CANADA

PROSPECTORS GUIDE

FOR

STRATEGIC MINERALS IN CANADA

(Third Edition)

Beryllium	Tin
Chromium	Tungsten
Columbium	Vanadium
Manganese	Fluorspar
Mercury	Iceland Spar
Molybdenum	Mica
Tantalum	Quartz Crystals

MINES AND GEOLOGY BRANCH
DEPARTMENT OF MINES AND RESOURCES
OTTAWA, CANADA
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INTRODUCTION

CANADA is a leading world source of several of the most important of the essential war minerals. But there are some that she does not produce at all, and others of which her production falls far short of her own needs in the present emergency, let alone those of her Allies.

This is the third edition of a booklet which was first published in 1941 to aid the prospector who was searching for the commonly known Canadian minerals, such as the ores of gold, copper, zinc, and lead, to search also for workable deposits of the less familiar deficiency or strategic minerals. The assurance of ample supplies of all the many minerals required for the purposes of the war is the primary responsibility of the Department of Munitions and Supply, and more particularly of the Metals Controller, who in that connection works in the closest co-operation with the British and United States governmental agencies of mineral supply. War shortages in mineral supply arise—and vary in degree—mainly from enemy action in restricting access to distant sources of supply and from rapidly expanding needs for war purposes. These shortages in supply may be relieved by the discovery and development of native or other accessible deposits, by the use of substitutes that can be obtained, and by the reopening of normal channels of supply. The list of strategic minerals is, therefore, subject to change. Those to which the attention of prospectors is specially directed at the present time are the ores of beryllium, chromium, columbium, manganese, molybdenum, tantalum, tin, and tungsten; also fluorspar, Iceland spar, muscovite mica of strategic quality, and quartz crystals. The search for mercury is still of interest, but not with its former urgency.

Most of these deficiency minerals come mainly from distant countries, over long ocean routes subject to high war risks. Ores of chromium, manganese, tin, and

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tungsten are examples of such minerals. Although Canada has recently become a small producer of by-product tin, and is already on the way to becoming a substantial producer of tungsten concentrates and chromite, the demand for these minerals is such that the discovery of economic deposits would be a real contribution to Dominion, Empire, and Allied security.

Deposits of other minerals described in the following pages have been found in Canada, and in many cases have been or are being worked; but, for one reason or another, the Dominion has drawn its requirements in large part from the more abundant resources of nearby friendly countries. In such cases, of which molybdenite and fluorspar are examples, developments of the past year have increasingly emphasized the need for further expanding Canadian production. *Discoveries of these minerals to be of immediate worthwhile national advantage must be of large deposits of the higher grade ores.*

Not all of the important strategic minerals are included, the striking omission being bauxite, the commercial ore of aluminium and the key mineral of aircraft production. Canada's aluminium-producing capacity, which is rapidly expanding to meet the growing demands of new domestic, British, and United States war-plane industries, is entirely dependent upon imported bauxite. However, the tropical or sub-tropical conditions with alternating wet and dry seasons generally considered an important essential for the formation and deposition of bauxite have not prevailed in Canada since the Ice Age; and any deposits which existed at the surface at that time have almost certainly been removed by glacial erosion from those huge areas of the Dominion which were covered by the ice sheets of the period. The chance of discovering economic deposits of bauxite in most of the areas under examination by prospectors appeared therefore to be too remote to warrant its inclusion in this booklet. It should be mentioned here that the lack of bauxite in Canada has stimulated the investigation of certain domestic minerals as possible sources of aluminium—but, because of the higher costs of producing the metal from such lower grade ores, these are unlikely to be used so long as bauxite can be obtained.

The information presented herein has been prepared by engineers, geologists, and other members of the staff of the Mines and Geology Branch, in consultation with the Office of the Metals Controller, and is based upon their own observations as well as upon authoritative reference works. Generally speaking, only the simple field identification tests are given, the less easily applied chemical and blow-pipe tests being inserted only when it is considered advisable to do so. Some minerals are very difficult to identify positively. In such circumstances prospectors working in provinces whose Departments of Mines provide mineral examination services should take advantage of them. The Bureau of Geology and Topography (Geological Survey), Ottawa, provides a similar service; and is also prepared to furnish specimens of many of the minerals described herein to the prospector to facilitate the identification of his finds. The charges made for these specimens, covering costs only, are listed on page 86. Arrangements can also be made for the testing of bulk samples in the ore-dressing laboratories of the Bureau of Mines, Ottawa.

The numbers used in the text to indicate the hardness of minerals are those of the Mohs scale, number 1 in which designates the hardness of the softest minerals, talc and graphite, 2 gypsum, 3 calcite, 4 fluorite, 5 apatite, 6 feldspar, 7 quartz, 8 topaz, 9 corundum, and 10 of diamond. The finger nail has a hardness in this scale of about 2·5, and an average knife blade, which is usually softer than glass, a hardness of about 5·5.

Special attention has been given to marketable grades of ores, current prices, and buyers, and brief mention is made of world and Canadian positions. It should be noted that all tons referred to are short tons of 2,000 pounds unless otherwise stated.

When a prospector discovers a deposit of one of the strategic minerals, and as the result of surface exploration and sampling feels that an examination by a geologist or engineer is warranted, he should write either to the Department of Mines of the province in which his property is situated or to the Mines and Geology Branch, Department of Mines and Resources, Ottawa. In that connection *it is important that he furnish full information* on the exact location of his property and its accessibility to road or railway; on the occurrence of the mineral and on the work which has been done to expose the ore-bearing zones; on sampling and assays; and on any other feature which may be of interest. With this information, the Department concerned will be in a position to give the necessary consideration; and, if the property is found to have commercial possibilities, to bring it to the attention of the Metals Controller.

Prospectors should bear in mind that, with the exception of Iceland spar, exports from Canada of ores and concentrates of all of the minerals described are prohibited at the present time except under permit. Applications for such permits to export should be made to the Export Permit Branch, Department of Trade and Commerce, Ottawa.

It is hoped that the information presented in this booklet will aid the prospector to make discoveries which will be of material benefit not only to himself personally but to Canada in the present critical emergency when national freedom itself is at stake.

Inquiries for further information should be addressed to—

The Director,
Mines and Geology Branch,
Department of Mines and Resources,
OTTAWA.

BERYLLIUM

Beryllium has been finding increasingly important use in recent years in a variety of special purpose alloys. The most important of such alloys is beryllium-copper, employed chiefly for small springs in business machines, pressure gauges, valves, electric contacts, and in precision control instruments. Its chief merit for such parts lies in its high fatigue-resistance and stability, coupled with resistance to corrosion, wear, and change of volume under load. It is used also for making low-sparking-hazard tools, in cast-set bits and reaming shells for diamond drilling, and for various other applications. Because of its varied valuable properties this alloy is now being specified for a number of military uses. Beryllium forms useful alloys with cobalt, nickel, and chromium; and, being the second lightest metal known, may prove to have value in beryllium-aluminium alloys for aircraft use.

Various beryllium salts are used in industry, the chief of which is the oxide, employed as a super-refractory in crucibles and insulators, in various forms of lighting equipment, in electron and radio tubes, and in heaters and induction furnaces. The mineral beryl, itself, is used in ground form as a batch ingredient of sparkplugs and other ceramic specialties.

Occurrence and Formation

Up to the present the only beryllium mineral of commerce is beryl, a silicate of beryllium and aluminium ($3BeO.Al_2O_3.6SiO_2$). The theoretical content of beryllium oxide in pure beryl is 14 per cent, corresponding to 5 per cent of beryllium, but usually some beryllium (also sometimes termed "glucinum") is found replaced by other elements, such as sodium, potassium, lithium, or caesium, so that commercial beryl seldom carries over 10 to 12 per cent BeO.

The occurrence of beryl is confined exclusively to granitic rocks, and usually to pegmatite dykes, in which scattered beryl crystals are not at all uncommon. Only comparatively rarely, however, is the mineral present in such dykes in sufficient amount that they can be worked economically for beryl alone, and the great bulk of the production has represented by-product material derived from pegmatites worked primarily for mica or feldspar. In some dykes the beryl tends to occur as localized concentrations of crystals in shoots, bands, or zones; and sometimes it is found as small anhedral, or shapeless, grains, usually in the finer-textured phases of the pegmatite. In size, the crystals commonly range from small individuals only one-half inch or so in diameter to larger masses six inches or more across. Crystals measuring as much as four feet across and fifteen feet long have been found.

Beryl is often present in pegmatites carrying lithium minerals, and in dykes rich in muscovite mica. There are, however, no definite characteristics that can be used to indicate the probable presence of beryl in a pegmatite.

The usual occurrence of beryl as scattered crystals entails the mining of large tonnages of lean or barren rock in order to recover a comparatively small amount of clean, cobbed crystals. No method of satisfactorily concentrating beryl from associated feldspar and quartz has yet been demonstrated in actual practice, so that the considerable loss of mineral contained in mixed rock is a serious economic factor.

In addition to common beryl, gem varieties of the mineral include emerald and aquamarine, respectively green and blue in colour; morganite, pink; and yellow to colourless shades.

A number of other minerals that contain beryllium are known, but most of them are comparatively rare and of no economic interest as a source of the metal. Most of them are minor accessory constituents of beryl-pegmatites, and occur more or less closely associated with the beryl. Chrysoberyl, beryllium aluminate ($BeO.Al_2O_3$), and phenacite, beryllium orthosilicate ($2BeO.SiO_2$), containing, respectively, 19 to 20 per cent and 44 to 46 per cent BeO, are among the less rare of such minerals.

Of interest is the recent discovery in New Mexico of an important deposit of the mineral helvite, a silicate-sulphide of beryllium, manganese, and iron, $3(Be, Mn, Fe)_2SiO_4.(Mn, Be, Fe)S$. This mineral, hitherto regarded as rare, theoretically contains about the same amount of beryllium oxide (13·6 per cent) as beryl. It is reported to occur at the above locality as a minor constituent, in the form of small crystals, of a metamorphosed limestone intruded by bodies of rhyolite and aplite, and now consisting of a fine-grained mixture of magnetite, garnet, and pyroxene. Although the average helvite content of this rock is low (around 3 per cent, corresponding to 0·4 per cent BeO), the available tonnage is very large, and the deposit is regarded as a valuable potential source of beryllium, provided that a satisfactory method of concentrating the helvite can be worked out.

Helvite is commonly of a brownish colour and closely resembles garnet, for which it might readily be mistaken. The above discovery suggests the possibility that other deposits of a similar character may also prove to contain the mineral, and indicates the desirability of prospecting attention being paid to occurrences in Canada of bodies of metamorphosed limestone associated with intrusives and consisting dominantly of intimate mixtures of garnet, magnetite, and pyroxene. Occurrences of this type containing much fluorspar, or where the associated intrusive carries beryl, are to be regarded as a specially favourable host rock. Samples of such rock suspected to contain helvite may be submitted to the Bureau of Mines for a spectroscopic test to determine the possible presence of beryllium, the most ready means of detecting the mineral. There are no recorded Canadian occurrences of helvite.

Identification

Beryl

Hardness —7·5 to 8. **Specific gravity**—2·6 to 2·8.
Lustre —Vitreous. **Streak**—White.
Colour —Commonly, various shades of green, to blue and yellow; more rarely, pink or white. Translucent, to transparent in the gem varieties.
Cleavage —Imperfect and indistinct. Breaks with a conchoidal to uneven fracture.

Beryl usually occurs as well-formed, long, prismatic crystals, having hexagonal shape and sometimes showing vertical striations. Distinct terminations, either basal or pyramidal, are rare. It is a conspicuous mineral, and is readily distinguished from most other minerals with which it is commonly associated. Minerals with which it might be confused are apatite and topaz, but its superior hardness distinguishes it from the former, and its lack of pronounced cleavage from the latter. More rarely, beryl is found in large granular to compact masses. In the form of small, shapeless grains, it is not uncommon as a constituent of the finer-textured phases of pegmatite.

Helvite

Hardness —6 to 6·5. **Specific gravity**—3·1 to 3·3.
Lustre —Vitreous to resinous. **Streak**—White.
Colour —Yellow to brown, red-brown, green.
Cleavage —Indistinct octahedral. Breaks with an uneven fracture.
Tenacity —Brittle.

Helvite is such an uncommon mineral that it is doubtful if it would be readily recognized by the prospector. It usually occurs in quite small tetrahedral crystals, resembling garnet, and, being often associated with that mineral, is very likely to escape detection.

Marketable Grades and Specifications

Beryl is marketed in the form of cobbed crystals or masses which must be substantially free from adhering or intergrown rock. Such beryl will commonly range from 10 to 12 per cent BeO, and sales are usually made on the basis of these grades, with penalties or premiums for a BeO content below or above such figures.

Beryllium determinations are very difficult to make with any degree of accuracy, owing to the close chemical affinity of beryllium and aluminium and the possibility that a considerable portion of the latter element contained in beryl will be reported with the beryllium. Analyses of beryl are always open to suspicion, unless made by a skilled chemist or spectroscopist, and consequently producers usually have to rely on determinations made by the purchaser.

Buyers

There are no plants in Canada for the treatment of beryllium ores, and any beryl produced must find an export market. The United States is the leading world consumer, with the following two concerns handling most of the beryl used:

Beryllium Corporation of Pennsylvania, Reading, Pennsylvania.

Brush Beryllium Company, 3714 Chester Avenue, Cleveland, Ohio.

As a result of the greatly increased demand for beryllium in the United States, for war purposes, the importation into that country of beryl and other beryllium ores, and of beryllium metal and salts, is now restricted to government agencies, or their authorized representatives, and all stocks of such commodities are under strict allocation control. Contracts for sale and export of beryl from Canada for United States Government account may be negotiated through the Metals Controller, Ottawa. All such exports are subject to special export permit.

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Prices

American prices for beryl, which previously had stood firm at $30 to $35 a short ton, f.o.b. mines, for 10 to 12 per cent grade, were trebled in 1942 in an effort to increase supply. The present price, f.o.b. mines, March, 1943, is $8.33 (United States funds) per short ton unit of contained BeO, equivalent to $100 per ton for 12 per cent standard grade, with corresponding price penalties for BeO contents below that figure. Material containing less than 10 per cent BeO is not desired.

World Production

No world statistics of beryl production are available, but estimated production in 1940 was about 2,500 short tons. Appreciable advances in output were recorded in 1941, and probably also in 1942. Principal sources of supply are Brazil, Argentina, and the United States.

Recent technologic progress has indicated an expanding field of usefulness for beryllium products, and demand for beryllium ores is likely to continue on an increasing scale.

Canada's Position

Although beryl has been found in numerous Canadian pegmatites, most of these occurrences are of doubtful economic interest, the mineral being present in small amount as scattered crystals that would not permit of profitable extraction.

One of the most promising deposits is located in Lyndoch township, Renfrew county, Ontario. Intermittent attempts at development have been made, and a few tons of cobbed beryl crystals have been taken out, as well as a few hundred tons of rock containing beryl that has been stockpiled pending the development of a method of concentration. Some of the pegmatites of the Winnipeg and Bird Rivers region, in southeastern

Manitoba, carry small amounts of beryl and have received prospecting attention, but have not as yet yielded any production. Beryl has also been reported to occur in some amount in pegmatites of the Yellowknife region, Northwest Territories.

Thus far, however, none of the Canadian occurrences has been shown to have any particular promise as an important source of beryl, and more development work is required in order to estimate the possibilities of the localities mentioned above. A little gem-quality beryl has been taken from some of the Manitoba occurrences and disposed of to the local jewellery trade.

CHROMIUM

Chromium is one of the principal alloying elements in a great variety of steels, chief of which, in amount of chromium used, are the highly important stainless and corrosion-resistant steels. The steel industry also consumes a large quantity of chromium ore in refractory bricks and furnace linings, and ore of chromium is also the source of the chromium chemicals used in the electroplating, dyeing, tanning, and paint industries.

Occurrence and Formation

The only economic ore of chromium is chromite (FeO, Cr_2O_3). Theoretically, it consists of 68 per cent chromic oxide (Cr_2O_3) and 32 per cent iron oxide (FeO), but it is never found in this state, because some of the iron and chromium is replaced by varying proportions of magnesium and aluminium. Commercial ores are relatively low in iron.

Chromite, where found, is invariably associated with ultrabasic igneous rocks, dunite, peridotites, and pyroxenites, and with the serpentines to which they alter. Scattered grains of the mineral occur throughout these rocks, the principal host rock being dunite, which is sometimes mistaken for chromite. Grains of the latter, however, are shiny, whereas dunite is a fine-grained, grey-black, iron-magnesian rock of a dull appearance and when scratched leaves a pale grey streak. The only other metallic mineral present is magnetite, which closely resembles chromite but is easily distinguished by its strong magnetic quality and black streak, whereas the streak of chromite is chocolate-brown.

Chromite ores fall into the following classes:

(a) Disseminated ores, in which individual grains of chromite are surrounded by serpentine. The size and concentration of the grains determine the richness of the ore. The disseminated ores may form long, narrow, parallel bands, separated from each other by similar bands of barren rock; or, less commonly, they may have lens-like shapes. In a few places, disseminated ores are accompanied by rounded nodules of practically solid chromite, ranging from about one-quarter inch to two inches in diameter. This is termed "grape ore," and constitutes a very small proportion of the ore-bodies.

(b) Massive ores—large nodules, plates, and short irregular vein-like masses of almost pure, solid chromite. These fill fault and joint fissures in zones of fracturing and faulting. The chief impurity is serpentine, which may be present in small quantity between the grains, or may traverse the massive ore in threads or veinlets.

Areas of interest to the prospector are the serpentine areas throughout the Dominion, especially those of the Eastern Townships, Quebec, and of British Columbia, in the latter of which chromite is sometimes associated with platinum, as in the Tulameen district. South-eastern Manitoba became an area of special interest in 1942 with the exploration of the Bird River deposits where the chromite is found in peridotite. This chromite has a low chrome-iron ratio and presents a special metallurgical problem.

Identification

Chromite has the following physical characteristics:

Hardness—5·5.

Specific gravity—4·3 to 4·6.

Colour—Black and brownish black.

Streak—Greyish brown to dark brown.

Lustre—Submetallic to metallic, opaque.

Tenacity—Brittle.

Chromite may be distinguished in the field from other similar-looking heavy minerals by its comparative softness and the fact that when scratched with a knife or the edge of a hammer it leaves a pale chocolate-brown streak. The finely powdered mineral is also brown.

Chromite is not magnetic, which distinguishes it from the highly magnetic, hard, black magnetite which it resembles. It may be so intimately mixed with particles of magnetite, however, that a specimen of it is slightly magnetic, but when the specimen is pulverized the magnetite can be withdrawn with the aid of a hand magnet. A piece of chromite gives a dead sound when struck with a hammer.

Marketable Grades and Specifications

Shipping Ore

For steel making, chromite must be converted to ferrochromium, and the ore should contain not less than 48 per cent Cr_2O_3 *and as little iron as possible*. The amount of chromium, computed as metal, should be at least three times that of the iron. Basic ceiling prices are for ores of the above grade and chromium-iron ratio, but, because of the short supply in the present emergency, ores as low as 40 per cent Cr_2O_3 and 2 to 1 ratio are accepted—at lower prices. When possible, the lower grade ores are mixed with those of the highest grades, the proportion depending upon whether the ferrochrome produced from the mixture is to be used for low- or high-carbon steels. The maximum allowance for sulphur is 0·50 per cent and for phosphorus 0·20 per cent. Although, ordinarily, lump ore is preferred, fines and concentrates are now used in quantity, in some cases being briquetted before use. The importance of low iron content in the ore or concentrate cannot be too strongly stressed.

For the special Canadian product known as Chrome X, low-grade ores have been used in which the chromium-iron ratio has been as low as 0·6 to 1 and the Cr_2O_3 content as low as 8 per cent. Such low-grade ores are not, however, used at present, more effective plant operation being obtained with the higher grade ores.

The specifications for chromite used in refractory bricks vary to some extent, depending in part upon the types of brick to be made. One Canadian manufacturer places a limit of 25 per cent on the iron oxide content, 18 per cent on the alumina (Al_2O_3), and 4 per cent on the silica (SiO_2). The silica should be as low as possible, since it usually occurs in the ore not as free silica but as serpentine, which has a comparatively low melting point.

It is very important that the chromite be present in an evenly and finely distributed form, not as coarse grains mixed with blobs of the silicate. The ore should also be hard and lumpy, none of it passing a 12-mesh screen. If the above specifications as regards impurities are fulfilled, the Cr_2O_3 content should be over 40 per cent.

Concentrates

Concentration, when required, can be effected by ordinary gravity methods, as most Canadian chromites are relatively free from heavy sulphides. High iron or magnetite chromites must undergo a preliminary roasting or straight magnetic separation. At present prices, it is doubtful whether an ore with less than 10 per cent Cr_2O_3 can be profitably treated.

Buyers

The Canadian buyers of chromite for metallurgical use are:

Chromium Mining and Smelting Corporation, Limited, 700 Bank of Commerce Building, Hamilton, Ontario.

Electro Metallurgical Company of Canada, Limited, Welland, Ontario.

The only important purchaser of refractory ore is:

Canadian Refractories, Limited, Canada Cement Building, Montreal, Quebec.

Prices

Canadian prices for high-grade ores are based upon the United States ceiling price, which is $43.50 per long ton at seaboard for ore containing 48 per cent Cr_2O_3 with a chromium-iron ratio of 3·0 to 1; plus or minus 90 cents per long ton unit of 22·4 pounds of contained Cr_2O_3 above or below 48 per cent; plus or minus $1.25 for each 0·1 chromium-iron ratio above or below 3·0 to 1, the limits being 3·5 to 1 and 2·0 to 1.

The price at a Canadian mine at Black Lake in the Eastern Townships of Quebec would, for example, approximate this basic ceiling price; plus freight of $2.28 from seaboard to Niagara Falls (near a Canadian consuming centre); plus exchange at 11 per cent to convert into Canadian funds; less $5.12 freight from Black Lake to Niagara Falls. For a 46 per cent Cr_2O_3 ore with chromium-iron ratio of 2·8 to 1, this price per long ton at Black Lake would thus amount to about $43.50, less penalties of $4.30, plus freight of $2.28, plus $4.56 exchange, less $5.12 freight, or to about $40.83 in Canadian funds.

Authorized prices for purchase of low-grade ores for treatment at the Chromeraine mill near Black Lake, Quebec, range, for ores with a chromium-iron ratio of 2·4 to 1, from $3.95 per ton for ores containing 10 per cent Cr_2O_3 to $16.45 for ores containing 32 per cent Cr_2O_3, the increase being 60 cents per unit of Cr_2O_3 over 10 per cent and up to 18 per cent and 55 cents per unit over 18 per cent to 32 per cent, plus or minus a price variation ranging from 25 to 75 cents per ton for each 0·1 chromium-iron ratio above or below 2·4 to 1.

World Production and Canada's Position

In 1939, world output of chromite was 1,300,000 tons, the four principal producing countries being, in order, Russia, Turkey, South Africa, Southern Rhodesia, and the Philippines, which all produce more than 100,000 tons annually. Production in Canada has come almost entirely from the Eastern Townships of Quebec. The output has been insignificant in recent years, but will become substantial from the current renewed and expanded operations in that field. Production cannot, however, be expected from the important Bird River discoveries in southeastern Manitoba until metallurgical difficulties arising from low chromium-iron ratio are overcome. The Canadian chromite supply position is still far from satisfactory despite the reduction in recent months in enemy threats to the movement of supplies from overseas sources. Special attention is, therefore, required on the part of the prospector in the search for worthwhile deposits of this highly essential war mineral.

FLUORSPAR

Fluorspar, the commoner name for the mineral fluorite, is a commodity of the highest industrial and defence importance. Its value lies in its fluxing properties, which make it an essential material for the melting of ferrous and non-ferrous metals, more especially for the manufacture of basic open-hearth steel Close to 70 per cent of the fluorspar produced in the United States in 1940 went to the steel industry. It also finds important uses in the ceramic (glass and enamels) trade; in the manufacture of hydrofluoric acid, which is used chiefly for making synthetic cryolite for the production of aluminium; in refrigerants of the "Freon" type; and for minor industrial purposes.

As far as North American requirements are concerned, the United States probably has adequate domestic reserves to draw on for considerable increased consumption, but production has been running behind requirements, forcing part dependence upon imports, chiefly from Newfoundland and Mexico. Improved methods of concentration have recently stepped up recovery and grade at a number of the United States mines, notably those in the important Illinois-Kentucky field.

Canadian requirements are met in small part by domestic production, mainly from the Madoc area of eastern Ontario, and by imports from Newfoundland and the United States. Because of the greatly increased war demand for fluorspar, the discovery of new deposits and their development into producers is of prime importance at this time.

Occurrence and Formation

Fluorspar is a simple compound of calcium and fluorine (CaF_2), with 51·1 per cent calcium and 48·9 per cent fluorine. It is common as a gangue mineral in metalliferous veins and also often occurs as a minor accessory constituent of igneous rocks, notably granite, syenites, and pegmatites, and in contact metamorphic deposits associated with such rocks. Such accessory fluorspar is rarely of economic interest, though small amounts have occasionally been recovered.

Fluorspar is usually deposited at moderate or shallow depths from circulating hydrothermal solutions, probably derived from a deep-seated igneous source. Many of the world's principal deposits are veins in limestones or other sedimentary rocks. Usually the sediments have

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been extensively fractured and jointed, providing a series of solution-channels in which the fluorspar was deposited as more or less closely-spaced veins. Fracturing with deposition of vein fluorspar may extend down into underlying igneous rock, as in the Madoc district, Ontario, where a number of the veins have been followed into granite.

Fluorspar may thus be found in rocks of very varied character, and there are no definite rules to guide the prospector. Where a strong vein of fluorspar is discovered, however, it is most likely that it will not be a single, isolated deposit, but will point to the existence of a fairly widespread occurrence of the mineral in the area.

Minerals commonly associated with fluorspar are calcite, barite, celestite, and quartz, and many deposits contain also sulphides such as galena, sphalerite, and pyrite. Usually, veins exhibit a banded structure, with alternating crusts of fluorspar and the associated calcite, barite, celestite, or quartz.

Identification

Fluorspar has the following characteristics:

Hardness—4.

Specific gravity—3·18.

Cleavage—Perfect octahedral.

Lustre—Glassy, transparent or translucent.

Crystallization—Isometric, usually in well-formed cubes, or in cubes modified by the octahedron.

Colour—Ranges from clear and colourless through varying shades of yellow, green, and purple.

Other Distinguishing Properties—Decrepitates violently on application of even moderate heat, and at higher temperatures shows in the dark a strong fluorescent glow, usually of a purple colour. Shows no effervescence with hydrochloric acid; and when powdered and heated with sulphuric acid gives off fumes of hydrofluoric acid which etch glass. Some fluorspars fluoresce in the cold under long-wave ultra-violet light, but others do not. Ultra-violet lamps cannot, therefore, usefully be employed in prospecting for the mineral.

Marketable Grades and Specifications

A large proportion of the fluorspar content of coarsely-crystallized ores can often be recovered as clean lump by hand-picking and cobbing, but there will always be considerable intergrown material that requires milling and concentration to bring it up to marketable grade. Where only one of the usual gangue minerals is present, beneficiation presents little difficulty, but where, as in the case of the Madoc ores, fluorspar-calcite-barite intergrowths are dominant, clean separation, combined with satisfactory recovery, has so far proved almost impossible of attainment by gravity methods. Flotation may yield better results on such mixtures, but has not proved particularly successful for acid grade. For metallurgical use the concentrate requires to be sintered or briquetted into lump form, since fine, powdery fluorspar is not acceptable to the trade.

Of the minerals commonly associated with fluorspar, barite, celestite, and metallic sulphides are the most objectionable to practically all the consuming industries, and the content of these must be reduced to a minimum. Calcite and quartz are not directly detrimental in metallurgical grades, but they lower the percentage of available fluorine and thus involve price penalties. Proper attention to picking and cobbing usually can ensure a certain tonnage that will meet market specifications for the three standard grades noted below, since most commercial deposits carry a considerable proportion of spar clean enough to ship with such preparation. Lower-grade fluorspar-calcite-barite or quartz intergrowths, down perhaps to 65 to 75 per cent

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calcium fluoride content, may be marketable to certain branches of the steel industry at corresponding price reductions, or may be concentrated, depending on the current available supply and the individual economic factors involved. Usually, each productive field has its own individual and fairly uniform type of ore, which requires specific study of its ore-dressing and economic problems. In any case, a deposit would require to be not less than 5 feet in width, with a fluorspar content of at least 50 per cent, to make it of probable economic interest for consistent underground mining.

Although certain consumers have their own individual specifications, most of the production is marketed in three standard grades, these, in order of descending quality, being:

Acid grade—Minimum CaF_2 content 98 per cent, maximum silica content 1 per cent; sold in lump, gravel, and ground form. Used in making hydrofluoric acid.

Ceramic grade—Minimum CaF_2 content 95 per cent, maximum silica content 3 per cent, maximum iron (Fe_2O_3) content 0·12 per cent; sold in ground form only, coarse, fine, and extra fine. Used as a batch fluxing ingredient in glass and enamels.

Metallurgical grade—Minimum CaF_2 content 85 per cent, maximum silica content 5 per cent; sold as washed or screened gravel or crude lump, preferably under one inch in size and with not more than 15 per cent of fines. Used as a flux mainly in making basic open-hearth steel, but also in foundries and in the melting of various ferrous and non-ferrous metals and alloys. In the present emergency, however, buyers are accepting material even below 60 per cent CaF_2, but the marketing of such sub-grade ores is subject to individual purchase agreement.

Buyers

The following firms are the principal Canadian consumers of metallurgical grades of fluorspar:

Steel Company of Canada, Limited, Hamilton, Ontario.

Dominion Steel and Coal Corporation, Limited, Sydney, Nova Scotia.

Dominion Foundries and Steel, Limited, Hamilton, Ontario.

Canadian Car and Foundry Company, Limited, Montreal, Quebec.

Atlas Steels, Limited, Welland, Ontario.

Electro Metallurgical Company of Canada, Limited, Welland, Ontario.

Algoma Steel Corporation, Limited, Sault Ste. Marie, Ontario.

Manitoba Rolling Mill Company, Limited, Winnipeg, Manitoba.

Dominion Magnesium, Limited, Haley's Station, Ontario.

Outlets for higher-quality, ceramic grade material exist with the undermentioned concerns:

Ferro Enamels (Canada), Limited, 629 Wellington Street, Ottawa, Ontario.

Dominion Glass Company, Limited, Montreal, Quebec.

North American Cyanamid, Limited, Niagara Falls, Ontario.

General Steel Wares, Limited, Toronto, Ontario.

Acid grade fluorspar is in demand chiefly by: Aluminum Company of Canada, Limited, Sun Life Building, Montreal, Quebec.

Prices

Current Canadian prices (March, 1943) are based on a price of $24 in United States funds per short ton for ore containing 85 per cent CaF_2 f.o.b. Kentucky-Illinois mines. To this is added the freight from the United States mines to the Canadian consumer, plus exchange at 11 per cent, plus the war exchange tax of 10 per cent, minus freight from the Canadian producer's shipping point to the consumer, minus 25 cents for each per cent CaF_2 below 85 per cent. The price of Canadian ore, f.o.b. shipping point, therefore, depends upon the consuming point to which it is shipped. The price paid for 85 per cent CaF_2 ore produced at Madoc would, for example, amount to $36.36 per ton f.o.b. Madoc on shipments to Sault Ste. Marie, and to $32.38 on shipments to Hamilton.

World Production

The total world production of fluorspar of all grades in 1938 (the last year for which fairly complete figures are available) was 458,000 tons, and in 1937 was 569,000 tons. About twenty countries have contributed to the total in recent years, but 90 per cent of the output has come from five sources: United States (32 per cent), Germany (29 per cent), Russia (13 per cent), United Kingdom (9 per cent), and France (7 per cent).

Canada's Position

Canadian requirements for the domestic steel trade and for use in other industries have been mostly imported in recent pre-war years, mainly from the United States, Newfoundland, France, and the United Kingdom. A small tonnage has been secured from the Madoc area, Ontario, the only producing field, and renewed activity there in 1940, 1941, and 1942 has resulted in considerably increased shipments. Most of this, however, has run considerably under standard market grade. At present, Newfoundland, the output from which has been steadily increasing and is capable of sustained expansion, is regarded as the principal future source of supply.

Aside from the Madoc area, and possibly also the Lake Ainslie district in Cape Breton, Nova Scotia, no important occurrences of fluorspar are known in Eastern

Canada. The only other deposit of major interest in Canada is the long-idle Rock Candy mine, near Grand Forks, British Columbia. High freight charges from this property to eastern consuming centres are a serious obstacle as long as Newfoundland material is available.

The increasing demands for war purposes are leading to severe shortages in domestic supply. The need for discovery of new worthwhile deposits is, therefore, urgent. Prospecting attention should also be given to any occurrence of the mineral in metalliferous deposits where it is present as a major gangue constituent, with the idea of recovering it as a by-product of milling operations.

ICELAND SPAR

Iceland spar, the name given to the perfectly transparent and colourless variety of calcite, is essential in the construction of certain optical instruments that are indispensable to scientific research and industrial development. From the time Bartholinus discovered the valuable optical properties of the mineral (in 1669) until the quarry was flooded during the first World War, the world's supply was obtained from Iceland. Since then, however, increasing difficulty has been encountered in obtaining an adequate supply from that source and the scarcity of the mineral has encouraged prospecting in other parts of the world. The market, however, even for the best quality spar is limited.

Occurrence

Iceland spar occurs in several countries but the best optical grades are rare. The principal deposits are in partly disintegrated basic igneous rocks; other deposits, so far of lesser importance, occur as veins in rocks of various types and ages. In Iceland, the type locality, the spar crystals are embedded in pockets of red residual clay in basalt. Similar deposits occur in South Africa in diabase, and in California, U.S.A., in basalt. Several deposits are known in the western United States in which the spar forms veins several feet wide and thousands of feet long. The quality of the spar in most of these veins of pure calcite is not the best. Iceland spar has been reported from several places in British Columbia and also the Northwest Territories.

Identification

The physical characteristics of Iceland spar are identical with those of ordinary pure calcite but in addition the spar must be colourless and in perfect rhombohedral crystals.

Hardness—3. **Lustre**—Vitreous.

Specific gravity—2·71. **Streak**—White.

It effervesces vigorously on application of cold dilute acids.

Marketable Grades and Treatment

Iceland spar suitable for optical use must be perfectly transparent, colourless, and in rhombohedral crystals at least one inch long and one-half inch thick each way. The slightest defect such as cloudiness, twinning, iridescence, cracks, or inclusions renders a crystal valueless for optical purposes.

The extracting of the crystals from the deposit must be done with the greatest care to avoid damaging them. Explosives cannot be used—the valuable material must actually be chiselled or wedged from the surrounding rock. Once a mass of crystal has been recovered, the trimming should be left to an expert, because even a light blow delivered by an inexpert hand may ruin a perfect crystal. Each crystal should be wrapped separately to avoid scratching and marring of the surfaces.

Buyers

There are at present no Canadian buyers of this mineral, but if a finder of Iceland spar will communicate with the Bureau of Mines, Ottawa, he will be advised where the crystals can be marketed.

Prices

No prices for Iceland spar are quoted, as factors influencing price are quality, size, and quantity to be sold, but within recent years the prices obtained in the United States for best quality spar ranged from $12 per pound for small crystals, up to $35 per pound for crystals over one pound in weight.

World Production

No statistics are available on production or consumption of Iceland spar, but it is unlikely that the present demand exceeds one ton per year. The original source in Iceland is now of historical importance only and the major part of the world's production at present comes from South Africa, New Mexico, and possibly Spain.

Canada's Position

Canada has not yet been a producer of Iceland spar although small deposits have been reported from time to time in British Columbia, among which may be mentioned those in the Trout Lake mining district; near Kamloops; and near Penticton. In 1940 a deposit of high-grade Iceland spar was reported found in the Northwest Territories west of Aklavik, but other than a few specimens there has been no production therefrom.

MANGANESE

Of the world output of manganese ore about 90 per cent is consumed in the production of ferromanganese and spiegeleisen for use in the manufacture of steel and special manganese steels. On this continent about 12·5

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pounds of manganese metal are required, on the average, for every ton of steel produced. The manganese ore consumed in this way is classed as metallurgical, and the remainder, which is used mostly for dry batteries, as chemical.

Occurrence and Formation

The most important, economically, of the numerous ores of manganese are the black oxides, chief of which and the commonest from the Canadian standpoint is pyrolusite, then psilomelane and manganite.

Most commercial deposits are a mixture of all three minerals, together with varying amounts of sand or clay, iron oxide, and barite.

Wad or bog manganese is an amorphous, earthy substance formed by precipitation from surface waters which have passed through rocks containing manganese. It commonly occurs as basin-shaped deposits a few feet deep or as small benches on gently sloping hillsides. The consolidated lumps occurring in the loose bog manganese are termed wad. There are very many of these bog deposits in Canada, particularly in the Maritime Provinces and, to less extent, in British Columbia and Manitoba. However, they are of low and variable grade. For this and other reasons ore from bog deposits is not at present being utilized, but in an emergency such ore might be beneficiated if the deposit is above average grade and the available tonnage from it, or the total tonnage from it and nearby deposits, is substantial.

Manganese minerals are found in Canada in limestone of Carboniferous age, in red shale, conglomerate, granite, and sandstone. The commonest occurrences are of the replacement type in limestone. They generally consist of irregular deposits of manganese oxide that follow the bedding of the limestone and often branch into pipes and veins. Overlying many of these deposits is soil, gravel, or residual clay up to 20 feet in depth in which occur nodules and larger masses of the manganese ore. Illustrating this type are the Markhamville deposits in Kings county, New Brunswick.

Less common occurrences consist of: lenticular veins in faults and fissures in biotite granite, such as occur at New Ross, Lunenburg county, Nova Scotia; veins and stringers in joints and shear zones in dark greenish volcanics and reddish felsite, as at Gowland Mountain in Albert county, New Brunswick; filling in fractures and as cementing material around breccia fragments in red-brown felsites, as at Jordan Mountain, Kings county, New Brunswick; replacements of limestone and solid nodules in reddish clay, as at Shepody Mountain, Albert county, New Brunswick; veins and joints in bedding planes of grey-buff brecciated limestone, as at East Mountain, near Truro, Colchester county, Nova Scotia; and manganese-coated iron-stone nodules in the clay and shale beds of the Riding Mountain and other areas of Manitoba, that, being low in grade, present problems in commercial treatment that have not yet been completely solved. In the Magdalen Islands, certain areas where limestone and grey sandstone underlie the recent covering of red sandstone contain manganese minerals, the best ore occurring as replacement nodules and bodies in the limestone, just below its contact with the red sandstone.

The most favourable areas for the prospector are the Maritime Provinces and the Magdalen Islands. The small amount of manganese ore that has been produced in Canada has come from the Maritime Provinces and British Columbia, chiefly the former.

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Identification

Pyrolusite

Pyrolusite (manganese dioxide, MnO_2) has when pure a content of 63·2 per cent of manganese. It is distinguished from the other black manganese minerals by its softness. An important feature is that it blackens the fingers very readily. It has the following physical characteristics:

Hardness—About 2.
Specific gravity—4·8.
Colour—Black to blackish grey.
Streak—Black.
Lustre—Metallic to dull, opaque.
Tenacity—Rather brittle.

It is frequently composed of short indistinct needle-shaped crystals, but is also found in massive, compact, or fibrous, columnar forms.

Psilomelane and Manganite

Psilomelane and manganite are black hydrous oxides of manganese which are much harder and have less oxygen than pyrolusite and usually give a brownish streak. In most Canadian deposits they occur with pyrolusite, but in relatively minor quantities.

Bog Manganese

Bog manganese, when pure, is black, like powdered pyrolusite, but usually is a red-brown to reddish black, depending on the amount of iron present and the degree of contamination by soil or peaty matter. It is earthy, soft, and loose, but sometimes hard and compact. It commonly soils the fingers. Other physical characteristics are:

Hardness—0·5 to 6.
Specific gravity—3 to 4·26.
Streak—Brown.
Lustre—Dull, opaque.

As black heavy nodules and lumps in the surface soil are common above many known deposits of manganese minerals their presence in the overburden points to the possibility of ore-bodies below. Instances are known, however, in which the float nodules have been transported by glacial action (usually in a southeasterly direction), as is typically exemplified in the area south of the Markhamville mine, New Brunswick. Such lumps are often ploughed up by farmers, and should be sent for identification to the Provincial Department of Mines or to the Bureau of Geology and Topography, Ottawa.

Grades and Specifications

The prime metallurgical grade of manganese ore is known as "ferrograde" since it is used for making ferromanganese, the form in which manganese is customarily added in steel manufacture. Specifications call for a minimum of 48 per cent metallic manganese and maxima of 7·0 per cent iron (the manganese content should be not less than seven times that of the iron), 8·0 per cent silica, 0·15 per cent phosphorus, 6·0 per cent alumina, and 1·0 per cent zinc. In addition, the content of copper, lead, and barium should each be quite low. The ore should be in hard lumps less than 4 inches across, and not more than 12 per cent should pass a 20-mesh screen. "Soft" ores like bog manganese must be briquetted, adding to costs.

Ore of chemical grade must be a manganese dioxide ore containing not less than 75 per cent MnO_2 and not more than 1·5 per cent iron, 1·0 per cent alumina, 6·0 per cent silica, 0·02 per cent copper, and 1·0 per cent moisture. Other metals should not be present in amounts exceeding 0·05 per cent. The ore should be pulverized, two grades being used, one above 150 mesh with a little coarse plus 8 mesh, the other all minus

150 mesh. Some users, however, purchase the unground ore as they are equipped to do their own grinding. Pyrolusite is the only ore used because of its high content of available oxygen, which is essential for dry batteries and for many of the chemical purposes to which manganese compounds are applied.

As regards treating low-grade manganese ores to obtain concentrates that will meet industry's requirements, a degree of economic success in this direction has recently been achieved, and some plants in the United States are now concentrating such ores by chemical and by electrolytic methods. The application of ordinary wet gravity methods to certain types of ore has also met with success, as has been demonstrated by the work of the Ore Testing Laboratories of the Department of Mines and Resources, Ottawa.

Buyers

The Canadian market for metallurgical ore is mainly confined to two manufacturers of manganese ferro-alloys:

Electro Metallurgical Co. of Canada, Ltd., Welland, Ont.

Canadian Furnace Co., Ltd., Port Colborne, Ont.

At least 3,000 tons of chemical grade ore is consumed annually in Canada, the bulk of it in dry batteries made by the following manufacturers:

Canadian National Carbon Company, Ltd., 805 Davenport Road, Toronto, Ont.

Burgess Battery Company, Niagara Falls, Ont.

General Dry Batteries of Canada, Limited, 228 St. Helens Avenue, Toronto, Ont.

The Metals Reserve Company, the United States Government mineral buying agency at Washington, D.C., is also a buyer of manganese ores.

Prices and Other Economic Considerations

Prices of ferrograde ore depend on manganese content and the amount of harmful impurities. Imported ore is usually quoted in cents per long-ton unit, i.e. in cents per 22·4 pounds (= 1 per cent of a long ton) of contained manganese.

United States prices for metallurgical ores are based on a standard duty-free ore (Cuban or domestic) containing 48 per cent manganese, 6 per cent iron, 11 per cent silica plus alumina, and 0·18 per cent phosphorus, and amount, for this grade, to 85 cents per long-ton unit (22·4 pounds) of contained manganese at Gulf of Mexico ports, and to 90 cents at New York and other Atlantic ports.

The price premiums and penalties for ores varying from the standard grade are as follows:—

Premiums per long-ton unit: ½ cent for each per cent manganese above 48 per cent, and ½ cent for each per cent iron below 6 per cent.

Penalties per long-ton unit:

(a) Manganese—1 cent for each per cent manganese below 48 per cent down to 44 per cent; 4 cents plus 1½ cents for each per cent manganese below 44 per cent down to 40 per cent; 10 cents plus 2 cents for each per cent manganese below 40 per cent down to and including 35 per cent.

(b) Iron—1 cent for each per cent iron above 6 per cent up to 8 per cent; 2 cents plus ¾ cent for each per cent iron above 8 per cent.

(c) Silica (SiO_2) plus Alumina (Al_2O_3)—1 cent for each per cent above 11 per cent $SiO_2+Al_2O_3$ up to 15 per cent; 4 cents plus ¾ cent for each per cent above 15 per cent $SiO_2+Al_2O_3$.

(d) Phosphorus—⅛ cent for each 0·01 per cent phosphorus above 0·18 per cent.

The ore should be in hard lumps less than 12 inches in size, and not more than 25 per cent should pass through a 20-mesh screen.

Prices of manganese ores of chemical grade (battery-grade ores) in February, 1943, were $55 per ton for Brazilian or Cuban ores (80 per cent minimum content of MnO_2) in carloads, f.o.b. New York, exclusive of duty. The delivered price in Canadian currency for finely ground chemical-grade (battery) ore in bags imported into Canada from Africa and Montana was about $60 to $80 a ton, depending on mesh and origin.

Although the actual manganese content is about the same as that of the best ferrograde ore, the price of chemical-grade ore is much greater, largely because of the special packing its softness necessitates, its high available oxygen, very low iron content, and freedom from moisture.

Imports from Canada into the United States of manganese ores containing 10 per cent or more of manganese are subject to a duty of one-half of a cent per pound of contained manganese, but are duty free if purchased and imported by the Metals Reserve Company.

World Production and Canada's Position

In 1938, world output of manganese ore was not far short of 6,000,000 tons, U.S.S.R. being by far the largest producer, followed, in order of importance as major producers, by India, Union of South Africa, Gold Coast, Brazil, Egypt, and Cuba.

The United States produced in 1941 about 85,000 tons of ore containing 35 per cent or more of manganese, but this was only 3 per cent of her consumption. Her imports of 48 to 50 per cent ore amounted to nearly 1·5 million tons in 1940. Canada's production is negligible relative to her requirements, and, as her imports normally are mainly from Africa, it is important that the search for workable Canadian deposits be thorough and persistent. Many deposits have already been found, but these are either too small or two low in grade for economic operation. Only deposits of substantial tonnage and satisfactory grade can be expected to yield production which can compete with imported ores obtained from the extensive high-grade deposits normally supplying the world's markets.

MERCURY

Mercury (quicksilver) and its salts are indispensable in both peace and war. Many peacetime uses fill also war needs, as in the case of medical supplies, electrical equipment (automatic devices, radio, etc.), and fulminate (for special types of detonators). Prior to the conservation order of January 26, 1942, a great amount was used in the United States in the form of mercuric oxide (HgO), in antifouling paints for ship bottoms.

Spain and Italy have always been the world's leading sources of mercury. With the cutting-off of the Italian supply in June, 1940, and the increasing demand for war purposes, the need for developing new sources of Allied supply became imperative. Since that time, Canada, which had been a negligible producer, has developed a deposit which is now yielding far in excess of domestic requirements, and production in the United States and Mexico has been greatly increased. The Allied mercury position has, therefore, become so much stronger that the urgency for intensive search for new deposits has largely disappeared, and only large deposits of economic grade ore would be considered of development interest at the present time.

Occurrence and Formation

The principal ore of mercury is cinnabar, a scarlet mercuric sulphide (HgS), accompanied in places by native mercury. Cinnabar is found in a great variety of rocks of recent age. It is not of sedimentary origin, but always associated with some evidence of igneous activity and found near the surface that existed at the time of its deposition. The containing rocks are fractured or porous, the largest and best deposits of cinnabar being those in which the mineral solutions have been trapped and preserved under a capping of impervious rock, such as lava, shale, or clay.

In Canada all known deposits of cinnabar are in British Columbia. Besides the property at Pinchi Lake in the north-central part of the province where a substantial production is now being maintained, cinnabar deposits are being prospected and worked in the Takla Lake area to the northwest, on both sides of Kamloops Lake, and in the Yalakom and Bridge River areas due west of there; and are also known at Sechart on the west coast of Vancouver Island.

Host rocks for the mineral include altered and carbonated limestone (ankerite), volcanic breccias, and green and purple andesitic lavas, especially if they have been subjected to shearing and fracturing. The ore occurs as discontinuous stringers, small grains, or scattered blobs, often in veins or stringers of dolomite or calcite. Ore-bodies are generally irregular and indefinite though usually confined to faulted or sheared zones.

Stibnite (antimony sulphide), a grey-black, shiny, very brittle mineral is found rather commonly with cinnabar; less common are pyrite and realgar, the orange-red sulphide of arsenic.

Identification

Cinnabar, when pure, has the composition HgS and contains 86·2 per cent mercury and 13·8 per cent sulphur. It has the following physical characteristics:

Hardness—2·0 to 2·5.

Specific gravity—8 to 8·2.

Colour—Scarlet, brownish-red, rarely blackish.

Lustre—Bright, somewhat "oily" appearance, dull when scattered through rock or in powdery masses.

Streak—Scarlet or vermilion.

Tenacity—Brittle to sectile (i.e. severable by knife with smooth cut, yet pulverizable).

When cinnabar occurs in white or buff-coloured rocks, the bright red colour and softness are means of identification, the solid mineral being often a blackish red and thin films of it sometimes assuming a fern-like appearance. Smears or stringers of red-brown hematite iron might be mistaken for cinnabar, but a comparison of the two minerals will quickly settle any doubt. A fairly reliable method of identification consists in pulverizing and panning a piece of rock containing the suspected mineral, when the cinnabar, if present, will appear as bright red specks at the point of the tail.

The presence of mercury can be readily detected by heating a small piece of rock to about 300° C. and placing it between an ultra-violet ray lamp* with purple filter and a screen coated with powdered willemite (zinc silicate). If mercury is present, a fume shadow will be cast on the screen. As little as 0·02 per cent mercury can be detected in this manner, but better results are achieved with a powdered sample.

When cinnabar is carefully heated in an open tube, fumes of burning sulphur are given off and metallic mercury condenses in minute globules on the cold walls of the tube.

Marketable Grades and Treatment

In the United States the grade of ore of the principal producing deposits averages slightly under 0·5 per cent. Many with 0·35 per cent ore are being profitably operated, and this is about the economic limit for any small producer in Canada at prevailing prices for mercury.

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* *See page 73 for further reference to this lamp.*

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Hand-cobbing is profitable if the ore is concentrated in small veins and not distributed throughout the rock. Owing to its brittleness, with consequent loss of fines, and its usually erratic occurrence, accurate sampling is difficult except in evenly disseminated deposits. A close check can be obtained, however, by panning numerous samples from the rock faces. Minute globules of mercury should also be looked for in the tail of the pannings.

As cinnabar generally occurs close to the present surface of erosion, open-pit methods of mining are common. Provision should always be made to save the fines.

The extraction of mercury is generally effected by roasting the coarsely crushed ore in furnaces that are usually of the rotary-kiln type through which air is circulated. The sulphur escapes as sulphur dioxide and the mercury is driven off as vapour, which is condensed to the liquid metal in cooling-chambers.

A prospector who wishes to treat specially high-grade ore during the initial stages of developing his property might find it sufficiently remunerative to roast the ore in a circular or D-shaped horizontal cast-iron retort and collect the escaping mercury vapour in a water-cooled pipe whose end dips into a bucket of water. The interior of the retort must not come in contact with flame or air. A little lime should be added, especially if any pyrite is present in the ore, in order to convert the sulphur into calcium sulphide.

Retorts made of fireclay in place of cast-iron may be used but if stibnite (antimony trisulphide) is present it may cause trouble owing to its tendency to fuse through the retort walls.

Buyers

The principal Canadian buyers of mercury are manufacturers of heavy chemicals, e.g.:

Canadian Industries, Ltd., 1135 Beaver Hall Hill, Montreal Que.

Other buyers are drug and medicinal manufacturers, e.g.:

Merck & Co., Ltd., 560 Decourcelles St., Montreal, Que.

N. C. Polson & Co., Ltd., 649-651 Notre Dame St. W., Montreal, Que.

Mallinckrodt Chemical Works, Ltd., 378 St. Paul St. W., Montreal, Que.

Prescott & Co., 774 St. Paul St. W., Montreal, Que.

A fair quantity of mercury, in the aggregate, is consumed by gold-mining companies that employ the amalgamation method of treating ore, and by the following manufacturers, among others, of electrical equipment:

Canadian General Electric Co., Ltd., 212 King St. W., Toronto, Ont.

Canadian Westinghouse Co., Ltd., Hamilton, Ont.

English Electric Co. of Canada, Ltd., St. Catharines, Ont.

Northern Electric Co., Ltd., 1261 Shearer St., Montreal. Que.

Because of the present substantial production of mercury in Canada surplus to domestic requirements, the larger Canadian buyers are not purchasing in less than 50- to 100-flask lots. Considerable difficulty is, therefore, experienced in disposing of small lots of a few flasks.

In the United States, the Metals Reserve Company, Washington, D.C., is an important buyer of mercury.

Prices and Other Economic Considerations

New York prices of mercury just prior to the war were about $75 per flask (76 pounds); prices at the end of January, 1943, were $196 to $198 in 100-flask lots. Specifications call for a minimum of 99·5 per cent mercury, and maxima of 0·3 per cent antimony and 0·1 per cent arsenic. The Canadian price was about the same as the United States price with exchange and sales and war taxes added. Any Canadian imports into United States would be subject to a tariff of 25 cents per pound, or $19 per flask, in United States currency.

Speaking somewhat generally it should be possible under favourable conditions to make a profit mining, on a fair scale, a deposit grading even lower than 0·25 per cent mercury, whenever the United States price for the metal is $180 per flask of 76 pounds, provided production can be developed that would enable sales in lots of not less than 50 flasks.

World Production and Canada's Position

Estimated world production of mercury in 1939 was 160,000 flasks of 76 pounds, equivalent to slightly over 6,000 tons. Italy, Spain, and United States are the chief producing countries. The output of United States in 1940 was 37,777 flasks, or nearly 1,436 tons, a record for many years and more than double that of 1939.

Canada's production, as has already been stated, was insignificant prior to 1940, but since June of that year, when the mine at Pinchi Lake in British Columbia came into production, it has reached a point where it is several times that of her consumption, permitting, therefore, of exports. It has already been indicated that as a result of this new production and of the greatly increased outputs of the United States and Mexico the assurance of mercury supplies for Allied war purposes is no longer causing undue concern. The need for intensive search for new Canadian deposits is, therefore, no longer urgent, and development interest is at present limited to the more economic, large deposits of the higher grade ores.

MICA

Mica is of essential importance as an electrical insulator. No satisfactory substitute has yet been found for it, and without it the electrical industry, including the generation of power, would be at a standstill.

Electrical mica is of two types, muscovite (often termed white mica) and phlogopite (amber mica). Muscovite is by far the commoner, being practically world-wide in its distribution, and many countries produce it. Phlogopite is much rarer, and the world supply has been derived mainly from Canada and Madagascar, in probably about equal proportions. Mexico is currently showing promise of becoming an additional source of supply. The muscovite requirements of the American Continent, as well as of the world in general, have been supplied mainly by India and Brazil, but there is now an important and growing production in the United States.

PHLOGOPITE

Following the capitulation of France in 1940 and the consequent uncertainty of maintaining the flow of supplies of phlogopite from Madagascar, it became necessary to give special attention to the increased production of this type of mica in Canada. This urgency has been very substantially eased by the restoration of that island to full Allied support, and the phlogopite supply position is at present not regarded as serious. Current Canadian production, together with available stocks, appears to be adequate for prospective requirements, particularly since specifications for the phlogopite used in aviation sparkplugs, one of its most important war uses, have been lowered, permitting the use of material hitherto considered unsuitable for that purpose. Phlogopite mica is, therefore, not considered a strategic mineral at the present time.

Although practically all phlogopite can be employed in general electrical insulation, only specially heat-resistant material meets the requirements of manufacturers of sparkplugs, and such mica is produced from relatively few Canadian properties. The Bureau of Mines, Ottawa, has tested the resistance to heat of a large number of Canadian phlogopites, and is prepared to test further samples and to advise on quality. Such information will prove of value for record in the event of any change in the present supply situation.

Muscovite mica is, however, in critical demand, and the following information of special interest to the mica prospector relates only to this type of mica.

MUSCOVITE

Occurrence and Formation

Sheet muscovite is always found in granite pegmatite dykes, which are widely distributed throughout the Archean rocks of Canada, from coast to coast. Only rarely has it been found, however, that the quantity and quality of the muscovite of such dykes are such as to offer any possibility of commercial development. Small amounts have occasionally been recovered as a by-product of feldspar mining from pegmatites, but, until recently, production has been comparatively unimportant. This situation has changed following the discovery in 1942 of a productive area in the Eau Claire district, near Mattawa, Ontario, which is now furnishing shipments of high-quality and exceptionally large sheet. Promising deposits of high-grade "ruby" muscovite have also been discovered near Les Escoumains, in Bergeronnes township, Saguenay county, Quebec, and are under development.

Although muscovite-bearing pegmatites are common and widely distributed throughout the Archean complex of Eastern Canada, in northern Manitoba and Saskatchewan, and in British Columbia, relatively few of the recorded occurrences have been found to carry mica of strategic quality or in quantity that would make them of economic interest in the war effort. Pegmatites in general are exceedingly variable in the character, and hence in the commercial usefulness, of the mica they may contain; and it is essential for appraising the economic possibilities of a discovery that some knowledge be possessed as to what constitutes commercial sheet mica, and more especially the class of muscovite termed "strategic" in the present war emergency.

One of the commonest imperfections in muscovite, and that rules it out of the strategic class, is black or red blotching or spotting, due to thin films of iron oxide between the layers. Grosser inclusions of mineral substance, such as garnet, quartz, tourmaline, black biotite mica, green chlorite, etc., are even more objectionable, the sheets being useless for any electrical purpose.

Common physical imperfections of muscovite include wedge form of crystals, giving rise to sheets of unequal thickness on splitting; cross-graining, ribbing, or reeving, caused by imperfect crystal growth; "herring-bone" and "tangle-sheet" structure, due to similar crystal imperfections; and "ruling", hairlines, and cracks. The last may be natural in origin, or may be caused by shock in blasting or rough handling. Almost all muscovite is subject in some degree to the above objectionable features, which inevitably occasion the discarding of a considerable proportion of the mine-run production and its relegation to the waste pile. Often so large a proportion is thus discarded that the recovery of the small amount of sound sheet contained in the crystals or "books" is uneconomic.

Every deposit needs to be considered on its own individual merits as to whether its yield of sound, strategic block mica will warrant mining, and this frequently can be determined only by sufficient development work to enable some idea of costs and revenue to be arrived at. Rarely can the economic possibilities of a raw prospect be appraised from surface indications, and any estimates formed on such evidence are liable to prove misleading. The only reliable method to follow is to blast out a few tons of rough crystals, which should then be passed through the hands of a competent trimmer or established mica dealer or shop, in order to determine the maximum yield of commercial block in the various trade qualities and sizes, and its value. For the unskilled operator, lacking the necessary technique and knowledge of trade practices, to undertake such work is to invite discouragement and probable failure in what might otherwise prove a successful venture.

In the case of a newly-discovered deposit, the prospector may obtain valuable information on the general character and probable value of his mica by submitting a representative sample, preferably about 10 pounds in weight, of roughly-trimmed sheet to the Bureau of Mines, Ottawa, which will advise on the probable commercial quality of the material.

Until the recent discovery of muscovite in the Eau Claire area in Ontario, no particular region or district in Canada could be regarded as specially favourable prospecting territory for the mineral, mica-bearing pegmatites being widely scattered without any pronounced localization. The uncovering of numerous dykes in this area suggests the existence of a perhaps extensive mica "province" extending beyond the confines of the already proven ground, and makes further prospecting in the region desirable.

Pegmatites, many of them mica-bearing, are known to occur as scattered dykes over a wide territory in eastern Ontario extending westward from Eau Claire to North Bay and Sudbury, as well as farther south in Nipissing and Parry Sound districts as far as Georgian Bay, and this area would also seem worthy of prospectors' attention.

Muscovite of good ruby quality is known to occur at a number of scattered localities in Saguenay county, Quebec, where there has recently been a small production; and further prospecting of the region would appear warranted. Although numerous occurrences are known in more northerly parts of Quebec, as well as in western Ontario and northern Manitoba, very few of the samples from such sources examined by the Bureau of Mines have proved to be of strategic quality.

Samples of muscovite of good grade have come from British Columbia, where occurrences are known in the Tête Jaune-Big Bend region, as well as on Finlay River, but these deposits are situated at such high altitudes, or are so remote from transportation, as to make them of doubtful economic interest.

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Marketable Grades and Specifications

In normal times, almost all qualities of muscovite are salable, uses ranging from condensers, which require the highest quality, radio bridges and supports, spark-plugs, mica plate, stoves, lamp chimneys, domestic heater appliances, punched segments, etc., down to mica washers, for which the lowest grade is suitable. Owing to the present greatly increased over-all production of mine-run muscovite in the United States, in an effort to increase the supply of high-grade (strategic quality) material, there is currently available an abundance of domestic lower-grade (so-called "electric", or spotted and stained) mica, as well as large supplies from South American sources. In addition, the demand for such mica is presently far less than in peace time, owing to the existing restrictions on the manufacture of consumer goods into which it enters. Consequently, at this time, only mica that will measure up to strategic standards is assured of a ready market, and lower-grade material may be difficult to dispose of at remunerative levels.

It should be clearly understood that very strict specifications govern strategic muscovite. Such mica has been defined as follows in a recent publication of the United States Bureau of Mines (Information Circular No. 7219, September, 1942): "Strategic mica is block and punch mica of better than heavy-stained quality, free of mineral inclusions (black or red spots, stains, or streaks), cracks, pinholes, cross-grains, reeves, and ribs, and relatively free of clay staining. It must be hard, clear, reasonably flat, and capable of being evenly and easily split into laminations or sheets of uniform thickness over the entire area, yielding sheets of at least 1 by 1 inch in size". The heaviest demand at present is for sheets measuring 1½ by 2 inches, 2 by 2 inches, and 2 by 3 inches. Although colour is some criterion of value, so-called "ruby" being regarded as the best quality, it is not necessarily a deciding factor; and green, smoky, "rum", and other shades find strategic uses.

Although rough mine-run mica can occasionally be sold by the producer to dealers who prepare it for the trade, such preparation usually requires to be performed by the mine operator. This entails the setting-up of some form of trimming establishment or mica "shop", in which the rough crystals or books are put through the various stages of rifting, trimming, classifying for quality, and grading for size, required to make a marketable trade product. Skilled hands are needed for this work, in order to avoid unnecessary waste in trimming, to classify and grade properly the trimmed sheets (termed "block" mica), and thus to obtain the maximum yield and monetary return from the material. Improperly classified and sized mica is difficult to sell and inevitably involves financial loss to the operator.

After a preliminary rough sorting at the mine to discard all definitely worthless material, the crystals are removed to the trimming establishment. Here they are first rifted or split up into thick sheets of sound mica and any imperfect material removed. The rifted sheets are then split down to a thickness of one-sixteenth of an inch, or less, and trimmed so as to remove all unsound rough edge-waste and otherwise imperfect material. In the trimming operation, it is important to cut away all mica that contains cracks, and to retain only sound, perfect sheets.

Trimming is performed variously by hand-knife, using a bevel or bias cut (so-called "sickle" or "India" trim), or by hand-operated guillotine knife ("shear" trim). The former is preferred, as it entails less waste and the bevel edge facilitates further preparation of the mica by the consumer. The trade recognizes three classes of trimmed mica: "full trim", where the sheets are trimmed all around; "three-quarter trim", where three sides are trimmed; and "half trim", where only two of the longer edges are trimmed, the remainder being left rough. Perfection of trimming has a large influence in value and materially enhances the price obtainable.

Classifying for quality of the trimmed sheets, and strict adherence to specifications, are of vital importance and can only be performed under expert supervision by one having full knowledge of trade requirements. Grading for size also needs careful attention because value rises rapidly with dimensions of sheet, and severe price penalties are entailed by improper sizing. Grading is usually performed in the case of larger and more valuable sizes with the aid of wooden templets.

When carried to the knife-trimmed stage, mica is usually termed "block"; and virtually the entire output of muscovite on the North American Continent is marketed in this form. Much muscovite is used in the form of so-called "splittings", or thin films only one- to two-thousandths of an inch thick employed in the manufacture of built-up mica plate, or "micanite". Such films are made by hand, and the operation is a slow, laborious process, even an expert worker being unable to turn out more than about one pound an hour of finished material. Owing to high labour costs, it has hitherto been impracticable to make muscovite splittings on this continent, and supplies have been imported mainly from India.

Trimmed block mica is sold in sheets of varying trade dimensions, and different producing countries (e.g. India, United States, and Canada) have adopted size classes that are not strictly uniform, though they are more or less comparable. As the United States is the chief present outlet for strategic muscovite, the sizes shown in the section on prices are the trade sizes of that country.

It is seldom practicable for a small mica producer to carry his product beyond the knife-trimmed stage, in which form he can dispose of it to a regular mica dealer having established trade connections, or to a consumer who will put it into finished form for his own particular requirements.

Buyers

The following firms are prepared to buy muscovite mica in either the rough or semi-prepared state. Persons having small lots of such mica to sell should submit representative samples to these concerns, who will advise on the price they are prepared to offer:

Mica Company of Canada, Lois Street, Hull, Quebec.

Purdy Mica Mines, Limited, Mattawa, Ontario.

Dominion Mica Reg'd., 14 St. Valier Street, Quebec.

Producers of substantial amounts of strictly strategic-quality muscovite are assured of a ready sale for all they have to offer, under term contract, to either the Canadian or United States Government, the Metals Controller, Ottawa, being the buying agency for the former, and Colonial Mica Corporation, 92 Liberty Street, New York, for the latter. Details regarding purchase and acceptance terms may be obtained from the Metals Controller. All sizes are acceptable, the chief need being for the smaller grades, 1 by 1 inch and 1½ by 2 inches.

Non-strategic mica is not included in the buying schedule of either of the above agencies, and such mica will have to be sold in the open market. Strategic mica can also be sold in the open market in Canada for domestic use, but cannot be exported to the United States except under export permit for purchase by the United States Government.

Prices

Mica prices are difficult to determine owing to the lack of reliable market quotations and to the prevailing system of trade discounts. Quality has such a bearing on value that the only satisfactory method of getting information is to submit samples to an accredited dealer for a quotation. The mica market is subject to pronounced periodic fluctuations in demand owing to prevailing trade conditions and the practice by consumers of laying in stocks well ahead of current requirements.

In an effort to stimulate production of strategic mica both in the United States and Canada, Colonial Mica Corporation has substantially raised the price-level above normal peacetime figures, and the following schedule shows the prices now obtainable for the various qualities and sizes of "full trim" muscovite mica, in Canadian funds, f.o.b. Ottawa:

Size, inches	Price per pound Clear	Slightly Stained	Stained
1 x 1	$0.825	$ 0.58	$0.33
1 x 2	1.10	0.77	0.44
1½ x 2	1.925	1.35	0.77
2 x 2	3.025	2.12	1.21
2 x 3	3.85	2.695	1.54
3 x 3	4.40	3.08	1.76
3 x 4	5.225	3.66	2.09
3 x 5	6.05	4.235	2.42
4 x 6	6.875	4.818	2.75
6 x 8	7.975	5.588	3.19
8 x 10	11.00	7.70	4.40
10 x 12	13.20	9.24	5.28

Canada's Position

Canada possesses probably substantial reserves of phlogopite mica and an established phlogopite industry, and is entirely self-sufficient in respect of all qualities of this type of mica, a large proportion of the production being exported. Heretofore, the greater part of Canada's muscovite mica requirements, consisting largely of splittings, has had to be imported. If current developments upon the newly-found deposits of strategic-quality muscovite have the hoped-for results, it is likely that Canada can become equally independent in respect of this type of mica, at any rate under war conditions.

The mica industry, as a whole, was very active in 1942, and production of all classes of product is estimated to have been higher than for many years past.

MOLYBDENUM

Molybdenum is used chiefly in steel to intensify the effects of other alloying elements, particularly nickel, chromium, and vanadium. Molybdenum alloys are used extensively for hard-wearing and other important parts of aeroplanes, trucks, etc., and also in the manufacture of shell steels, and in armour plating and high-speed tool steels.

Occurrence and Formation

Molybdenite (MoS_2), the sulphide of molybdenum, is by far the most important ore, and contains 60 per cent molybdenum and 40 per cent sulphur. It occurs in many different types of rocks. In Eastern Canada the more common occurrences are in pegmatite dykes or in green pyroxenite, usually at or near the contact between gneisses and crystalline limestone. Pyrite and pyrrhotite are the metallic minerals commonly present. In northern and western Ontario and in British Columbia, molybdenite usually occurs in quartz veins or as disseminations in granite. An example of the vein type is the deposit in La Corne township, Abitibi county, in western Quebec, now in production, where the molybdenite occurs in quartz veins intimately associated with sericite schist zones in granite.

Most of the world's production comes, however, not from deposits of the "contact" type referred to above, but from those in which the molybdenite is evenly distributed throughout large bodies of rock. It is mainly discoveries of the latter type containing at least 0·75 per cent molybdenite that are of special interest to Canada at the present time. As an example, the molybdenite in the largest and most important deposit so far found in Canada, in Preissac township, also in Abitibi county, occurs disseminated in a wide zone between grey biotite granite porphyry and red muscovite granite. On Timothy Mountain in the south Cariboo area of central British Columbia, molybdenite is disseminated through a wide zone of brecciated quartz-diorite.

Identification

Molybdenite has the following properties:

Hardness—1 to 1·5.

Specific gravity—4·7.

Colour—Lead grey; a bluish grey trace on paper.

Lustre—Metallic.

Molybdenite is a very soft, shiny, grey-blue mineral. It occurs as very pliable flakes or leaves and often as crystals which are hexagonal in shape and made up as "books" of leaves resembling fresh lead foil. Flakes vary in size from a pin's head to several inches. An infallible test is the dark olive-green smear it imparts when rubbed on glazed white porcelain or enamel (a piece of a china cup will serve), the smear of graphite which it closely resembles being grey.

Marketable Grades and Specifications

The ore must be in the form of a concentrate containing not less than 85 per cent molybdenum sulphide and very low in copper, arsenic, and bismuth. In deposits containing large, pure flakes or crystals a marketable grade might be obtained by hand-picking, but the amount would be small. Hand-cobbing to bring up the grade of the mill feed is often done on certain types of irregular large-flake deposits. Most molybdenite ores readily respond to ordinary flotation methods of concentration, though the amount and type of flotation reagents may vary considerably for different ores.

Molybdenite concentrate is not added direct to the steel, but must first be converted into a suitable addition agent.

Buyers

Several steel and alloy manufacturers use molybdenite concentrate in the form of addition agents. These agents are not made in Canada, except at the Moss mine at Quyon, Quebec, where the company has a small plant for converting its own concentrates, and most of the Dominion's requirements are imported from the United States. The duty on concentrates is much too high to permit their entry into the United States market. Canadian molybdenite concentrates can, therefore, be sold only to or through the Metals Controller, Ottawa. Because of the greatly increased war use of the metal, arising in part from its partial substitution for tungsten, these concentrates are in urgent demand, and prospective Canadian producers should write to the Metals Controller for information on selling arrangements.

Prices

The United States quotation in February, 1943, for a molybdenite concentrate containing 90 per cent MoS_2 was 45 cents per pound of contained MoS_2, f.o.b. United States mines.

The Metals Controller, Ottawa, is prepared to purchase concentrates containing 80 per cent or over MoS_2 from Canadian producers who will contract to deliver, in each case, concentrates containing at least 100,000 pounds of MoS_2 per year, at prices approximating 85 cents per pound of contained MoS_2, delivered at Ottawa.

Ores of a certain minimum MoS_2 content may be sold to a producer accepting custom ore for milling and selling his concentrate under contract with the Metals Controller, who will furnish the necessary information.

The prices of imported addition agents per pound of contained molybdenum, f.o.b. Toronto, are 98 cents for molybdic oxide and calcium molybdate, and $1.23 for ferromolybdenum.

World Production

Close to 95 per cent of the world production in 1940 came from the United States, where Climax Molybdenum Company alone contributed about 66 per cent of the domestic output. Consumption of molybdenum in the United States in 1940 was 50 per cent greater than in 1939; and in Canada, though the consumption is still relatively small, it is far in excess of the peacetime consumption.

Canada's Position

More than 400 molybdenite occurrences and deposits are known throughout Canada, but nearly all are small. Under suitable market conditions, however, some of these, if developed as a group, could probably be operated successfully. With the development of substantial production in 1943 from the important Dome discovery in Preissac township, Abitibi county, Quebec, there is much less urgency for the development of the small submarginal deposits. The attention of the prospector is more usefully directed to the search for economic deposits in which the molybdenite is evenly disseminated in commercial grade throughout large bodies of rock.

QUARTZ CRYSTALS

Quartz crystals of a certain type are required as a source of thin plates for use in Piezo-Electric Resonators and Oscillators. These instruments have special applications in connection with apparatus for depth-sounding, directional sound-detection, control of radio signals in both sending and receiving, in multiple telegraphy, and in wireless field telephones, etc.

Occurrence and Formation

Quartz crystals occur in all countries, but material suitable for Piezo-Electrical purposes has been found in commercial quantity only in Brazil and Madagascar.

In Brazil, the crystal is a constituent of pegmatite dykes. These dykes are deeply weathered and decomposed, and consequently the crystals are in general not difficult to recover. In several places weathering has been deep enough to disintegrate the pegmatite completely, resulting in residual deposits in which the crystals are embedded in clay. In a few places the residual deposits have been worked over by streams leaving a placer or gravel containing broken or worn crystals.

In Madagascar, quartz occurs in many associations, in granites, rhyolites, and schists, and good specimens have also been obtained from pegmatites, but the bulk of the well-crystallized material is now won from cavities in quartzites found in the mountainous region southwest of Antananarivo.

Opencast working is the common method in both Brazil and Madagascar, the quartz-bearing deposits being opened up by hand labour. It is a frequent event for representatives of buyers to be in close touch with the mine owners and so to obtain first choice of the crystals. In some cases exporters own their own deposits.

The search for Piezo-Electric quartz within the Empire has been greatly stimulated since the outbreak of war, and localities of some promise have been discovered in India, Uganda, and Tanganyika.

Identification

Crystals of quartz are very common, both large and small, and loose and attached, but those of suitable size and transparency are difficult to obtain. Quartz is silicon dioxide (SiO_2), or silica.

Hardness—7. **Specific gravity**—2·66 ±

Lustre—Vitreous.

Colour—More often white, or colourless, but may be any colour. Transparent to translucent, rarely opaque.

Cleavage is practically absent, but the crystals break with a glassy conchoidal fracture.

An ideal crystal of quartz takes the apparent form of a hexagonal prism, the faces of which are horizontally striated. The crystal is terminated by apparent hexagonal pyramids but possesses trigonal symmetry so that the pyramid and prism faces are similar only alternately.

Quartz often resembles calcite but is distinguished by its superior hardness and lack of cleavage. Quartz cannot be scratched with a knife.

Grades and Specifications

Crystals suitable for electrical use must be clear (internally), two or more faces should be well defined with definite horizontal striae (preferably six faces alternately parallel and straight); the faces should be free from natural etched patterns (indicating twinning) and the striae should not be broken or irregular. The interior of the crystals should be free from cloudiness or fractures of any kind, and visible gas bubbles and mineral inclusions should be absent.

Crystals should be at least 1 inch in diameter and from $2\frac{1}{2}$ to 3 inches long. If the diameter is greater, shorter pieces can be used. They should weigh preferably not over 10 pounds. Usually, good crystals are attached to mother rock at one end, and only rarely are crystals found with double terminations. Where crystals are attached the lower end is usually cloudy and fractured. It is only the upper clear part that can be used, but in sending specimens the clear part should not be broken away from the more clouded material.

Poor quality material not suitable for electrical use usually contains excessive twinning. The presence of twinning is frequently shown by a natural etching on some of the parallel faces. Crystals that show this type of twinning on pyramid faces are in most cases useless. Again, twinning is shown when two alternate sets of faces (generally one part rough and one part smooth) are present on one or more of the apparently flat faces of the crystal. Another type of twinning is shown when the crystal is irregular and obviously of composite structure. In this case the growth lines (striae) are irregular and discontinuous, but the texture of the two sets of alternate faces is similar.

Buyers

There are at present no steady Canadian buyers of this mineral, but if a finder of quartz crystals will communicate with the Bureau of Mines, Ottawa, he will be advised where the crystals can be marketed.

Prices and Other Economic Considerations

No prices for quartz crystals suitable for Piezo-Electric use are quoted, as prices depend upon quality, size, and quantity to be sold. In the United States, prices for Brazilian crystals have stiffened considerably during the past year, and have ranged from $3 per pound up to $35 and more for exceptional material suitable for optical work.

No value can be assigned to any material in advance of its inspection. As noted above, samples less than $\frac{3}{4}$ pound in weight and less than $1\frac{1}{4}$ inches in diameter are ordinarily not considered suitable. An exception might be made if the crystals are particularly clear, but in no case would material less than 1 inch across be considered. Before it can be determined whether the material is of value, thin slices have to be sawn from the crystal in certain particular directions, and these have to be subjected to actual test.

World Production and Canada's Position

For a number of years Brazil has been the principal and almost the sole source of supply for quartz crystals. The only other source worthy of mention is Madagascar, but, so far, only a small percentage of material exported from that country has been found suitable for optical and electrical purposes. Figures of production are hard to obtain but it is probable that Brazil produced in 1940 close to 1,000,000 kilograms, or 2,200,000 pounds.

Canada, so far, has not produced any crystals suitable for Piezo-Electric use, but it is possible that localities may be found where quartz crystals of suitable size and quality occur in sufficient quantity to make their exploitation economical.

TANTALUM—COLUMBIUM

Tantalum and columbium, the latter sometimes called niobium, are nearly-related metallic elements; and, being commonly found closely associated in nature, can most conveniently be considered together.

Both tantalum and columbium find important industrial uses, the field of which is restricted only by their relative scarcity, and demand would expand greatly with availability of larger supplies.

Tantalum

Tantalum is employed in making ultra-hard cemented carbides for dies, tools, and wear-resistant mechanical parts; for corrosion-resistant chemical equipment; in radio and neon tubes, lamp filaments, electrolytic cathodes, surgical and dental instruments, pump and valve parts, nozzles, spinnerets for rayon and other synthetic textiles, electrical contacts, and for various other specialty uses where high resistance to wear and corrosion is required. Tantalum oxide is a component of special glass having very high refractive index and low dispersion and used in aerial camera lenses.

Columbium

Columbium is the more abundant of the two elements, and finds application mainly in ferrous metallurgy, to inhibit intergranular corrosion, reduce air-hardening, and to increase oxidation resistance, creep and impact strength of steel and various ferrous alloys. It is an important ingredient of stainless steels, and is also added to copper and its alloys and to certain aluminium alloys used in aircraft to raise the softening temperature.

Occurrence and Formation

The chief sources of tantalum and columbium are the two minerals tantalite and columbite, respectively a tantalate and columbate of iron and manganese (Fe, Mn)O. Ta_2O_5 and (Fe, Mn)O. Cb_2O_5. These minerals are rarely, if ever, found pure in nature, tantalum and columbium replacing one another in widely variable proportions between the theoretical limits. Analyses show a range in the content of tantalum oxide (Ta_2O_5) of from 0·8 per cent to 82 per cent, and of columbium oxide (Cb_2O_5) of from 3·5 per cent to 78 per cent. Contents of the two oxides usually total around 80 per cent. Theoretically, the mineral is classed as tantalite or as columbite, depending upon the predominant element. There is, however, no arbitrary dividing line; and in trade practice the mineral is termed columbite, ranking as an ore of columbium, if it contains 50 per cent or over of columbium oxide; it is termed tantalite, ranking as an ore of tantalum, if it contains 30 per cent or more of tantalum oxide. The iron and manganese contents likewise vary, and minor quantities of titanium and tin are often present.

Tantalum and columbium also occur in other minerals, most of which are rare complex compounds of one or both elements with rare earths, titanium, uranium, etc. Such minerals are seldom found in sufficient quantities to make them of important economic interest. Moreover, these ores are difficult to treat for recovery of the contained tantalum and columbium; and so are not favourably regarded as ores.

The occurrence of all tantalum-columbium minerals is restricted to granite pegmatites, or to placer deposits derived from such rock. Columbite-tantalite is likely to be found in any pegmatite, but, generally, is higher in tantalum content when associated with pegmatites rich in lithium minerals.

Identification

Tantalite-columbite has the following properties:

Hardness	—6.	**Specific Gravity**	—5·3 to 7·3.
Lustre	—Sub-metallic, often brilliant, sub-resinous.		
Cleavage	—Fairly distinct.	**Fracture**	—Sub-conchoidal to uneven.
Tenacity	—Brittle.	**Streak**	—Dark red to black.
Colour	—Iron-black, brownish black to steel grey. Opaque, rarely reddish brown, and translucent.		

The specific gravity, colour, lustre vary considerably between the limits indicated, according to the proportions of tantalum and columbium present. The specific gravity increases with the tantalum content, and serves as a useful index of this content, a specific gravity of 6·0 corresponding to a Ta_2O_5 content of about 30 per cent; 6·3, 40 per cent; 6·5, 50 per cent; 6·8, 60 per cent; and 7·2, about 70 per cent. A deep black colour usually indicates a high tantalum content, while a grey colour, combined with a lower lustre and often with a somewhat granular texture, suggests a high columbium content.

Crystal habit is also a useful indicator. The mineral crystallizes in the orthorhombic system, usually in tabular-prismatic forms, which may occur either singly or in radiated groups. In general, high tantalum content is associated with the stouter and more equidimensional crystals, and high columbium content with thin platy forms, the latter frequently occurring in parallel growth with feldspar.

A number of minerals common to pegmatites or related rocks may be mistaken for tantalite-columbite. These include ilmenite, magnetite, wolframite, euxenite, uraninite, and various complex rare-element species, some of which contain important quantities of either or both of these elements.

Tantalite-columbite is only feebly magnetic, and this serves to distinguish it from magnetite and ilmenite.

Marketable Grades and Specifications

Commercial tantalite is required to carry a minimum combined Ta_2O_5–Cb_2O_5 content of 70 per cent, with a minimum Ta_2O_5 content of 30 per cent. The maximum content of tin oxide allowed is 3 per cent, and of titanium oxide also 3 per cent.

Commercial columbite should contain a minimum of 50 per cent Cb_2O_5, the maximum tolerance for tin oxide being 5 per cent, and for titanium oxide 7 per cent.

These specifications relate not only to tantalite and columbite but to tantalum and columbium ores in general.

Buyers

There is no market for either tantalite or columbite in Canada, the chief demand being in the United States. The principal United States buyer of tantalite is the Fansteel Metallurgical Corporation, North Chicago, Illinois; and of columbite the Electro-Metallurgical Company, 30 East 42nd Street, New York City.

Prices

Tantalite is at present (March, 1943) in urgent demand; and, in addition to the Fansteel Metallurgical Corporation, Metals Reserve Company, the United States Government mineral buying agency, is open to purchase shipments or parcels, no matter how small, at the following scale of prices in United States funds, f.o.b. New York:

Tantalite Ores, Content of Ta_2O_5	Price per pound of contained Ta_2O_5 (U.S. funds, f.o.b. New York)
30 per cent..........	$1.00.
40 to 50 per cent.....	1.25, plus 5 cents for each per cent Ta_2O_5 over 40 per cent.
50 to 65 per cent.....	1.75, plus 4 cents for each per cent over 50 per cent.
Over 65 per cent.....	2.35, plus 5 cents for each per cent over 65 per cent.

Columbite ore is readily salable, although not in such urgent demand as tantalite. Metals Reserve Company will purchase columbite with a minimum Cb_2O_5 content of 50 per cent at 50 cents (United States funds) per pound of contained Cb_2O_5, f.o.b. New York.

Contracts for the sale of either mineral to Metals Reserve Company may be negotiated through the Metals Controller, Ottawa.

There are no restrictions against open sale of Canadian tantalite-columbite for domestic consumption or for export, but export permits are required for both minerals. Tantalite is under allocation control by the United States authorities, but columbite is not at present under such control.

World Production

Most of the world supply of tantalite is derived from western Australia, Belgian Congo, Brazil, and South Africa. A few tons were formerly produced annually in the United States, but supply from this source has dwindled to negligible proportions in recent years.

Nigeria is the main source of columbite.

No statistics of world production are available, but the combined annual output of both classes of ore probably does not much exceed 1,000 tons. Scale of production is indicated by imports into the United States, possibly the largest consumer; such imports for the first nine months of 1941 amounting to slightly under 500 short tons of columbite ("columbium ore") and 138 tons of tantalite ("tantalum ore").

Canada's Position

Canada has no metallurgical plant for the treatment of tantalum and columbium ores for the recovery of these metals, and is, therefore, dependent upon imports for her relatively small domestic requirements.

Although tantalite-columbite has been found in a number of Canadian pegmatites, none of the occurrences has so far shown promise of being of commercial interest. Most of this material, also, would rate as columbite rather than tantalite. Tantalite has been reported to occur in pegmatites in the Yellowknife area of the Northwest Territories, and in southeastern Manitoba; and a recent discovery in Figuery and Preissac townships, Abitibi county, in northwestern Quebec, was under investigation in 1942.

TIN

Tin is widely distributed, but in only a few countries are the deposits sufficiently large for commercial development. Although tin has few, if any, specific military uses, the application of its ordinary industrial uses to war purposes makes it one of the most important of the essential war metals, and it is thus necessary for countries without sufficient supplies of their own to have convenient access to supplies from other countries. The metal is used chiefly in the manufacture of tin plate, mainly for use in the making of tin cans and of containers of all kinds. It is a necessary ingredient of solder and is a component part of most babbit and other anti-friction metals, without which manufacturing and transportation would be impossible. Smaller quantities are used in foil, which in normal times is used for wrapping food, tobacco, etc.; in terne-plate; in pipe and tubing; in type metal; in bronze; and in bar tin.

Occurrence and Formation

Cassiterite (SnO_2) is the only important ore of tin and in the pure state it contains 78·6 per cent of the metal. Some workable deposits of the mineral, however, contain less than one per cent of tin. Stannite, a sulphide of copper, iron, and tin, is of little significance as an ore mineral.

Although there is considerable difference in detail between the types of tin deposits of the principal tin-producing countries, they are similar in a broad way. The lode deposits are related in origin to granite or some closely allied intrusive rock and occur either in the intrusive rock itself or in adjacent rocks. The classic deposits of Cornwall in England are quartz veins in granite of latest Palaeozoic age and in adjacent sedimentary rocks of Palaeozoic age. The ore mineral is cassiterite and associated with it is tourmaline. The granite wall-rocks contain quartz, muscovite, tourmaline, cassiterite, stannite, and topaz. In Bolivia, the lodes are quartz veins in granite or allied types of intrusive rocks or in adjacent slates and contain cassiterite, tourmaline, pyrrhotite, and wolframite. Silver-tin deposits in Bolivia are somewhat similar, but contain considerable stannite and pyrite. In Malaya, the production is mainly from placer deposits and is called stream tin. The stream tin is cassiterite and was derived by erosion from cassiterite-bearing quartz veins, pegmatites and pipe-like deposits and also from cassiterite disseminations in granite. The lodes are associated with granite of Mesozoic age.

Attempts to mine lode deposits of tin in South Dakota, the Carolinas, California, Texas, and Virginia have been mostly unsuccessful because the deposits are too small or too low in grade. Alaska, however, supplied about 50 tons of stream tin in 1940.

Stannite is present in the veins at the Snowflake property near Revelstoke, British Columbia, and cassiterite and stannite have been noted at several other places in the province. The small cassiterite content of the silver-lead-zinc ore of the Sullivan mine at Kimberley is now being recovered, and is the source of Canada's recently developed tin production. Cassiterite occurs also in many other places in Canada, but no commercial deposits have yet been found. Occurrences in the Rush Lake area of southeastern Manitoba have been under recent investigation. In the unglaciated parts of Yukon, stream tin associated with tungsten ores has been found in small quantity, but no serious attempt seems to have been made to thoroughly test the gravels for tin.

If commercial tin deposits do occur in Canada, the lode deposits will be found in the Cordilleran region, the Canadian Shield, or in the Maritime Provinces, and will be in granites or closely allied intrusives or in adjacent rocks. Commercial stream tin may occur in Yukon and in British Columbia, the occurrences in the Yukon-Tanana (Alaska) region, with those on the Yukon River and on the Finlay River in British Columbia, suggesting the possibility of a tin-bearing belt extending from Central Alaska through the Yukon into the northern interior of British Columbia.

Identification

Cassiterite

Hardness—6 to 7.
Specific gravity—7.
Streak—White, greyish, brownish.
Lustre—Diamond-like.

Colour—Sometimes white, or colourless, more often black or brown. Red and yellow varieties also occur. In powdered form, it is usually pale brown.

Other properties—Occurs with prismatic crystal forms as granular masses and disseminated grains; occasionally fibrous, with structure resembling wood; insoluble in acid; when treated with a few drops of hydrochloric acid on a zinc plate, small fragments of cassiterite will, within a few minutes, become coated with a film of metallic tin which in turn will become bright on being rubbed.

Stannite

Hardness—4.
Lustre—Metallic.
Specific gravity—4·3 to 4·5.
Streak—Blackish.

Colour—Steel-grey to iron-black; sometimes a bluish tarnish; often yellowish from the presence of chalcopyrite.

Other properties—Opaque; massive, granular, and disseminated.

Marketable Grades and Specifications

The impurities generally present in tin ores are copper, arsenic, antimony, lead, iron, bismuth, and traces of sulphur and silver; tungsten, manganese, and stannic oxide are sometimes also found. The tendency of the impurities is to increase the hardness and to diminish the malleability of the metal. As a rule, tin ore occurring in veins yields a less pure metal than does placer tin.

Because of changing conditions and the wide range in the market value of the metal, no definite statement can be made as to what constitutes payable ore. Under wartime conditions, however, provided the deposit is reasonably large, it is worthy of attention, even though the grade of the material is lower than would ordinarily be regarded as suitable for commercial development. Most tin ores are too low in grade to be treated directly and accordingly must be concentrated. As a rule, also, they contain impurities which must be removed as far as possible before they can be smelted. The ore is prepared partly by hand-picking, but chiefly by gravity methods of concentration, in which advantage is taken of the high specific gravity of cassiterite.

Concentrates are in most cases purchased on a 60 per cent tin basis and for each unit or fraction above or below 60 per cent the returning charge is reduced or increased. They are subject to penalties if they contain more than 1 per cent sulphur and 5 per cent iron. Impurities such as lead, copper, arsenic, antimony, and bismuth are not penalized, but an increased charge is made to cover the costs arising from the treatment of such ores.

Buyers

The only sizable tin smelter on the North American Continent is at Texas City, Texas. Though recently built to treat Bolivian tin concentrates, it is possible that the smelter will accept concentrates from other sources. The Consolidated Mining and Smelting Company of Canada, Limited would also be prepared to treat tin concentrates at its new smelter at Kimberley, British Columbia, to the limit of its relatively small capacity.

If available in sufficient quantities, the British enterprises listed below would likely be interested in the purchase of tin concentrates produced in Canada. In any event, under present conditions, little difficulty would be experienced in the disposal of concentrates.

Victor G. Stevens, Limited, Felling-on-Tyne, England.

Capper Pass and Son, Limited, Bedminster Smelting Works, Bristol, England.

Philipp and Leon, 28 Finsbury Square, London, E.C. 2.

Metal Traders, Limited, 7 Gracechurch Street, London, E.C. 3.

Henry Gardner and Company, Limited, 2 Metal Exchange Building, London.

Anglo Metal Company, Limited, 2 Crosby Square, London, E.C. 3.

The Metals Controller, Ottawa, is the only buyer of refined tin in Canada for domestic distribution.

Prices

Under normal conditions the prices of best quality refined tin fluctuate fairly widely. The price at which tin can now be sold in Canada is fixed at $63\frac{1}{2}$ cents per pound at Toronto for metal of 99·8 per cent purity in lots of 10,000 pounds, and at $62\frac{3}{4}$ cents per pound for tin of purities ranging from 99·0 to 99·7 per cent inclusive.

World Production

Of the world output of tin in 1940, estimated at 259,500 tons, the Malay States were the source of 37 per cent, and the chief contributors to the remainder were Netherlands Indies, Bolivia, Thailand, Nigeria, Belgian Congo, China, Burma, and Australia, in that order.

Canada's Position

The amount of tin produced near Trail, British Columbia, and the small domestic recovery of secondary tin fall far short of meeting the Canadian requirements of the metal, which in peace time amounted to about 2,700 tons a year. For the greater part they were obtained from smelters in the Straits Settlements. The Allied tin position became critical with the enemy capture of these smelters and of the Malayan tin mines, resulting in increasingly rigid curtailment of consumption for civilian use. The search for commercial deposits in Canada has, therefore, acquired new importance.

TUNGSTEN

Tungsten is used, for by far the most part, in certain types of steel and in cemented carbides for the manufacture of dies and metal-cutting tools. The commoner high-speed tool steels which are so essential for turning out the instruments of war contain up to 18 per cent of tungsten. The present limited supplies of tungsten, however, have made it necessary to use molybdenum in part as substitute.

Occurrence and Formation

The two principal tungsten ores are wolframite and scheelite, the former an iron-manganese tungstate (Fe, Mn, WO_4), the latter, calcium tungstate ($CaWO_4$).

Wolframite

Wolframite and the closely related minerals ferberite and hubnerite are not common in Canada, occurring, so far as is at present known, in only about half a dozen isolated localities from New Brunswick to Yukon and the Northwest Territories. They are found in pegmatites and in veins associated with siliceous igneous rocks.

Scheelite

Scheelite is the tungsten mineral generally occurring in Canada. Found in almost all types of rocks and nearly always close to granite, it is principally associated in Eastern Canada with quartz veins, through which it is irregularly distributed as angular nodules, patches, or thin streaks, often being the only ore mineral present. In the important deposits found in British Columbia the scheelite occurs in alteration zones along the contacts of granite and impure limestone, and is often associated with massive garnetite and epidote, locally known as "skarn".

Recently it has been found in the ores of a number of producing gold mines throughout Canada. Quartz veins in gold regions should, therefore, be carefully examined for scheelite. Several deposits are known in which scheelite occurs in quartz veins associated with iron, copper, lead, zinc, and occasionally tin minerals. White scheelite, which closely resembles barite (heavy spar), has been found in several localities in Canada.

Identification

Wolframite

Wolframite, which contains when pure about 76 per cent tungsten trioxide (WO_3), occurs in crystals somewhat tabular in shape, or crystal aggregates. It has the following physical characteristics:

Hardness—5·0 to 5·5.
Specific gravity—7·0 to 7·5.
Colour—Dark brown to black.
Streak—Black to dark reddish-brown.
Lustre—Submetallic to metallic.
Tenacity—Brittle; cleavage perfect in one direction.

Minerals of the wolframite group are difficult to identify in the field because of their resemblance to many of the commoner heavy black minerals with bright lustre, but they are heavier and softer.

Wolframite fuses readily under the blowpipe to a bead which is magnetic.

Scheelite

Scheelite has a theoretical content of 80·6 per cent WO_3 and the following characteristics:

Hardness—4·5 to 5·0.
Specific gravity—6·0.
Colour—Yellow-brown, buff, grey or white.
Streak—White.
Lustre—Dull, greasy (as feldspar).
Tenacity—Brittle.

When scheelite occurs in quartz it can be identified in the field by its colour (usually buff), heavy weight, and its relative softness (it can be scratched with a knife). It powders fairly easily when struck with a hammer and the fractured particles have smooth, flat, glassy surfaces. Iron-stained white rocks, particularly quartz, might, under some circumstances, be mistaken for scheelite, but quartz will scratch glass while scheelite will not. In some regions, particularly in British Columbia, a brownish-buff ankerite carbonate might be mistaken for scheelite but is much softer, light in weight, and effervesces when ground and treated with hot hydrochloric acid. This also applies to the buff-coloured calcite that sometimes occurs in quartz. Massive, white scheelite closely resembles barite, which is also a heavy mineral.

If a portion of rock containing scheelite is pulverized and panned, the tungsten mineral, on account of its heavy weight, will appear as a whitish powder in the tails. Both scheelite and the wolframites occur in some placer-gold deposits of British Columbia and Yukon, and whenever heavy minerals (black as well as light-coloured), found in the tails of the pan or in the final clean-up of placer operations, are not recognized as the usual sulphides or magnetite arrangements should be made to have them identified.

When scheelite occurs in rocks other than quartz and the typical buff colour is not observable, the only method of identifying it in the field by physical means is with a special mercury-vapour violet lamp and purple filter, under which scheelite exhibits in the dark a brilliant blue-white fluorescence. Neither wolframite nor tungstite fluoresces. A yellowish fluorescence may indicate the presence of molybdenum, in the form of powellite (calcium molybdate), in a mixture with scheelite, but sometimes the scheelite is entirely absent, as in the case of most of the eastern Canadian molybdenite ores. Portable lamps* fitted with a dry battery are now being used by some mining companies and prospectors and have proved invaluable in searching for the mineral on the surface or underground.

If no lamp is available a small piece of the suspected mineral can be finely powdered and boiled in a test-tube with strong hydrochloric acid. After continued boiling, a yellow residue will appear at the bottom if scheelite is present. If a piece of zinc, aluminium, or tin is added (a piece of galvanized iron or of tin can will serve as a substitute), the solution turns blue and, later, brown. The yellow residue is soluble in ammonia.

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* *Particulars may be obtained by writing to the Bureau of Mines, Department of Mines and Resources, Ottawa, or to a Provincial Department of Mines. By Order in Council P.C. 997, passed on February 9, 1942, these ultra-violet ray lamps were exempt from customs duty, war exchange tax, and sales tax.*

A groove well sawed with the clean blade of an ordinary knife in a piece of clean scheelite which has first been moistened with a drop of hydrochloric acid turns to a grey-blue colour, which deepens on exposure but disappears in an hour or two.

Marketable Grades and Concentrates

In examining a promising prospect, consideration must be given to the question whether it is better to resort to selective mining, cob the tungsten mineral from the gangue and wall-rock, and ship it as high-grade ore, or to extract a mining width and mill the whole to a concentrate of shipping grade. The prospect should be examined if possible with an ultra-violet lamp, since much depends upon whether the scheelite occurs in finely disseminated form or as relatively coarse crystals. Samples should in any case be taken across a mining width of, say, 3 feet or across and along the vein. Scheelite powders very easily, and special attention must be taken to include all the fines in the sample, particularly when sampling horizontal surfaces. Bulk sampling is, however, much more reliable than chip or channel sampling. After experience, reasonably reliable estimates of grade may be made visually under the lamp by measuring the areas of scheelite on the rock face being graded ("Lamp sampling"). Attention should be paid to the actual width of the vein. On a small scale, concentration can be effected by cobbing and sorting from a vein of tungsten mineral as small as 1 inch thick or by crushing and sluicing as for gold in placer operations. Owing to its brittleness scheelite should be cobbed over a sheet or receptacle to catch the fines which might otherwise be lost.

The wolframite minerals must be converted into ferrotungsten before being added to steel, and for this purpose the concentrates must contain a minimum of 55 per cent WO_3. Scheelite, on the other hand, can be added direct if its content is not less than 70 per cent and it is practically free from harmful impurities, particularly lead, zinc, phosphorus, and arsenic, and if it contains less than 0·5 per cent sulphur.

Canada has, as yet, no plants for the manufacture of ferrotungsten or other tungsten addition-agents. The Canadian market can, therefore, absorb only high-grade scheelite concentrates containing not less than 70 per cent WO_3. Concentrates (flotation) containing as low as 10 per cent WO_3 can be treated chemically for a recovery of 90 per cent of contained tungsten in plants in the United States. Concentration of Canadian tungsten ores is thus a problem of producing a high-grade scheelite concentrate for sale and consumption in Canada, and other concentrates which, though unsuitable for Canadian use, can be marketed in the United States.

Generally, the coarse scheelite is recovered by gravity methods of jigging and tabling, and the finer scheelite by floating the table tails. Because of the heavy weight of the tungsten minerals this presents no difficulty provided the ores are free from metallic sulphides. If these are present they are floated off early in the circuit, and it may be necessary to employ magnetic roasting or leaching methods. Since the ore, especially scheelite, tends to slime, care must be taken in the grinding to avoid excessive loss from this tendency.

All complex ores should be tried out by preliminary concentration tests. As stated in the introduction to this pamphlet, arrangements can be made for the treatment of bulk samples in the laboratories of the Bureau of Mines at Ottawa, or at Val d'Or, Quebec, operated by the Quebec Department of Mines, and at Vancouver, British Columbia, operated by the British Columbia War Metals Research Board.

Buyers

Wolframite has no domestic market because ferro-tungsten is not yet being made in Canada, but if of the requisite grade it can be sold to the Metals Controller, Ottawa, for export to the United States.

The only Canadian consumer of high-grade scheelite concentrates is Atlas Steels, Limited, Welland, Ontario. Such concentrates are also bought by the Metals Controller.

Prices and Other Economic Considerations

Tungsten concentrates, which usually have to contain 60 per cent or more of WO_3, are quoted on the short-ton unit basis, i.e. at so much per 20 pounds of contained WO_3. The Canadian price of scheelite concentrate containing not less than 60 per cent WO_3 is at present (February, 1943) $26.50 per unit (equivalent to $1.32 per pound of WO_3), delivered at Welland. A ton of concentrate containing 70 per cent WO_3 would, therefore, bring $1,855 delivered. The United States price of imported wolframite concentrate (60 per cent WO_3) is about $24 per unit, delivered at New York, less a duty of $7.93 per unit.

In order to be commercial at present prices, a deposit situated where transportation and power facilities are reasonably good and from which a fair tonnage could be treated daily should average not less than 0·5 per cent WO_3. For small operations in areas not very accessible, the average grade should be at least 1 per cent WO_3, and if the scheelite blobs are free, not less than half an inch in size, and constitute about one-quarter of the vein matter, hand-cobbing should prove profitable.

World Production and Canada's Position

The world production of tungsten ore in 1939 was 35,000 tons of concentrates containing 60 per cent WO_3. China, Burma, United States, Portugal, and Bolivia, in that order, were the chief sources of supply, China being outstanding with its contribution of 12,000 tons. Owing to hostilities, however, Chinese exports in 1940 dropped below those from Burma. In that year the United States consumed about 12,000 tons of tungsten concentrates, less than half of which was produced from domestic sources. Canada produced a trifling amount only, but with the new developments of 1942 and with the bringing into production this year of the outstanding discovery at the Emerald mine in southern British Columbia the output will be very substantially increased by the end of 1943. Nevertheless, the expanding war demands for tungsten clearly call for every effort on the part of the prospector and miner to discover and produce this important strategic mineral.

VANADIUM

The principal use of vanadium is in the steel industry. It enables high-speed tool steels to better maintain their strength and hardness at high temperatures. Steels with vanadium and one or more other alloying elements are used mostly in springs and axles, crankshafts, pinion gears, and many other locomotive and automotive castings. In cast iron, vanadium tends to maintain a strong, tough structure.

It is used, but in much less quantity, as a catalyst and in the non-ferrous, glass, ceramic, and colour industries.

Occurrence and Formation

Vanadium is a widely distributed element, being found in small amounts in granites, sedimentary rocks and clays, as well as in many iron, lead, and copper ores, bitumens and petroleums. The chief ore minerals of vanadium are patronite, roscoelite, carnotite, and vanadinite. There are as yet no known occurrences of these minerals in Canada.

Vanadium is recovered as a by-product from other metal mining, from vanadates in the oxidized zones of some lead mines, and from vanadium ore in the western United States, Peru, and some other countries.

In the western United States the ores consist of carnotite, roscoelite, vanoxite and other less common vanadium minerals. They are replacement deposits along certain beds of Mesozoic sandstone and along brecciated zones in the same rocks. The ore is associated with gypsum and carbonized wood. In Peru a high-grade and very productive deposit of vanadium ore occurs as a lens along the bedding planes of Mesozoic shale. There, the ore is a complex sulphide called patronite associated with gypsum and greenish black masses of a hydrocarbon. The association with gypsum, carbonized wood, and hydrocarbons supports the generally held view that the ores were deposited from surface waters of the sulphate type and were aided in deposition by reaction with carbon or hydrocarbons in the sedimentary rocks.

The outlook for finding vanadium-bearing sediments or asphalts in Canada is not particularly promising, though the possibility of such occurrences should not be overlooked. Tests so far made of what appeared a most promising possibility, namely, the bituminous sands of Alberta, were disappointing, as also were those of the Upper Carboniferous sediments of New Brunswick and Nova Scotia, which held out promise because of their appreciable content of copper in various forms concentrated around carbonized wood or coaly matter.

A small exposure of a shallow bed, varying from 1 to 4 inches in depth, of very hard, black, vanadium-bearing rock lying between two lava flows of the Valdes group, probably Triassic, is known on the north end of Quadra Island, about 6 miles northeast of Vancouver Island. Samples of this rock averaged 2·16 per cent V_2O_5, too low to be of commercial grade except possibly in the case of large ore-bodies.

All titaniferous magnetite ores, of which there are several deposits in Canada, contain small amounts of vanadium. The recovery of the vanadium as a by-product is, however, a metallurgical problem which has not yet been solved commercially, except in ores in which the titanium oxide (TiO_2) content is less than 2·5 per cent.

As regards finding carnotite sandstones in Canada, so little is known of the origin of this mineral that no definite statement can be made one way or the other. Sandstones containing carbonized matter should be closely scrutinized, especially if showing evidence of any yellow stain or incrustation.

Identification

Patronite

Patronite is an impure vanadium sulphide of uncertain composition, with a content of from 19 to 25 per cent of vanadium. It occurs in non-crystalline masses associated with asphalt- and coke-like material. It has the following features:

Hardness—2·5.

Specific gravity—2·7 (= that of quartz).

Lustre—Metallic to dull.

Colour—Lead-grey to greenish black.

Note.—Coals, asphalts, and petroleums are known sometimes to contain vanadium, perhaps in the form of patronite. Ashes from these substances may run high in the metal.

Roscoelite

Roscoelite, or vanadium mica, is of doubtful composition, but is mainly a hydrous silicate of vanadium and aluminium, with about 29 per cent vanadic oxide (V_2O_5) when pure. It is found in minute scales or star- or fan-shaped groups of micaceous aggregates. The grains are sometimes so small that the ore looks like a shale, but the mineral usually impregnates a sandstone in which may occur petrified wood and a little carnotite. It has the following additional characteristics:

Hardness—2.

Specific gravity—2·92 to 2·94.

Colour—Green to brown.

Lustre—Dull to pearly or greyish.

Cleavage—Splits, like all micas, easily into thin plates.

Note.—Roscoelite might be confused with chlorite micas, but the latter are found only very rarely in sandstone.

Carnotite

Carnotite is a hydrated vanadate of uranium and potassium, with a content of from 3 to 5 per cent V_2O_5 in ordinary commercial ores. It occurs usually as a crystalline powder, sometimes as loosely cohering masses of minute scales. It has the following characteristics:

Hardness—Easily scratched with finger nail.

Specific gravity—4·1.

Lustre—Dull.

Colour—Canary yellow.

Note.—The colour is sometimes red or black owing to association with other vanadium minerals.

VANADINITE

Vanadinite is a chloro-vanadate of lead containing in the pure state 19·3 per cent V_2O_5 and 73·1 per cent lead. Zinc, lime, iron, and copper are sometimes present in amounts up to about 1 or 2 per cent. It occurs in prismatic, sharply formed, hexagonal crystals, sometimes hollow. A large crystal may be made up of numerous smaller parallel ones, the whole group tapering to a slender point. Other physical characteristics of vanadinite are:

Hardness—2·5 to 3.
Specific gravity—6·6 to 7·2.
Colour—Bright red, orange-red.
Lustre—Adamantine; resinous on fracture.
Streak—White to pale yellow.
Tenacity—Brittle.

Concentration and Specifications

Most vanadium ores are not readily amenable to concentration. From the patronite deposit in Peru, a shipping product of about 11 per cent V_2O_5 is sorted, the lower grade ore being crushed and burned to yield an ash containing about 22 per cent V_2O_5. High-grade concentrates have been obtained from the roscoelite in a gold ore in California during the concentration of the ore for gold.

Vanadinite is easily concentrated by the ordinary gravity methods, but if wulfenite is present separation is difficult because it has about the same specific gravity. In Spain, the vanadinite ore, which contained 4 to 5 per cent V_2O_5 as mined, used to be hand-picked and concentrated to a 12 per cent product.

As ferrovanadium is the form in which vanadium is introduced into iron or steel, the vanadium ores from which this alloy is made in the electric furnace must contain little copper, molybdenum, tungsten, chromium, sulphur, lead, zinc, arsenic, phosphorus, alumina, and silica. For this reason buyers often demand complete analyses of vanadium ores and concentrates. The vanadium content of the grades of ferrovanadium marketed ranges from 30 to 45 per cent.

Buyers

Vanadium oxide for conversion into ferrovanadium is bought by:

Electro Metallurgical Co. of Canada, Ltd., Welland, Ont.

The principal Canadian consumers of ferrovanadium in 1940 were:

Atlas Steels, Ltd., Welland, Ont.
Dominion Foundries and Steel, Ltd., Hamilton, Ont.
Steel Company of Canada, Ltd., Hamilton, Ont.

Chromium Mining and Smelting Corporation, Limited, Sault Ste. Marie, Ont., is interested in securing or leasing promising vanadium-mineral properties.

The leading Canadian chemical companies (see page 41) are possible buyers of V_2O_5.

Prices

The United States quotation, February, 1943, on vanadium ore, in ton lots, was 27½ cents per pound contained V_2O_5 f.o.b. shipping point.

World Production and Canada's Position

In 1940 world production of vanadium ores, in terms of vanadium content, was about 3,300 tons, nearly all from four countries, of which Peru and the United States were the chief.

In addition, a certain amount of vanadium was recovered during the refining of bauxite in Italy; from boiler and stack soot of ships and industrial plants burning certain fuel oils; and, in Germany, from the slag resulting in treating vanadium-bearing iron ores.

Canada is to-day dependent entirely upon imports.

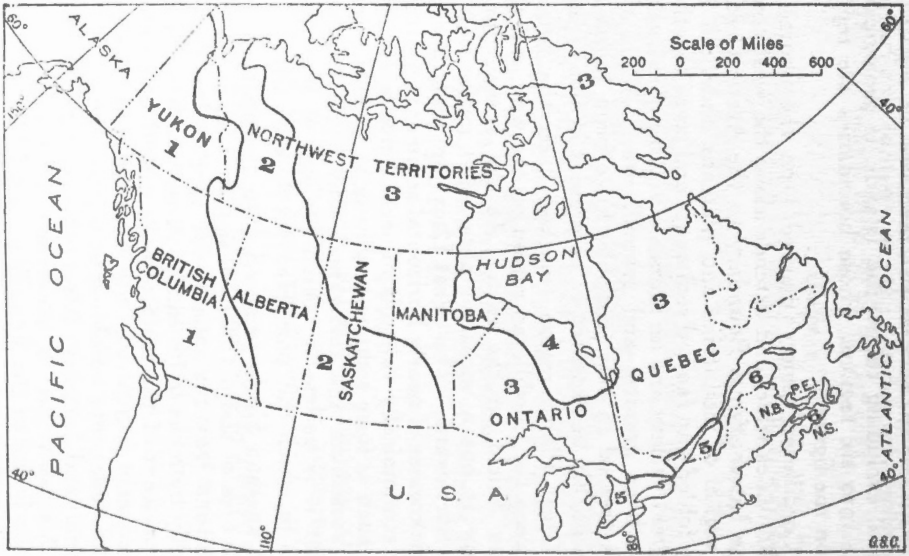
GEOLOGICAL REGIONS IN RELATION TO STRATEGIC MINERALS

Canada, excluding the Arctic Islands, is geologically divisible into six regions, whose boundaries are represented on the figure.

The Cordilleran region (marked 1 on the figure) is about 400 miles wide, and extends along the west coast from the International Boundary to the Arctic Ocean. It is a region of mountains and plateaus underlain by strongly folded and faulted sediments and lavas together with a great variety and an immense volume of intrusive rocks such as granites and granodiorites. All of the minerals treated in this pamphlet have been found or may reasonably be expected to be present in this region.

The Great Plains region (marked 2 on the figure) lies between the Cordilleran region on the west and the Canadian Shield on the east. At the International Boundary it has a width of about 800 miles, but it narrows northward. The Great Plains are underlain by great thicknesses of nearly horizontal sedimentary strata and the economically valuable mineral deposits are confined to such as form sedimentary beds or originate from them. Vanadium and manganese may occur in these rocks but it is useless to search for any of the other minerals to which this pamphlet directs attention.

The Canadian Shield (marked 3 on the figure) is an immense area of about 1,800,000 square miles extending north and east from the upper Great Lakes. It is underlain wholly by rocks of Precambrian age and between 80 and 90 per cent of the surface rocks consist of granites and allied acid intrusives; the remainder, of volcanic rocks and sediments. Folding and faulting have been widespread and intense. Most of the minerals with which this pamphlet is concerned have been found within the limits of the Canadian Shield but so far no important deposits of manganese and none of mercury or vanadium have been found.



FIGURE—Geological Divisions of Canada: 1, Cordilleran region; 2, Great Plains and northern extension; 3, Canadian Shield; 4, Hudson Bay Lowland; 5, St. Lawrence Lowland; 6, Appalachian region.

The St. Lawrence and Hudson Bay Lowlands (marked 5 and 4, respectively, on the figure) are underlain by nearly horizontal sedimentary beds. The economically valuable mineral deposits are confined to such as form sedimentary beds or originate from them. Vanadium, manganese, quartz crystals, and Iceland spar may occur in these rocks and fluorspar has been mined from veins at Madoc, Ontario, but it is useless to search for any of the other minerals to which this pamphlet directs attention.

The Appalachian region (marked 6 on the figure) includes most of Canada east of the St. Lawrence River. It is underlain by sedimentary and volcanic rocks in places invaded by granite or by bodies of basic rocks. Manganese deposits have been found in Nova Scotia and New Brunswick and on the Magdalen Islands. Chromite is associated with basic intrusives in the Eastern Townships and Gaspé Peninsula, Quebec. Tungsten-bearing minerals occur in New Brunswick and Nova Scotia.

MINERAL SPECIMENS AVAILABLE AND PRICES

Specimens of a number of Canadian minerals and rocks can be purchased at 5, 10, and 15 cents each, according to size and quality, from the Bureau of Geology and Topography, Department of Mines and Resources. Sets of mineral chips and sets of rock chips, each set consisting of about 35 specimens and costing 50 cents, are also available for the prospector's use.

Of the strategic minerals dealt with in this pamphlet, specimens, about 1 inch square, of the following are on hand in limited supply at prices somewhat higher than those named above because they have mostly to be imported:

		Cents
Beryllium Minerals	Beryl	25
Chromium "	Chromite	05
Columbium "	Columbite	25
Manganese "	Manganese Ore (hard)	10
	Bog Manganese	10
Mercury "	Cinnabar	25
Molybdenum "	Molybdenite	15
Tantalum "	Tantalite	30
Tin "	Cassiterite	30
	Stannite	30
Tungsten "	Scheelite	30
	Ferberite	30
Vanadium "	Carnotite	15
	Patronite	15
	Roscoelite	15
Fluorspar	Fluorite	05
Mica	Muscovite	05
	Phlogopite	05

An order for specimens should be addressed to the above-mentioned Bureau and must be accompanied with payment in full by money order or certified cheque made out to the Receiver General of Canada.

OTTAWA
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PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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