-70.

DeBenneville, J. S. Some Alloys of Iron with Molybdenum, Wolfram, and Chromium as Solutions. Jour. Am. Chem. Soc., vol. 16, 1894, pp. 735-57.

Ternary Alloys of Iron with Chromium, Cobalt and Wolfram. Jour. Iron and Steel Inst., No. 1, 1895, pp. 202-248.

Debray, H. Researches on Molybdenum. Compt. Rend. vol. 46, 1858, pp. 1098-1102. Describes early experiments in the production of metallic molybdenum.

Dittus, E. J., and Bowman, R. G. The Direct Production of Molybdenum Steel in Electric Furnace. Trans. Am. Electrochemical Soc., vol. 20, 1911, pp. 355-372; also Met. and Chem. Eng., vol. IX, 1911, p. 531.

Escard, J. Electrometallurgy of Molybdenum. Chem. and Met. Eng., June 15, 1919, p. 645. Describes preparation of pure molybdenum.

Evans, J. W. Ferro-molybdenum in Canada. Trans. Can. Min. Inst., 1918, pp. 154-61. Tivani Steel Company's operations at Belleville, Ont., describes furnace and method of analysis. See also Can. Chem. Jour., Aug., 1918, p. 208.

Fahrenwald, F. A. Tungsten and Molybdenum as Substitutes for Platinum. Am. Inst. of Min. Eng., Bull. 109, 1916, pp. 103-149. Research by National Dental Assoc. Trans. Am. Inst. Min. and Met. Eng., 1916, pp. 541-93. The System Tungsten-molybdenum. Trans. Am. Inst. Min. and Met. Eng., 1916, pp. 612-19.

Fansteel Products Company. The Manufacture of Molybdenum. Chem. & Met. Eng., 1920, p. 837.

Fink, C. G. Ductile Molybdenum and Tungsten. Trans. Am. Electrochem. Soc., vol. 17, 1910, pp. 229-234. Compares physical properties of tungsten and molybdenum wire.

French, H. F. Effect of Heat Treatment on Mechanical Properties of Carbon-molybdenum and Chrome-molybdenum Steels. Am. Soc. for Steel Treat., vol. II, No. 9, June, 1922, pp. 768-798.

Friend, N. J., and Marshall, C. W. The Influence of Molybdenum on the Corrodibility of Steel. Jour. Min. and Steel Inst., vol. 89, No. 1, 1914, pp. 503-507. Describes various tests in fresh, acid, and salt waters.

Heat treatment tests on Molybdenum-chromium Steels. Trans. Am. Soc. for Steel Treat.

See also Chem. and Met. Eng., Oct. 12, 1921, p. 713.

Gin, G. Methods of Treating Simple and Complex Ores of Molybdenum, also Electrometallurgy of Rare Metals. Trans. Am. Electrochem. Soc., vol. 12, 1907, p. 411. Deals chiefly with manufacture of ferro-molybdenum in the electric furnace.

Proc. 7th Int. Cong. Appl. Chem., vol. 10, 1919, p. 10. Treating wulfenite to obtain ferro-molybdenum of low carbon content.

Gledhill, J. M. The Development and Use of High-speed Tool Steel. Jour. Iron and Steel Inst., 1904, No. 2, pp. 127-182.

Guillet, Léon. The Properties and Constitution of Molybdenum Steels. Compt. Rend., vol. 139, Oct. 3, 1904, pp. 540-2.

Researches in the Realm of Molybdenum. Génie Civil, vol. 45, 1904, pp. 242-4. Gives microphotographs. See also Eng. and Min. Jour., Oct. 13, 1904.

Hadfield, Sir Robert A. Alloys of Iron and Molybdenum. Proc. Inst. of Mech. Eng. (London), Nov., 1915, pp. 701-13.

Haynes, Elwood. Alloys of Cobalt with Chromium and Other Metals. Trans. Am. Inst., Min. Eng., vol. 44, 1912, pp. 573-7. Describes cobalt-chromium molybdenum, and chromium, cobalt, wulfram, molybdenum alloys.

Hibbard, H. D. Manufacture and Uses of Alloy Steels. U.S. Bur. of Mines, Bull. 100, 1915, pp. 58-61.

Holman, C. V. "Molybdenum", Steel's Latest Beneficiary. Am. Indust., Jan., 1917, pp. 20-22.

Ores of Molybdenum. Min. Amer., May 19, 1917, pp. 8-9.

Howe, H. M. The Erosion of Guns. Am. Inst., Min. Eng., Bull. 134, pp. 335-90. Author finds absence of molybdenum in German guns.

Humphries, C. H. Preparation of Pure Molybdenum. Min. and Sci. Press. June 30, 1917; also Queens. Govt. Min. Jour., Dec., 1917.

Hunter, A. H. Molybdenum and Molybdenum Steel. Trans. Am. Iron and Steel Inst., May 27, 1921. General review of the molybdenum steel, gives tables, tests, manufacture, costs, etc. See also Iron and Coal Trade Rev., July 22, 1921, p. 104; also Blast Furnace and Steel Plant, July, 1921, pp. 426-91; also Metal Ind. (London), July 15, 1921, pp. 47-9; also Iron Age, June 2, 1921, pp. 1469, 1511-12; also Raw. Mat., Sept., 1921, pp. 306-312.

Jeffries, Z. Tungsten-molybdenum Equilibrium Diagram and System of Crystallization. Trans. Amer. Inst., Min. and Met. Eng., 1916, pp. 600-611.

Judge, A. W. Ferrous Materials—Air and Auto Materials of Construction, 1920, p. 668.

Keeney, R. M. Direct Production of Ferro-Alloys in Electric Furnace. Carnegie Sch. Mem. Iron and Steel Inst., vol. I, 1912, pp. 108-84.

Electric smelting of Chromium, Wolfram, Molybdenum and Vanadium ores. Trans. Am. Electrochem. Soc., vol. 24, 1913, p. 167-189. Historical data, pp. 184-8.

Ferro-molybdenum. Can. Min. Jour., Sept. 15, 1918, p. 318; also Iron Age, Sept. 12, 1918, p. 624.

Manufacturers of Ferro-Alloys in the Electric Furnace. Trans. Am. Inst., Min and Met. Eng., 1920, pp. 40-3.

Keeney, R. M., Lyon, D. A., and Cullen, J. F. The Electric Furnace in Metallurgical Work. U.S. Bur. of Mines, Bull. 77, 1914, pp. 146-151.

Electric Smelting of Molybdenum Concentrates. Met. and Chem. Eng., vol. VI, 1913, p. 579.

Kissock, A. Calcium Molybdate as an Addition Agent in Steel Making. Chem. and Met. Eng., June 2, 1920, pp. 1018-20.

Molybdenum and Molybdenum Steel. Min. and Sci. Press, Feb. 7, 1920, pp. 184.

Lamble, B. C. Ferro-Molybdenum in Canada. Can. Min. Jour., April 15, 1916, p. 185. Practice at Orillia, analysis and sampling. Trans. Can. Min. Inst., vol. 22, 1919, pp. 61-67. General review properties of molybdenum and the production of ferro-molybdenum.

McConnell, A. J. Interesting Facts Regarding Molybdenum. Canad. Machy., June 3, 1920, pp. 102, 531. Criticism of J. O. Arnold's Steel.

McKnight, C., Jr. Achievements in the Realm of Molybdenum Steels. Trans. Am. Soc. for Steel Treat., vol. I, No. 6, March, 1921, pp. 288-96. Tensile tests of molybdenum steels. See also Raw Mat., April, 1921, pp. 118-23.

Mathews, J. A. Molybdenum Steels. Trans. Am. Inst. of Min. and Met. Engrs. No. 1059, Feb., 1921. Gives brief history of future outlook. See also Chem. and Met. Eng., Mar. 2, 1921, pp. 395-6; also Iron Age, Feb. 24, 1921, pp. 505-6.

Meyers, R. E. Elements for Incandescent lamps. Trans. Am. Inst. Chem. Eng., vol. 3, 1910, pp. 172-187. Interesting data on ductile metallic Molybdenum.

Moissan, Henri. Preparation and Properties of Molybdenum. Compt. Rend., vol. 120, 1895, pp. 1320-6.

The Electric Furnace. Translated by V. Lehuer, 1904, 305 pages. Preparation of metallic Molybdenum, pp. 155-61.

Northrup, E. F. Uses of Molybdenum in a Molybdenum-Tungsten Thermo-couple. Met. and Chem. Eng., Jan., 1913, p. 45. Gives temperature curves from 1° to 1,000° C.

Portevin, A. M. Study of Special Ternary Steels. Carnegie Sch. Mem. Iron and Steel Inst. (London), vol. I, 1909, pp. 275-6, 330-3. Gives electrical resistance and physical properties.

Iron and Steel Inst., Sept. 5, 1921, No. 5. Constituents found in Tungsten and Molybdenum steels, pp. 141-4.

Raydt, U., and Tammann, G. Alloys of Molybdenum and Cobalt. Sci. Abstracts, Dec. 30, 1914. Molybdenum. Amer. Bureau Min., 1914.

Sources of Molybdenum Ores. Imp. Inst., Tech. Information Bureau, 1915.

Ruder, W. E. Solubility of Wrought Tungsten and Molybdenum. Jour. Am. Chem. Soc., Vol. 34, 1912, pp. 387-89.

High Temperatures Resistance Furnaces with Ductile Molybdenum Resistors. Am. Inst. Min. Eng., Bull. 134, Feb., 1918, pp. 585-591.

Sargent, G. W. Molybdenum as an Alloying Element in Structural Steels. Trans. Am. Soc. Steel Treat., vol. I, No. 10, July, 1921, pp. 589-96; 596-7. Tests, physical properties, tables, photographs, etc.

Sargent, G. W., and Weitzenkorn, J. W. Direct Reduction of Molybdenite. Chem. and Met. Eng., Feb. 22, 1922, p. 371. Exothermic reaction with manganese oxide.

Schad, L. W., and Hidnert, P. Preliminary Determination of the Thermal Expansion of Molybdenum. U.S. Bureau of Standards, Sci. Paper No. 332, Jan. 29, 1919, pp. 31-40.

Schmid, M. H. Molybdenum Steel and its Application. Trans. Am. Soc. for Steel Treat., vol. I, No. 9, June, 1921, pp. 500-505. See also Chem. and Met. Eng., May 25, 1921, pp. 927-9; also Iron and Trade Rev., Sept. 1, 1921, pp. 559-61; also Iron Age, June 2, 1921, pp. 1444-5. Tests, properties and uses in automobiles, etc.

Simpson, W. E. Molybdenum and Molybdenum Steel. Min. and Sci Press, Dec. 20, 1919, pp. 894-6; also Iron Age, Jan. 22, 1920, pp. 268-9.

Swinden, T. Carbon-molybdenum Steels. Carnegie Sch. Mem., Iron and Steel Inst., (London), vol. 3, 1911, pp. 66-124. Study of mechanical properties of molybdenum steels and a comparison with corresponding tungsten steels; also vol. 5, 1913, pp. 100-168, with appendix, the mechanical properties of some low molybdenum alloy steels.

Taylor, F. W. On the Art of Cutting Metals. Trans. Am. Soc. Mech. Eng., vol. 28, 1907, pp. 31-350. Discusses molybdenum as a substitute for tungsten, pp. 243-4.

Waddell, J. A. L. Review of Molybdenum Commercial Steels. Eng. and Contractor, April 28, 1920, pp. 482-3.

Analyses

Auchy, G. The Rapid Determination of Molybdenum in Steel. Iron Age, Mar. 20, 1902, p. 4.

Bailar, J. C. Analyses of Molybdenum. Colo. Sch. of Mines Bull. IV, No. 3, May, 1908, p. 172.

Bonardi, J. P. Department of Interior, Bur. of Mines, Tech. Paper 230, 1920—Volumetric and gravometrical analyses—35 pages report; see also Chem. and Met. Eng., Aug. 4, 1920, pp. 205-6; also May 11, 1921, pp. 847-50.

Molybdite and Separation of Copper in presence of Molybdenum. U.S. Bur. of Mines, Tech. Paper 230, 1920. Determination of molybdenum (32 pages).

Bonardi, J. P., and Shapiro, M. Behaviour of Copper in Molybdenum Ores, Chem. and Met. Eng., 1921, pp. 847-50.

Clennell, J. E. Molybdenum in Cyanide Solutions. Eng. and Min. Jour., Feb. 14, 1914, pp. 363-4; also April 11, 1914, p. 773.

Crook, W. J., and M. L. A. Determination of Molybdenum in Ores. Queensland Govt. Min. Jour., Dec., 1918, pp. 565-6.

Darroch, J., and Meiklejohn, C. A. A rapid Method of Determining Molybdenum. Eng. and Min. Jour., vol. 82, 1906, p. 818; also Metallurgy, Dec. 15, 1906.

Davis R. S. Analysis of Wulfenite. Met. and Chem. Eng., vol. 9, 1911, pp. 458-9.

Evans, J. C. Determination of Molybdenum in Wulfenite. Min. and Sci. Press, vol. 97, p. 161.

Jamieson, G. S. Determination of Molybdenum by Potassium Iodide Method. Am. Chem. Soc. Jour., vol. 39, Feb., 1917, pp. 246-9.

Markaker, E. E. Separation of Tungsten from Molybdenum. Jour. Am. Chem. Soc., vol. 37, No. 1, 1915, p. 86.

Moir, J. Methods of Testing for Molybdenum. Soc. Chem. Ind., June 15, 1916, p. 656.

Rudneck, P., and Cooke, R. D. Notes on Recovery of Molybdic Acid. Jour. Ind. and Eng. Chem., vol. 9, Jan., 1917, pp. 109-110.

Scott, W. Determination of Molybdenum by Rotating Zinc Reductor. Jour. Indus. and Chem., vol. 12, No. 6, June, 1920, pp. 578-80.

Weinig, A. J. Molybdenum Cyanide Solutions. Eng. and Min. Jour., vol. 97, 1914, p. 773. Qualitative tests for molybdenum with potassium sulphocyanide

General (Occurrences, Ores, Metallurgy, etc.)

Andrews, E. C. The Molybdenum Industry in New South Wales. N.S.W. Geol. Surv. Mineral Resources No. 24, 1916. General monograph on molybdenum with special reference to New South Wales—200 pages.

The Mammoth Molybdenite Mining Company, New South Wales, and General World Review. The Mining Magazine, June 28, 1917, p. 390; The Attungo deposits, Dept. Min., N.S.W., 1917, p. 159.

Aston, J. Molybdenum Min. Indust., 1913, p. 507; 1914, p. 528; 1915, p. 504. Brief review of the molybdenum industry—occurrences, manufacture, etc.

Ball, S. H. Market Conditions and Prices, Ores of Molybdenum. Eng. and Min. Jour., Aug. 25, 1917, pp. 333-8. A detailed article on modes of occurrences, prices and mainly geology.

Proc. Com. Inst. of Min. Eng., Sept. 27, 1917, General review—uses, etc. Eng. and Min. Jour., Jan. 11, 1919, p. 83, U.S. prices of molybdenite.

Becket, F. M. Molybdenum. Electrochem. and Met. Ind., Dec., 1906. Occurrence and Uses of Molybdenum Ores. Iron and Coal Trade Rev., Aug. 28, 1908.

Boalich, E. S., and Castello, W. B. Properties, Ores, Occurrences and Uses of Tungsten and Molybdenum. California State Min. Bur., Prel. Rept. No. 4, March, 1918, pp. 21-8.

Bonardi, J. P. United States Molybdite and Wulfenite Producing Mines and Metallurgy of Wulfenite. Chem. and Met. Eng., Sept. 15, 1919, p. 364.

Brattan, W. N. Mineral Industry, 1920, pp. 64-65. R. & S. Molybdenite Mine, New Mexico. General Review, p. 458. Ann. Repts. on the industry to date. (1921 to 1923).

Brown, J. Coggin. Notes on Chromite and Molybdenite. Bull. 9, Indian Indus. and Labour, 1921, p. 19; also ores in Burma. Rec. Geol. Surv., India, vol. 50, 1919, pp. 101-21.

Claudet, H. H. Molybdenum Mining in Norway. Can. Min. Inst., Bull. 51, July, 1916, pp. 609-616. A detailed description of the Norwegian mines and methods of concentration; also notes on molybdenite operations in Norway. Trans. Can. Min. Inst., vol. XIX, 1916, pp. 124-130.

Dunstan, B. Molybdenite. Queensland Geol. Surv. Art. 4, Industrial Minerals, 1920. A review of occurrences, treatment, uses, values and production with special reference to Queenlsand—24 pages with bibliography; also a serial article in Queensland Govt. Mining Jour., starting July 15, 1916, p. 314; also Queens. Min. Jour., Dec. 15, 1920, pp. 504-508.

Dyes, Dr. A Handbook of the World's Chemical Industry Trade, 1913-14, 1919, 1920, vol. I, Edition E., pp. 497-508. Various abstracts from authors and leading journals, in English and German.

Hardy, C. Molybdenum. Eng. and Min. Jour., Jan. 12, 1918, p. 92; General review—prices, etc. Eng. and Min. Jour., Jan. 11, 1919, p. 83; General review, markets, Climax mine and mill, etc., Jan. 17, 1920, p. 215.

Hess, F. L. U.S.A. Mineral Resources Bulletins: 1906, 1907, pp. 527-529; 1908, 1909, pp. 745-47; 1915, pp. 807-812; 1916, pp. 777-779; 1917, pp. 907-915; 1918, pp. 795-805; 1919, pp. 713-714; 1920, p. 403.

Horton, F. W. Molybdenum: Its Ores and their Concentration with a Discussion of Markets, Prices and Uses. U.S. Bur. of Mines, Bull. 111, 1916. A detailed monograph of 127 pages; also U.S. Geol. Survey., 666 U., 1917. Molybdenite deposits in U.S.A., also Min. and Sci. Press., Feb. 24, 1917, p. 276. The ores of molybdenum, concentration, etc.

Johnstone, S. J. Molybdenum within the Empire. Jour. Soc. of Chem. Ind., Dec. 16, 1918, p. 448R. Statistics of world's production and particularly of progress in mines throughout British Empire.

Phillipson, B. F. Molybdenum. Eng. and Min. Jour., Jan. 2, 1922, p. 91. Discusses future prospects for molybdenum industry.

Poole, Wm. Production, Properties, Metallurgy and Uses of Molybdenum. Queensland Govt. Min. Jour., Aug. 15, 1918, pp. 361-364.

Pratt, Hyde J. Tungsten, Molybdenum and Vanadium in the United States, U.S. Geol. Surv., 1901.

Molybdenum Ore. The Engineer, Dec., 1902.

Molybdenum Steel. Industries and Iron, Nov. 8, 1903, also Mines and Minerals, No. 44, vol. 24, 1903.

Production of Steel and Iron Hardening Metals, Min. Res. U.S., for 1904, U.S. Geol. Surv., 1905, pp. 338-43.

Rastall, R. H. Molybdenum Ores. Imp. Inst., Monograph, 1922. A complete monograph on world's occurrences, uses, metallurgy, etc.

Schaller, W. T. Notes on Powellite and Molybdite. Am. Jour. Sci., ser. 4, vol. 25, 1908, pp. 71-75. Describes powellite from Texas, and molybdite from Colorado.

Notes on Powellite. U.S. Geol. Surv., Bull. 490, pp. 80-3.

Notes on Ilsemannite. Jour. Washington Acad. Sci., 1917, vol. 7, No. 13, pp. 417-20.

Smith, G. Otis. Use of Molybdenum during the War. Eng. and Min. Jour., March 15, 1919, pp. 501-2.

Stewart, O. J. Mineral Foote Notes, May, 1917. General world review—history, output, tests, uses, etc.; also Jan. and Feb., 1919.

Ullman, A. T. A New Mineral (Chillagite). Proc. Roy. Soc. of N.S.W., for 1912, vol. 46, Pt. 2, pp. 186, 207-19.

Walker, T. L. Molybdenum Ores of Canada. Mines Br. Rept. No. 93, 1911, 64 pages monograph.

Wilson, A. W. G. Articles for the Mineral Industry. General world reviews, occurrences and status of industry, 1916, pp. 509-18; 1917, pp. 454-67; 1918, pp. 490-7; 1919, pp. 467-75.

Wolf, H. J. Colorado Sch. of Mines, No. 2, Jan. 1919. Markets and prices. Detailed list of the ores of molybdenum, tests, concentration, etc.

Worcester, P. G. Molybdenum deposits of Colorado, with general notes on the molybdenum industry. Col. Geol. Surv., Bull. 14, 1919, monograph of 130 pages.

Yancey, H. F. Ilsemannite—A Study of the Blue Water in a Utah Mine. Chem. and Met. Eng., Aug. 15, 1918, pp. 186-190.

Recently Published

Molybdenum, Cerium and related Alloy Steels. Am. Chem. Soc. Monograph Series, 1925. A. W. Gillet and E. L. Mack. Monograph (300 pages) dealing with the latest experiments on molybdenum and other alloy steels, and includes a detailed bibliography.

PLATE II

Chisholm mine, Sheffield township, Ont. No. 1 pit, looking east. Bottom of this pit is solid iron sulphides carrying molybdenite.

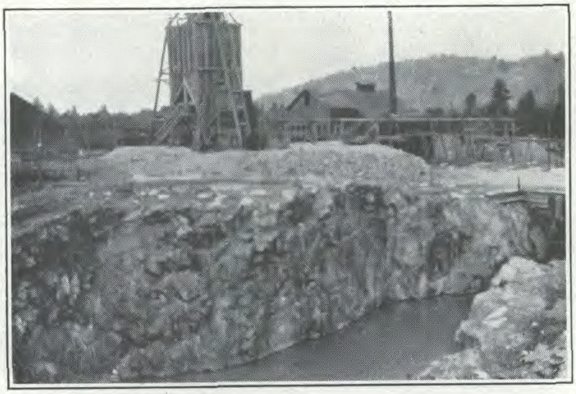
PLATE III

Phoenix Molybdenite Corporation (Taylor mine), Bagot township, Ont., showing distortion on contact of gneiss and limestone between which the molybdenite occurs.

PLATE IV

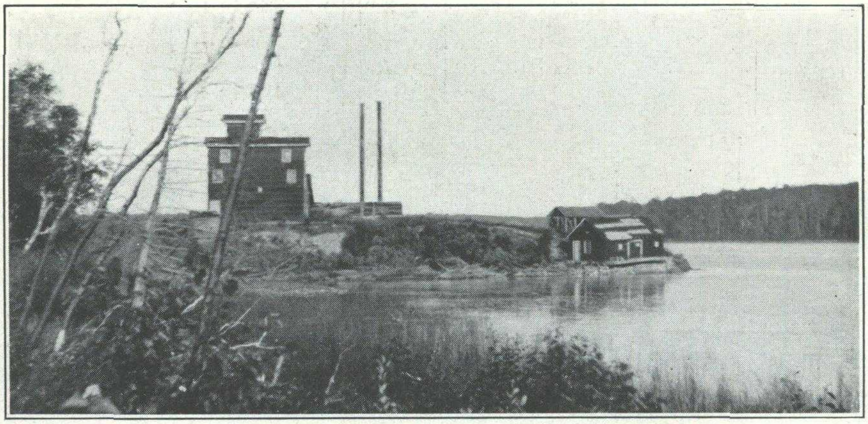
Jamieson mine, Lyndoch township, Ont. Open-cut showing shaft, looking northwest.

PLATE V



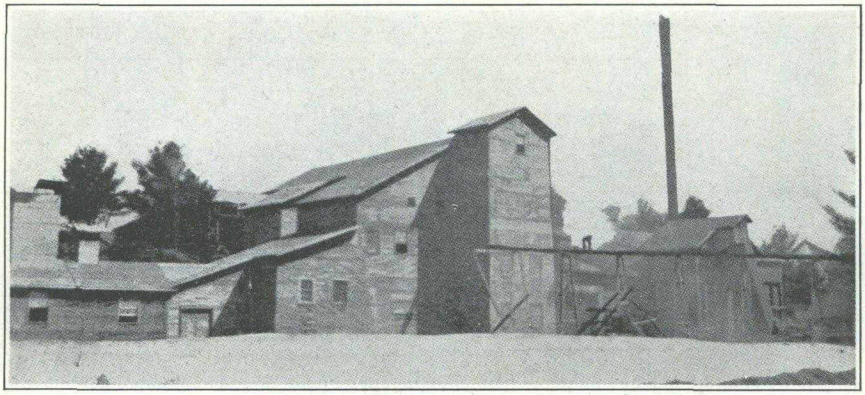
Moss mine, Onslow township, Que. Main pit, looking northwest towards No. 1 shaft.

PLATE VI



St. Maurice Mines Co., Ltd., Indian peninsula, Que.

PLATE VII

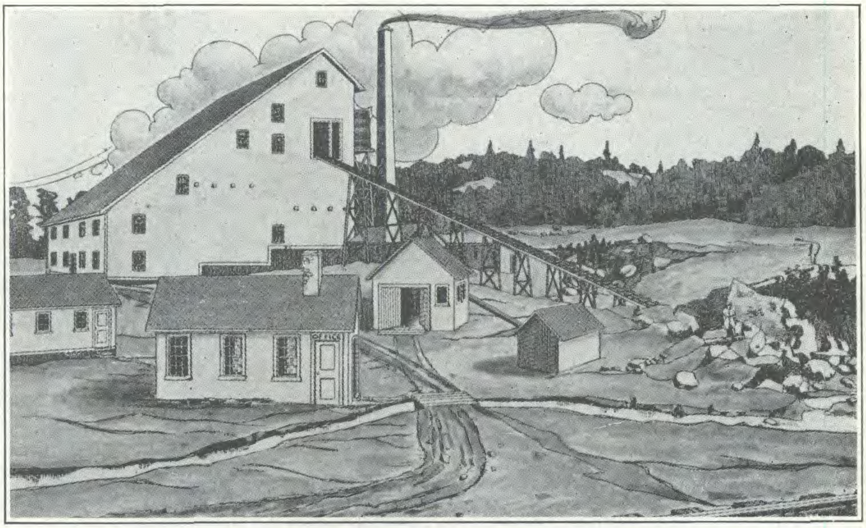


Dominion Molybdenite Co's. concentrator, Quyon, Que.

Plate VIII

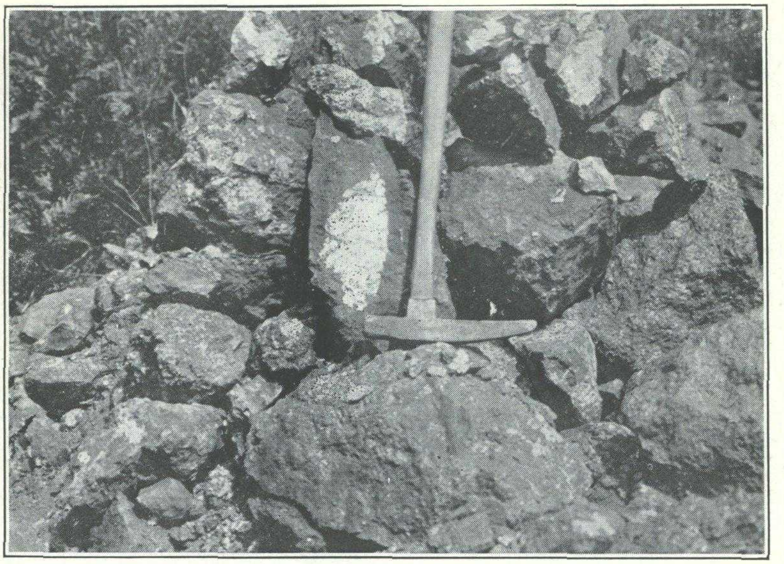
Spain Mine concentrator, Dacre, Ont.

Plate IX



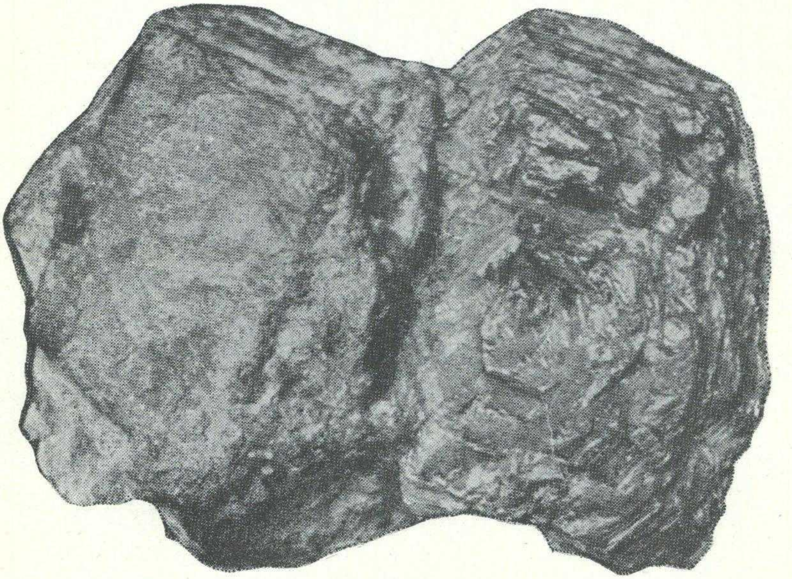
American Molybdenites, Ltd., concentrator, Wilberforce, Ont.

PLATE X



High-grade ore, Bain prospect, Masham township, Que.
White patches are molybdenite.

PLATE XI



Presented to McGill University mineral collection by John A. Dresser.
Trans. Royal Soc. of Canada, Vol. XII, 1918, by R. P. D. Graham.

Pseudomorph of bismuthinite (left) after molybdenite (right). The Height of Land Mining Co's. property, northern Quebec.

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CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN MCLEISH, DIRECTOR
1925

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Base map from plates of the Chief Geographer's office, Department of the Interior.

MOLYBDENITE OCCURRENCES
IN
BRITISH COLUMBIA

Scale:- 35 miles to 1 inch
25 0 25 50

To accompany Report No. 592 by V. L. Eardley-Wilmot on "Molybdenum"

Numbers on map correspond to those in text of report.

CANADA
DEPARTMENT OF MINES
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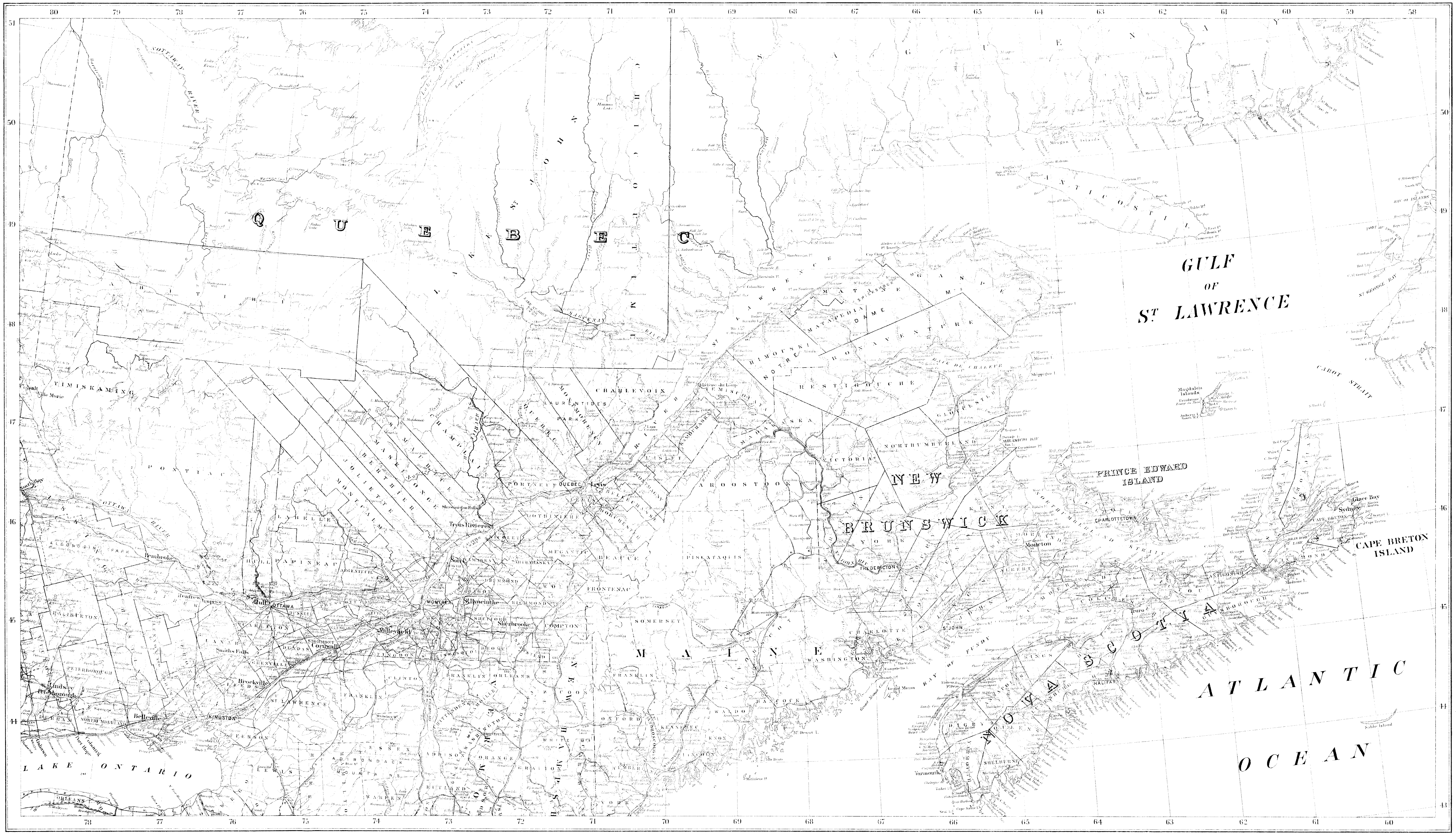
JOHN McLEISH, DIRECTOR
1925



596

Base map from plates of the Chief Geographer's office, Department of the Interior.

MOLYBDENITE OCCURRENCES
IN
QUEBEC AND MARITIME PROVINCES

Scale 35 miles to 1 inch
25 0 25 50

To accompany Report No. 592 by V. L. Eardley-Wilmot on "Molybdenum."

Numbers on map correspond to those in text of report.

CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN MCLEISH, DIRECTOR
1925

595

Base map from plates of the Chief Geographer's office, Department of the Interior

MOLYBDENITE OCCURRENCES
IN
ONTARIO

Scale—35 miles to 1 inch
25 0 25 50

To accompany Report No. 592 by V. L. Eardley-Wilmot on "Molybdenum."

Numbers on map correspond to those in text of report