ANHYDRITE IN CANADA

OCCURRENCE, PROPERTIES, AND UTILIZATION

L. HEBER COLE AND R. A. ROGERS

MINES BRANCH
DEPARTMENT OF MINES
OTTAWA
1933
NO. 732

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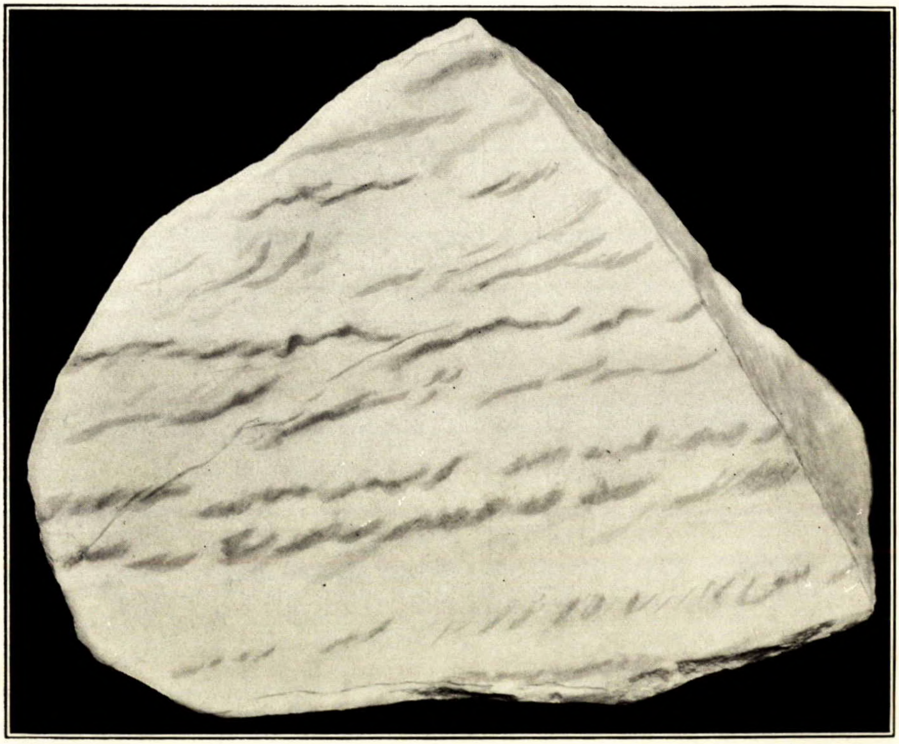

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Banded anhydrite from Wilson brook, Albert county, New Brunswick.

CANADA
DEPARTMENT OF MINES
Hon. W. A. Gordon, Minister; Charles Camsell, Deputy Minister

MINES BRANCH
John McLeish, Director

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INTRODUCTORY

Canada possesses large deposits of anhydrite, the anhydrous calcium sulphate, the larger occurrences so far known being in the provinces of Nova Scotia, New Brunswick, Ontario, Manitoba, Alberta, and British Columbia. The deposits, as a rule, occur associated with gypsum, salt, and limestone.

Heretofore, this anhydrite has been of little commercial value, in fact, occurring as it does so intimately associated with gypsum, it has been regarded as a serious adulterant to the latter material, since anhydrite in gypsum lowers the grade of plaster that can be made.

In consequence, at nearly all Canadian gypsum quarries, notably in Nova Scotia and New Brunswick, the anhydrite when encountered has been sorted out by hand, with the result that large dumps of anhydrite or a mixture of anhydrite and gypsum have accumulated. This sorting has naturally increased the cost of the recovery of the gypsum, so that any utilization of a material, now almost a waste product, would not only materially benefit the gypsum industry, but would tend to establish other industries.

Many attempts have been made to utilize anhydrite in some way but, until recently, with little success. Recent researches on anhydrite, however, have produced such encouraging results that the mineral promises to become of considerable industrial importance. The successful development of further uses for anhydrite is, naturally, of great importance to Canada with its large reserves of such material at present practically undeveloped.

At present, over 40,000 tons of anhydrite are shipped from Nova Scotia each year to the southern areas of the United States which border on the Atlantic seaboard, where it is ground and used as a fertilizer principally for the peanut crops. In England and continental Europe considerable tonnages of anhydrite are used in the manufacture of ammonium sulphate for fertilizer purposes and in the manufacture of cement and sulphuric acid. Recent investigations in the United States and elsewhere have demonstrated that it is possible to use as much as 50 per cent of anhydrite with gypsum as a retarder for Portland cement.

Recently, however, the greatest interest has centred in the use of anhydrite for commercial plasters, and many patents covering this use have been filed in Canada, the United States, and Europe. The pioneer work in Canada has been carried on by A. E. Flynn, professor of mining engineering at the Nova Scotia Technical College, Halifax, N.S., and his report, "Anhydrite Plasters and Cements," published by the Department of Public Works and Mines, Halifax, N.S., shows that plasters made from anhydrite, with the addition of varying small proportions of certain chemical salts as "catalysers" would "set," and in a number of cases develop a tensile strength comparable to many gypsum plasters now on the market.

The present report is published in order to give some idea of Canada's resources of anhydrite, to collect in one volume all the references and data on this mineral at present scattered through the many publications of the Mines Branch and the Geological Survey, to summarize briefly the present known uses, and to give the results obtained in the Mines Branch laboratories of an extensive series of tests made on a number of Canadian anhydrites with regard to their suitability for plaster manufacture. While the work already done is by no means complete, it is thought that the publication of results so far achieved will stimulate an increasing interest in the subject that will lead to further intensive research along this line.

ACKNOWLEDGMENTS

The field work on the several deposits of anhydrite in Canada was carried out by L. H. Cole, during the course of his investigation of the gypsum industry of Canada, while the laboratory tests on the samples collected were under the direction of R. A. Rogers. The thanks of the authors are extended to the managers of the several gypsum companies, who, by their kindness in granting permission to visit and sample their properties, have been of the greatest assistance. The report by Professor A. E. Flynn, previously mentioned, has been consulted freely and his helpful suggestions have been greatly appreciated. The courtesy of Mr. Victor Lefebure of London, England, in furnishing an advance copy of the results of his experiments on similar lines in England is gratefully acknowledged.

Acknowledgment is also made to Dr. J. H. Ross in charge of Pulp and Paper Division, Forest Products Laboratories of Canada, Montreal, for his courtesy in making tests on a sample of anhydrite submitted to him as to its suitability for use as a paper filler, and the report on such tests by G. D. O. Jones, Laboratory Assistant, and H. Chalk, McGill summer student, made under Dr. Ross' direction, is embodied in Chapter IV.

CHAPTER I

MINERALOGY, CHEMICAL AND PHYSICAL CHARACTERISTICS, AND ORIGIN

Anhydrite, the anhydrous calcium sulphate, is represented by the chemical formula $CaSO_4$.

This may be represented as follows:

$$\text{Anhydrite } (CaSO_4) = \begin{cases} \text{Sulphur trioxide } (SO_3) = 58 \cdot 8 \text{ per cent.} \\ \text{Lime } (CaO) = 41 \cdot 2 \text{ per cent.} \end{cases}$$

Anhydrite was first discovered in 1794 by Abbé Poda and was called muriacite under the impression that the substance was a chloride (muriate). The name anhydrite was given by A. G. Werner in 1804[1] because of the absence of water as contrasted with the presence of water in gypsum. Another name for the species is *karstenite*. A peculiar variety occurring as contorted concretionary masses, is known as tripestone, and a scaly granular variety from Vulpino, near Bergamo, in Lombardy, Italy, as vulpinite; the latter is cut and polished for ornamental purposes.

Anhydrite differs chemically from the more commonly known mineral gypsum, in containing no water of crystallization. It crystallizes in the orthorhombic system, and has three directions of almost perfect cleavage, parallel to the three planes of symmetry.

Well-developed crystals are somewhat rare, the mineral usually occurring in the massive form. The colour is usually white or bluish-white, sometimes greyish, bluish, or reddish. Its lustre is pearly on the best developed of its cleavage faces, while on the other surfaces it is of the ordinary vitreous type. When found in crystal form it is sometimes brown, blue, or brick red.

The streak is greyish white, and it has a hardness of 3 to 3·5 with a specific gravity of 2·7 to 3. The melting point is 3 on the scale of fusibility. The mineral is brittle with a conchoidal fracture, and its index of refraction is 1·571 to 1·614.

Anhydrite usually occurs in the massive form commonly associated with limestone and gypsum, and because of its general similarity to either of these two minerals it is somewhat difficult to recognize at sight in the field, in consequence of which it may have been frequently overlooked. While the similarity between anhydrite and gypsum is quite marked in a general way and they may easily be confused by careless observers, the two minerals have markedly different properties which enable them to be readily distinguished both in the field and under the microscope by anyone familiar with their characteristics. Anhydrite and gypsum also occur intimately mixed, either as a fine intergrowth of the two minerals that will require the microscope or chemical analysis to show its complex character, or as masses of anhydrite surrounded by gypsum, and as

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[1] Encyclopædia Britannica, Eleventh Edition, vol. 2 p. 47.

such may frequently be classed as all gypsum. "Hard" gypsum is well known to the gypsum miners but few of them recognize this harder denser compound by its true mineral name of anhydrite.

The following tabulation, after Rogers,[1] gives a number of tests by which anhydrite and gypsum may be distinguished:—

Anhydrite, $CaSO_4$	*Gypsum,* $CaSO_4 \cdot 2H_2O$
Orthorhombic	Monoclinic.
Cleavage, pseudo-cubic	Cleavage, perfect in one direction.
Specific gravity about 2·9	Specific gravity about 2·3.
Hardness, 3 to 3·5	Hardness, 1½ to 2·5.
Fragments are square or rectangular with parallel extinction.	Fragments are platy with oblique extinction, or have aggregate polarization.
High relief in clove oil or balsam ($n\lambda$=1·614; $n\lambda$=1·571	Low relief in clove oil or balsam. ($n\lambda$=1·529; $n\lambda$=1·520).
Double refraction, rather strong; max. value 0·043	Double refraction, rather weak; max. value 0·009.
Soluble with difficulty in dilute HCl	Easily soluble in dilute HCl.
Little or no water in closed tube	Abundant water (20·9 per cent in closed tube).

For preliminary tests the specific gravity test is probably better than the hardness test, since although the hardness of gypsum in the pure state is normally 2, compact varieties frequently run higher than this and often cannot be scratched by the finger nail.

When the two are found closely associated the optical properties are the best means of identifying the one from the other. By means of a method depending on the differing refractive indices of anhydrite and gypsum, these two minerals can readily be distinguished under the microscope, and these optical tests can be made as readily on crushed fragments as in thin sections.

In a saturated solution of sodium chloride at a temperature of 30° C. (86°F.) calcium sulphate deposits in the form of anhydrite. With sea water this deposition, according to Van't Hoff's experiments, takes place at 25°C. and since a temperature of 25°C. would more than likely be reached in surface waters during seasons of rapid evaporation (i.e. arid climates) it is altogether probable that much of the calcium sulphate occurring in nature was originally precipitated in the form of anhydrite.

Anhydrite is soluble to a certain extent in water, the rate of solubility increasing rapidly the finer the material is ground. Unlike calcined gypsum, anhydrite when ground to the fineness of ordinary gypsum plaster shows little or no setting properties. If, however, the material is very finely ground (325 mesh and finer) a certain set does take place and in one test the writers obtained a tensile strength of 342 pounds per square inch.

Anhydrite, as found in nature, is rarely, if ever, free from small amounts of impurities such as gypsum, limestone, etc., and it is therefore necessary, in working out any process for the use of anhydrite, to know beforehand the exact nature of any deposit, since slight differences in the percentages of impurities present appreciably affect the results. In this

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[1] Notes on the Occurrence of Anhydrite in the United States by Austin F. Rogers, Columbia School of Mines Quarterly, vol. XXXVI, 1915, p. 125.

connexion it should be thoroughly understood that the samples used in making the tests referred to in this report were in nearly all cases taken from the surface of the deposits examined, and for this reason probably contain higher percentages of impurities, especially of gypsum, than would normally be encountered in the main body of the deposit. Such tests, therefore, would naturally be most severe, and it can be expected that as a deposit is opened up beyond the area of surface hydration that the anhydrite content of the rock would tend to increase greatly.

EARLY HISTORY

The association of anhydrite with gypsum has been recognized in Canada for a good many years. The occurrence of gypsum in the Maritimes has been known from the time of the earliest settlers and records are available that show that such deposits were worked as early as 1770. That anhydrite was recognized even by these early operators is evident by a careful examination of some of the old dumps from these ancient workings. While most of the material on the surface is impure gypsum, the rock, a few feet under the surface, shows a large proportion of anhydrite, showing that the quarrymen of that day, while probably not recognizing the anhydrite under its proper name, at least made a crude differentiation between 'hard rock' (anhydrite) and 'soft rock' (gypsum). In fact, the names 'hard rock,' 'bull rock,' 'hard plaster,' 'sharkstone,' etc., are common terms used to denote anhydrite even by the quarrymen in the Maritimes at the present time.

The earlier writers on the mineralogy of Nova Scotia mention the presence of anhydrite associated with gypsum. How[1] in 1868 mentions the occurrence of anhydrite at a number of localities in Hants county, N.S., and the mineral had probably been recognized at even an earlier date.

Logan[2] in 1863 stated that anhydrite was not yet known to occur in 'Canada', referring in this case to Upper and Lower Canada which did not then include the Maritimes.

Dr. T. Sterry Hunt[3] probably records the first known occurrence of anhydrite in Ontario when he mentions the presence of anhydrite in a bore hole put down by Mr. Attrell in 1876 at Goderich where anhydrite was encountered below 1,170 feet in depth.

Since that time anhydrite has been recognized in a large number of localities throughout the Maritimes, in many drill holes in southwestern Ontario, in Manitoba at Gypsumville and Amaranth, in Alberta at McMurray, and in a number of deposits in British Columbia. Many of these occurrences are of large extent so that it may safely be said that commercial deposits of anhydrite are available at many localities in Canada from the Atlantic to the Pacific.

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[1] Mineralogy of Nova Scotia, 1868, by Henry How, D.C.L. Published by Chas. Annand, 11 Prince St., Halifax, N.S., 1869, p. 138.

[2] Sir Wm. Logan. "Geology of Canada, 1863," p. 460. Published by the Geological Survey of Canada.

[3] Geol. Surv., Canada, Rept. of Prog. 1876-77, p. 231.

ORIGIN OF GYPSUM-ANHYDRITE DEPOSITS IN CANADA

The source of these extensive deposits of anhydrite scattered throughout the country is still in many cases a debatable question and numerous theories have been advanced for their origin.

Bell[1] in summing up the several theories so far advanced for the origin of gypsum and anhydrite classifies the existing deposits of calcium sulphate (either gypsum or anhydrite) as follows:

Class (A) Due to the evaporation of sea water.

- Subclass (*a*) In marginal salt pans—shallow depressions along a sea margin into which the sea water finds intermittent entry by overwash at high tide, during storms, or during seasonal inshore winds.
- Subclass (*b*) In marginal salinas. A salina is a marginal depression at or near a seashore, superficially cut off from the sea by a bar or other barrier that is nevertheless pervious in whole or in part to the sea water.
- Subclass (*c*) In sea lagoons. Lagoons differ from salt pans in greater depth, and connexion with the open sea is not rapidly intermittent but is continuous over or through a bar or barrier for long intervals of time.
- Subclass (*d*) In relict seas—inland depressions with sea water completely severed from the parent body. (Partake of qualities of both (A) and (B).)
- Subclass (*e*) Accumulation of cyclic salts, i.e. of salts carried inland from the sea by winds. (Partake of qualities of both (A) and (B).)

Class (B) Continental concentrations of disseminated gypsum.

- Subclass (*a*) In inland lakes.
- Subclass (*b*) In river valleys.
- Subclass (*c*) As surface efflorescences.
- Subclass (*d*) In spring deposits.
- Subclass (*e*) As dunes or wind-blown deposits.

Class (C) Vein deposits.

Class (D) Products of alteration or replacement.

In discussing this classification with respect to the deposits of Nova Scotia, especially those in the Windsor district, Bell gives a number of reasons why it is improbable that such deposits were formed by the action of sulphuric acid on limestone (Class D), as put forward by Sir William Dawson[2], and rather favours the theory that their origin is due to the evaporation of sea water from the ancient Windsor sea (Class A) but

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[1] Bell, W. A.: Horton-Windsor District, Nova Scotia, Mem. 155, Geol. Surv., Canada, 1929, pp. 81-88.

[2] Dawson, J. W. Acad. Geol., 3rd Edition, pp. 262-394.

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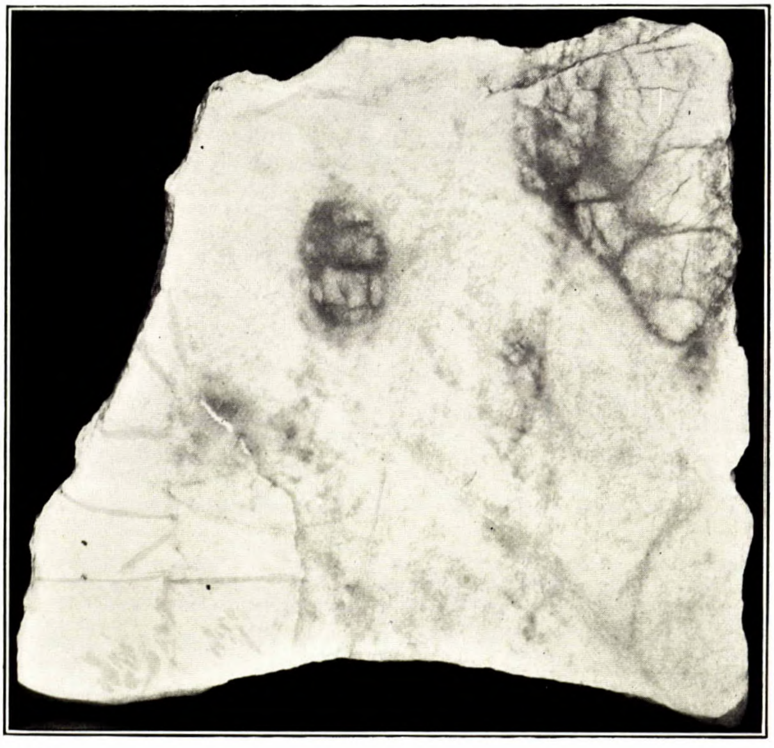
A. Anhydrite-gypsum block from quarries of Albert Manufacturing Company, Hillsborough, N.B., showing alteration of anhydrite to gypsum. **A,** anhydrite; **Tr.,** altered anhydrite; **G,** gypsum.



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B. Anhydrite-gypsum block from quarries of Albert Manufacturing Company, Hillsborough, N.B., showing alteration of anhydrite to gypsum in various stages of completion. **A,** anhydrite; **G,** gypsum.

that each deposit must be evaluated on its own merits as to the probable subclass under which it can be classified since it is probable that more than one type of saline basin existed.

One point Bell brings out is the necessity of calcium carbonate within the sulphate beds in amounts (0·5 per cent +) sufficient to fulfil the requirements of equilibrium, but how the Windsor deposits meet this test could not be stated owing to the absence of sufficient complete analyses. In the analyses of the anhydrite samples from Nova Scotia given elsewhere in this report, the content of calcium carbonate ranges from 0·64 to 4·05 per cent so that his argument is further strengthened by reason of these more recent results.

The question naturally arises as to whether the calcium sulphate deposits of the Maritimes were laid down originally as anhydrite or as gypsum, and while nothing has, as yet, been definitely proved, many indications are present in the deposits which tend to favour the theory that probably the greater part of the original deposition was in the form of anhydrite and that the large masses of gypsum present were subsequently formed by the hydration of the anhydrite in part by circulating meteoric waters. A number of these reasons may be briefly enumerated as follows:

1. The concentration of the sea water with respect to sodium chloride was in all probability sufficiently high and the temperature of the water favourable for the deposition of the calcium sulphate as anhydrite rather than gypsum.

2. The increasing prevalence of anhydrite in many quarries as they are opened up to depth.

3. The almost universal encountering of anhydrite below a certain depth in the many drill holes put down in the Maritimes in which calcium sulphate was present.

4. The many evidences in the rock excavated in the quarries of samples where anhydrite is partly altered to gypsum. (See Plate II A and B, also Plate III A.)

5. Where anhydrite lenses occur as irregular masses in the gypsum, the evidence indicates that these masses are remnants of the original anhydrite which have not been completely hydrated to gypsum.

6. The minute crystals of anhydrite in the salt crystal mass at the Malagash salt mine indicate that at the time of salt deposition the salinity of the sea and the temperature were favourable for anhydrite deposition.

If the evidence given above has not been misinterpreted it is of the greatest importance, since it tends to show that the presence of gypsum is more or less an incidental development, closely confined to surface deposits, and that anhydrite is the more common and stable compound. It follows naturally, therefore, if such proves to be the case, that we can look for a gradual depletion of our gypsum deposits, sooner probably than may now be anticipated, with the proving up of more and more areas of anhydrite. If, therefore, new and increasing uses for anhydrite can be developed it will be of the greatest benefit not only to the present gypsum operators, inasmuch as it will enable them to market a material which at present they are compelled to quarry practically at a dead loss, but will also develop new products which to a great extent will be complementary to the products that are now produced from gypsum.

With respect to the origin of the gypsum-anhydrite deposits of southwestern Ontario, Dyer[1] in summing up his conclusions after a study of these deposits says:—

> The salt (sodium chloride) deposits of southwestern Ontario are very probably the result of the concentration of disseminated connate sodium chloride into a central desert basin with inward drainage, while the calcium sulphate apparently represents the less soluble connate material, which remained behind after the sodium chloride had been leached out. Some leaching of the calcium sulphate evidently took place also, the material being partially concentrated around the salt basin.
>
> The greater part of the calcium sulphate was deposited in the first instance as the anhydrous variety, but towards the surface it was changed to gypsum by circulating meteoric waters.

These conclusions would, therefore, place the Ontario deposits in Class (B) as given by Bell with some of the qualities of both (A) and (B).

In the opinion of Wallace[2] the anhydrite in the Upper Silurian of Manitoba is primary, and the order gypsum-anhydrite-gypsum represents the mineralogical sequence of deposition in Upper Silurian times. In other words Wallace considered that both anhydrite and gypsum were deposited as such in the Gypsumville area in Manitoba, but that probably some of the top beds of anhydrite have since been altered to gypsum by hydration.

More recent work by Brownell[3] on the Amaranth deposit, which has been discovered since Wallace studied the Gypsumville area, leads one to surmise that even in the Gypsumville area the calcium sulphate was originally all deposited in the anhydrous form, with subsequent hydration to gypsum by the action of ground water both from the top and bottom of the beds.

Brownell assumes that the Amaranth calcium sulphate deposit was originally a deposit of anhydrite formed by the evaporation of sea water in some enclosed basin and that climatic conditions were such that the temperature during deposition was above 25° Centigrade; that the erosion of overlying strata during glaciation had brought the anhydrite beds to the surface and that the gypsum had been formed by the alteration of the anhydrite since glacial times, by the action of ground water proceeding upwards from the bottom of the bed as well as downwards from the top.

The origin of the calcium sulphate deposits at Falkland, B.C., is more obscure and sufficient time has not as yet been spent on these deposits to study in detail their mode of occurrence. From the brief examinations so far made in this area there are indications which suggest that they may possibly have been formed by the alteration of lens-shaped masses of lime-

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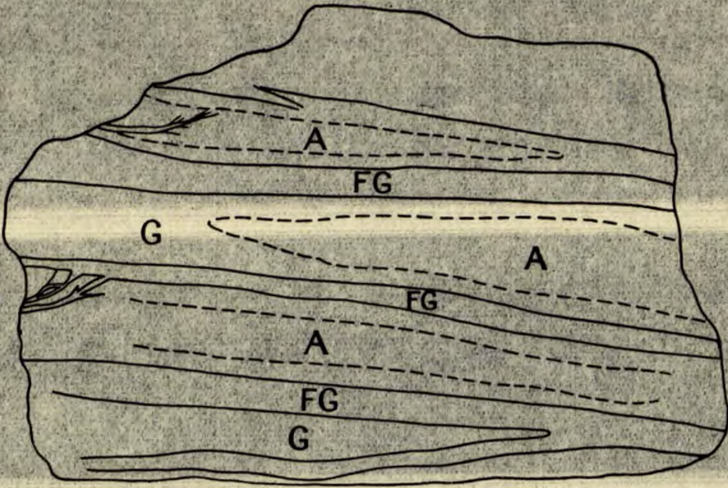
[1] Geology of the Gypsum Deposits of Southwestern Ontario, by W. S. Dyer, Ontario Dept. of Mines Report, vol. XXXIV, pt. 2, p. 58.

[2] Gypsum and Anhydrite in Genetic Relationship, by R. C. Wallace. Geol. Mag., N.S. Decade VI, vol. I, pp. 271-6, June, 1914.

[3] The Amaranth Gypsum Deposit, by G. M. Brownell. Trans. Can. Inst. of Mining and Metallurgy, 1931.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A. Anhydrite-gypsum block from quarries of Albert Manufacturing Company, Hillsborough, N.B., showing anhydrite fractured and cut by veins of satin spar (fibrous gypsum) leaving original, unaltered or partly altered anhydrite as a core between the veins. **A,** anhydrite; **FG,** fibrous gypsum; **G,** gypsum.

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B. Massive, blue translucent anhydrite from Plasterco, Va., U.S.A., containing included crystals of selenite (crystalline gypsum). Similar material may be found in a number of Canadian deposits as well as masses of gypsum enclosing selenite crystals in a like manner. **S,** selenite; **A,** anhydrite.

stone similar to those that so frequently occur in the "volcanic" belt over wide and extended areas in other parts of the district to the southeast of Falkland.

Summing up this information on the Canadian calcium sulphate deposits it appears probable that they were (with the possible exception of the deposits at Falkland, B.C., as well as some other British Columbia occurrences) formed by evaporation of sea water in some enclosed basins or partly enclosed basins; that climatic and other conditions at the time of deposition were such as to be favourable in most cases to the deposition of the calcium sulphate in the anhydrous form; that hydration of portions of the anhydrite beds to gypsum has taken place since deposition.

CHAPTER II

OCCURRENCES OF ANHYDRITE IN CANADA

INTRODUCTION

Anhydrite is widely distributed, associated with deposits of gypsum, in the provinces of Nova Scotia, New Brunswick, Ontario, Manitoba, Alberta, and British Columbia. Many of these deposits are of sufficient size and so situated with respect to transportation and industrial centres that they can be economically operated when sufficient markets are developed for the material.

Gypsum deposits in Canada, especially those in the Maritime Provinces, have been known for many years, and although anhydrite was recognized at an early date as occurring with the gypsum, it is only within recent years that the vast extent of anhydrite has been fully realized. In fact, it is becoming increasingly apparent, as each year the gypsum quarries are further developed, that anhydrite is a great deal more prevalent than was at first supposed, and deposits, which at one time were opened up in clean gypsum and which were considered to be gypsum throughout, are frequently encountering anhydrite the more they are developed to depth.

This fact is of considerable importance since, although Canada has many deposits of good gypsum as yet unexploited, which together with the present known reserves in the deposits being operated, will last for a good many years, it indicates the possibility that, in time, such deposits may become depleted due to change to anhydrite at depth.

It is therefore extremely important at the present time to summarize briefly our present knowledge of anhydrite occurrences in Canada in order to gain a true picture of the situation. It is obviously impossible to give a detailed description of each individual occurrence and only a few of the more important representative localities will be described.

In the following descriptions those deposits from which samples were taken are indicated under sample numbers by which the samples are referred to in Chapter IV, in the section on Laboratory Tests.

NOVA SCOTIA

Many of the anhydrite deposits of Nova Scotia occur closely associated with deposits of gypsum. In addition to the deposits directly asssociated with gypsum extensive cliffs of anhydrite, fairly free from gypsum, are exposed in many localities and from these large tonnages could be obtained.

Victoria County

Aspy Bay. A gypsiferous area, some 8 square miles in extent, occurs on the east shore of Cape Breton at Aspy bay. Two rivers cut through the gypsum beds at this point exposing cliffs from 40 to 60 feet high. Occasional patches of anhydrite are exposed, but in a series of drill holes put down anhydrite was encountered in nearly all of the holes at a depth around 70 feet. According to Jennison[1] this deposit shows some little

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[1] Gypsum Deposits of the Maritime Provinces by W. F. Jennison, p. 43. Mines Branch Report No. 84 (1911).

anhydrite which carries petroleum in small (pea size) cells at the base of the exposure. The following is an analysis of the anhydrite showing cells of crude petroleum:—

	Per cent
Lime (CaO)	41.30
Sulphur trioxide (SO_3)	57.91
Water, loss on ignition	0.82
Insoluble mineral matter	0.07
Bitumen	0.08
	100.18

It is probable, therefore, that at such time as this deposit is worked for gypsum, appreciable tonnages of anhydrite will be developed.

A channel through the bar at the mouth of the harbour would have to be dredged in order to give access to North pond at Dingwall. The pond has sufficient depth for shipping purposes.

Ingonish. On the north side of Ingonish harbour a gypsiferous area about 3,000 acres underlain with anhydrite occurs. This deposit was operated successfully for a number of years by the Ingonish Gypsum Company, a subsidiary of the Canada Cement Company, for the recovery of gypsum for use as a retarder in the manufacture of Portland cement. Open-cut methods were employed and the quarry was worked to a depth of 35 feet with a width of over 100 feet and a length of 600 feet or more. Considerable anhydrite was encountered in the lower workings and the floor of the quarry in many places showed anhydrite, so that it is probable that an extensive tonnage of this material could be obtained from this locality. Water transportation is available at this deposit.

St. Ann. At Goose cove, St. Ann harbour, the Victoria Gypsum Mining and Manufacturing Company, Ltd. operated extensive quarries for gypsum for a number of years but active quarrying was suspended in 1916. While sinking on the floor of the first quarry anhydrite was discovered in considerable quantities. Jennison[1] gives the analysis of this anhydrite as follows:—

	Per cent
Lime (CaO)	42.80
Ferric oxide and alumina (Fe_2O_3 and Al_2O_3)	tr.
Sulphur trioxide (SO_3)	56.16
Water, loss on ignition	0.73
Insoluble mineral matter	0.80
	100.49

The company owns 4½ miles of track, 42-inch gauge, and hauled the gypsum to the shipping pier located at Munro point on St. Ann harbour. The distances are 3½ and 4 miles respectively from the first and second quarry.

Baddeck Bay and Big Harbour Area. From Baddeck bay on the west to St. Ann harbour on the east there is a large gypsiferous area covering

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[1] Op. cit. p. 57.

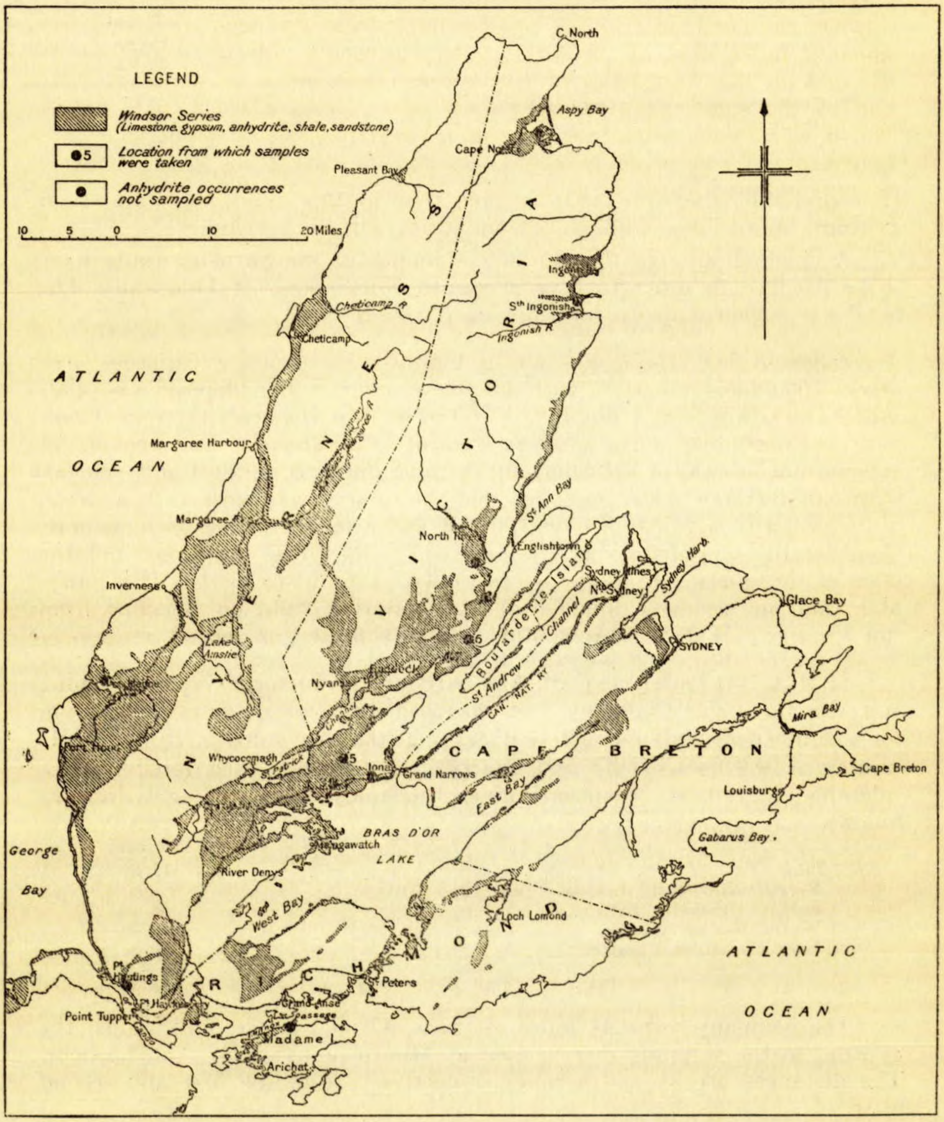

Figure 1. Sketch map showing anhydrite occurrences in Cape Breton island, Nova Scotia.

over 15 square miles. Many outcrops of gypsum and anhydrite occur in this area, anhydrite being probably more predominant at the surface in the western part of the district, between Baddeck bay and Big Harbour.

On the north side of the road running from Baddeck to Ross Ferry, about 3 miles west of the latter place, extensive cliffs of anhydrite are exposed on the west bank of Bevis creek, just north of where it enters one of the small bays of Bras d'Or lake. (*See* Plate IVA.) Sample No. 6 was taken from this outcrop. The cliffs rise precipitously for a height of 75 feet or more above the level of the creek and extend for several hundred yards or more north from the road. The surface of the deposit is densely wooded and is deeply indented with numerous sink holes which are filled with soil and debris. The deposit is only a short distance from deep-water transportation and could be served by either a wagon road or a narrow gauge track.

Extensive cliffs of anhydrite, probably a continuation toward the southeast of the deposit just mentioned, occur for over a mile in length along the southwest side of the small bay into which Bevis creek enters, these cliffs extending also as far as Bevis point.

Anhydrite exposures were also noticed, associated with gypsum outcrops in this area, in the neighbourhood of North and South gut, St. Ann harbour.

Recently an extensive body of clean blue anhydrite has been encountered in the floor of the quarry of the North American Gypsum Company on their property at the head of Baddeck bay. The line of demarcation between the overlying gypsum and the anhydrite body is well marked so that there would be little difficulty in obtaining extensive tonnages of clean material free from gypsum. As this deposit was discovered since the samples for this report were collected no tests on the material are available.

In the gypsiferous area situated at the east end of Baddeck bay on the farm of J. H. McLeod, lying to the southeast of the gypsum property being operated by the North American Gypsum Company, there are large masses of anhydrite associated with gypsum which could probably be excavated with reasonable cost. Sample No. 7 was taken from this deposit. The outcrop could be reached by an extension of the narrow gauge railway serving the above-mentioned company.

Washabuck Peninsula. In the district lying between St. Patrick channel and Bras d'Or lake there is a large area some 25 square miles in extent underlain by gypsum and anhydrite. The exposures are many and anhydrite outcrops in numerous places as large irregular masses.

At Lieutenant pond, a few miles north of Iona, gypsum deposits have been worked for a number of years by the Iona Consolidated Gypsum Corporation. While only small amounts of anhydrite have been encountered in those parts of the deposits at present being operated there are a number of localities on the property where extensive tonnages of this material could be obtained sufficiently close to water transportation to allow of economical handling. At the present time such deposits have not been developed. Jennison[1] gives an analysis of a sample taken from one of these localities showing that there is probably a small percentage of gypsum mixed with the anhydrite.

	Per cent
Lime (CaO)	40·16
Sulphur trioxide (SO_3)	55·60
Water, loss on ignition	4·52
Insoluble mineral matter	0·13
	100·41

At Jamesville, high precipitous cliffs of gypsum occur with which anhydrite is intimately associated.

At Ottawa brook, one-half mile to the north of the trestle on the Canadian National railway, 500 yards west of Ottawa Brook station, are extensive quarries owned by the Newark Plaster Company. These quarries are connected by a narrow gauge railway with the company's shipping pier at the entrance of McKinnon harbour, a distance of 1¼ miles. Associated with the gypsum in these deposits are large masses of anhydrite and vast waste piles of this material are lying on the quarry floor at the present time, as well as in stock piles at the shipping point. In addition, there are many points in the quarry where anhydrite could readily be quarried and the floor in part of the lower quarries is composed of anhydrite.

Two samples of anhydrite were taken from this deposit, Sample No. 3 from freshly broken faces in the quarry, and Sample No. 4 from the extensive stock pile of anhydrite at the shipping pier.

In the district to the north of Ottawa brook and McKinnon harbour extensive cliffs of anhydrite are exposed along the banks of the Washabuck river and also along the road running from Washabuck river to Little Narrows. At Nineveh there is a cliff composed almost entirely of anhydrite with a perpendicular face 60 to 80 feet in height with a length of over 800 feet. At Cain Mountain, on property owned by Donald MacLeod, there are extensive cliffs of anhydrite exposed on the west side of a small lake, an enlargement of the Washabuck river. (*See* Plate IVB.) These cliffs rise 100 feet or more from the water and are exposed for over 1,000 feet in length. The surface is densely wooded and heavily pitted with many sink holes. While the surface material has, in places, altered to gypsum, a few inches beneath the surface the material is massive anhydrite. Sample No. 5 was taken from this deposit.

Richmond County

Madame Island. Probably the largest gypsiferous area in this county is that occurring on the north shore of Madame island to the south of Lennox passage. The area is over 3 square miles in extent and the most prominent outcrops occur one mile back from the shore, 1¼ miles east of the bridge to the island from the mainland.

Anhydrite occurs in this area in irregular patches throughout the gypsum and a large tonnage could be readily obtained.

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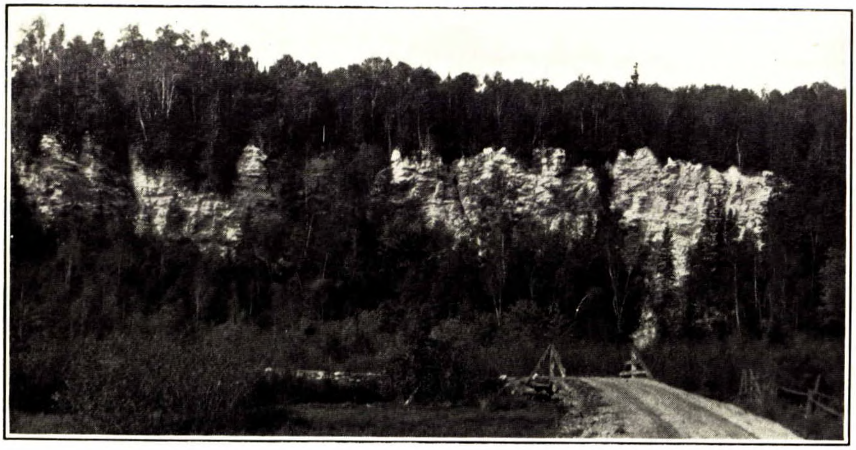
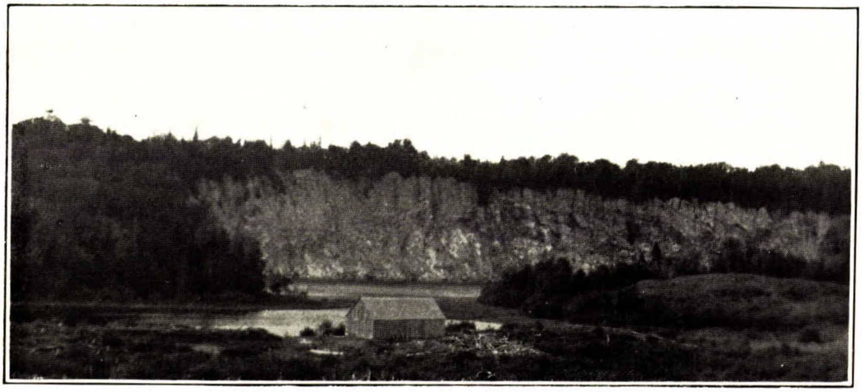
[1] W. F. Jennison. Op. cit., p. 52.



4838

A. Massive cliffs of anhydrite occurring on north side of road at Bevis creek, Victoria county, Nova Scotia, 3 miles west of Ross Ferry.



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B. Massive anhydrite occurring in prominent cliffs at Cain Mountain, Victoria county, Nova Scotia.

Inverness County

Port Hastings. Cliffs of anhydrite associated with a little gypsum are found in a small area on the east side of the road running from Hawkesbury to Port Hastings and a short distance south of the latter place. The outcrops are from 30 to 60 feet high. Jennison[1] gives an analysis of the anhydrite from this deposit as follows:

	Per cent
Lime (CaO)	40·48
Sulphur trioxide (SO_3)	55·48
Water, loss on ignition	3·90
Insoluble mineral matter	0·44
	100·30

Mabou. Anhydrite may be noticed in places at the base of the massive cliffs of gypsum that occur in this district.

Pictou County

Bridgeville. Anhydrite occurs in considerable quantities associated with gypsum in the neighbourhood of Bridgeville, 6 miles south of Ferrona Junction, on the Canadian National railway.

Colchester County

East Mountain. According to Jennison[2] there is an area of about 90 acres in this locality in which most of the material is a translucent anhydrite which analyses as follows:

	Per cent
Lime (CaO)	41·20
Sulphur trioxide (SO_3)	58·36
Water, loss on ignition	....
Insoluble mineral matter	0·28
	99·84

Shubenacadie River Area. Anhydrite associated with gypsum outcrops at many places in the area drained by the Shubenacadie river. Most of them, however, are not conveniently situated with respect to transportation.

In the vicinity of Brookfield on the Canadian National railway from Truro to Halifax where the gypsum area is close to the contact, anhydrite is generally present in quantity.

Two analyses of anhydrite on the farm of Leonard Carter in this district, where it occurs in close contact with limestone, are given by Jennison[3] as follows:

	Per cent	Per cent
Lime (CaO)	38·20	39·88
Magnesia (MgO)	1·06	....
Sulphur trioxide (SO_3)	53·80	51·28
Carbonic anhydrite (CO_2)	1·17	1·80
Water, loss on ignition	5·16	7·16
Insoluble mineral matter	0·10	....
	99·49	100·12

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[1] W. F. Jennison. Op. cit., p. 69.

[2] W. F. Jennison. Op. cit., p. 62.

[3] W. F. Jennison. Op. cit., p. 64.

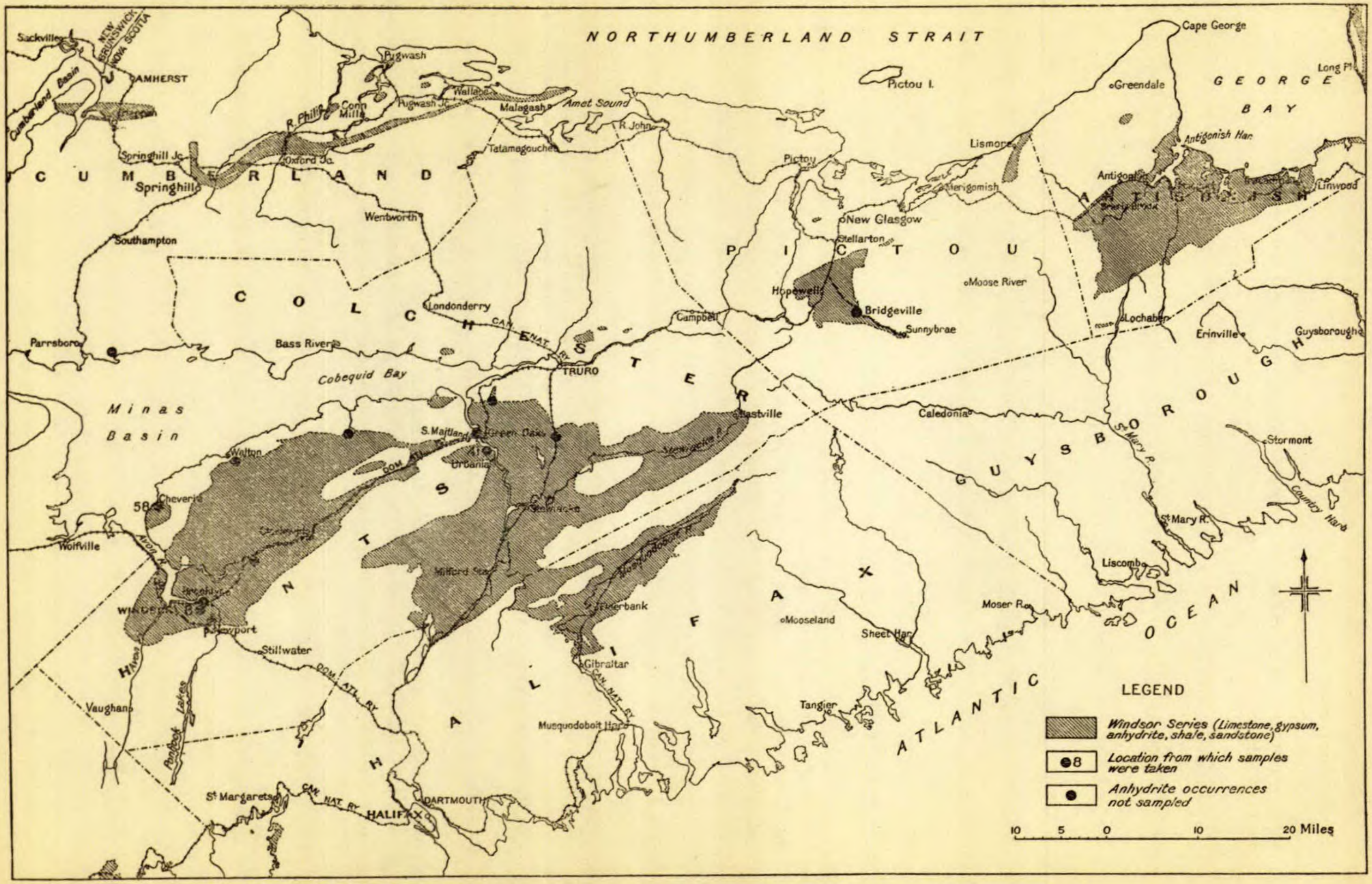

Figure 2. Sketch map showing anhydrite occurrences in Nova Scotia mainland.

Anhydrite is also to be seen at Beaver brook, 8 miles southeast of Truro, and also on the west side of the Shubenacadie river just opposite Eaglesnest point, where the beds of gypsum take an anticlinal structure with a core of anhydrite. An analysis of this anhydrite after Jennison[1] is as follows:

	Per cent
Lime (CaO)	38·40
Magnesia (MgO)	tr.
Ferric oxide and alumina (Fe_2O_3 and Al_2O_3)	1·60
Sulphur trioxide (SO_3)	54·44
Water, loss on ignition	5·76
Insoluble mineral matter	0·60
	100·80

Farther up the Shubenacadie river, on the west bank, and about half way between the railway bridge at South Maitland and Urbania extensive outcrops of anhydrite and gypsum are to be seen along the shore and extending over half a mile inland before being covered with excessive overburden. Numerous sink holes occur and the surface of the deposit is heavily wooded but with only a few feet of overburden. Sample No. 41 was taken from this property for testing. The normal means of transportation from this deposit would be by steamer down the Shubenacadie river, but unfortunately when the railway bridge was built not sufficient draw was left to allow modern-sized vessels to pass under it so that all the deposits of gypsum and anhydrite that lie above this bridge are practically cut off from water transportation, except by barges and small sailing vessels. The tides also on the river are extremely strong and have to be thoroughly understood by anyone wishing to navigate them successfully. At the mouth of the river the tide rises 30 feet in 3 hours and recedes in the same length of time. At Eaglesnest point the bore at high tide in some cases reaches 10 feet in height.

In the vicinity of Latties brook extensive outcrops of gypsum occur in which anhydrite is present in appreciable quantities and anhydrite also shows in many other deposits in this area. Two analyses of anhydrite from this area as given by Jennison[2] are as follows:

	I	II
Lime (CaO)	39·60	38·80
Magnesia (MgO)	tr.	....
Sulphur trioxide (SO_3)	55·20	53·40
Carbonic anhydrite (CO_2)	0·78	....
Water, loss on ignition	4·05	8·05
Insoluble mineral matter	tr.	0·40
	99·63	100·65

I. From high face near cave east of Burton, on the Andrew Hayes property.
II. From the Geary property east of Burton on the railway.

Judging from the analyses there is a quantity of gypsum mixed with the anhydrite.

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[1] W. F. Jennison. Op. cit., p. 67.
[2] W. F. Jennison. Op. cit., pp. 68-69.

Hants County

Windsor District. Probably the most widely known gypsiferous area in Nova Scotia and the one from which the largest tonnage has been shipped is that starting on the Avon river a few miles southwest of the town of Windsor and running northeasterly in almost a continual series of outcrops and sink holes on each side of the Dominion Atlantic railway (C.P.R.) to where it joins the Shubenacadie area at South Maitland. The area has a width in places of over 10 miles and a length of nearly 40 miles, and the area supposed to be underlain by gypsum and anhydrite is over 150 square miles in extent. The beds of gypsum are very massive and compact and thicknesses of over 100 feet have been worked. It is in the Windsor area that some of the largest gypsum quarries in the province are situated, and it is here that the gypsum industry of the province had its beginning since many of the properties are within easy reach of tidewater on the bay of Fundy.

Anhydrite is closely associated with the gypsum in this area, not only in the quarries already operated but in many individual outcrops as well. In consequence of the length of time which many of these quarries have been operated for gypsum, the accumulation of anhydrite on the dump piles and waste heaps in this district has been considerable, and it is probable that a large tonnage of anhydrite already quarried could be reclaimed at small expense from this source. It will not be possible to enumerate all the occurrences of anhydrite in this district, a few only being mentioned as representative.

On the "Meadows" property of the Canadian Gypsum Company, the largest operating company in the Maritime Provinces, anhydrite occurs in irregular patches and when encountered is removed to a waste pile or else shipped to the southern Atlantic states for use in the fertilizer trade. Sample No. 8 was obtained from this property for testing as being representative of the anhydrite of the district.

Jennison[1] mentions the occurrence of anhydrite at a number of localities in this area, such as at Mount Denison, where the greater part of the exposure appears as anhydrite; on the Scott estate and the Hannah property between the west shore of the Avon river and the main road leading to Windsor from the west. On the Scott property the gypsum is associated with considerable anhydrite, and on the Hannah property the principal outcrops are anhydrite.

In the old Pellow quarry (now abandoned), situated within the limits of the town of Windsor, anhydrite occurs in lenticular masses from 2 to 10 feet thick in the centre and from 50 to 75 feet long, embedded in the gypsum.

Above the St. Croix public bridge crossing the St. Croix river, on the south side, high prominent cliffs of gypsum and anhydrite are seen and from here back to Newport station on the Dominion Atlantic railway (C.P.R.) occurs an almost continuous series of outcrops, the greater part showing anhydrite in abundance.

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[1] W. F. Jennison. Op. cit., pp. 76-82.

Farther to the east prominent exposures of anhydrite occur on the Chambers property, situated on the west side of river Hebert near the railway.

In the quarries of the Atlantic Gypsum Products Corporation at Walton, anhydrite is frequently encountered, and occasional shipments of this material have been made to the United States.

At Noel to the east of Walton, anhydrite occurs in a form peculiar to this place, not in veins, masses nor beds, but in round spire-like pinnacles protruding through the gypsum.

Cheverie. A small gypsiferous area, some 5 square miles in extent, occurs to the south of Cheverie on the south side of Minas basin. Here anhydrite occurs in prominent cliffs along the shore between the village and the shipping wharf to the south and also in the floor of several of the old abandoned quarries. In places the anhydrite is badly contorted and twisted and is associated with limestone and calcite. (*See* Plate VA.) Occasional shipments of anhydrite have been made from this district to points in the United States for fertilizer and cement retarder use. Sample No. 58 was taken for testing from this district.

Jennison[1] gives an analysis of the anhydrite from this district as follows:

	Per cent
Lime (CaO)	40·80
Sulphur trioxide (SO_3)	58·16
Water, loss on ignition	1·55
	100·51

Cumberland County

Parrsboro. Occasional outcrops or patches of anhydrite occur in a small gypsiferous area situated about 4 miles east of Parrsboro and about 1 mile inland.

NEW BRUNSWICK

In the province of New Brunswick prominent outcrops of anhydrite occur associated with the gypsum deposits, especially in Albert county in the vicinity of the quarries at Hillsborough, and in the district to the south of that place. While small occasional patches of anhydrite have been noticed in some of the other gypsiferous areas in the province none of these have, so far, been sufficiently developed to show up any extensive tonnages of this material.

In the quarries of the Canadian Gypsum Company, formerly the Albert Manufacturing Company, anhydrite is frequently encountered in large lenticular masses as well as in the floor of some of the openings. This company has been in continuous operation since 1854 and in consequence large waste piles of anhydrite have accumulated so that extensive tonnages

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[1] W. F. Jennison. Op. cit., p. 74.

of material already quarried are available. Two samples, Nos. 1 and 9, were taken from this property as representative of the area. Both water and rail transportation are available, the quarries being served by a narrow gauge railway.

Several miles to the south of Hillsborough, on the south side of Wilson brook about ¼ mile from where the side road leaves the main highway, extensive cliffs of anhydrite occur, rising from 50 to 60 feet above the level of the creek. The surface of the face of this deposit for perhaps a few inches, in places, has been altered to gypsum, but once a fresh exposure is made the rock is solid and compact with little alteration. Sample No. 10 was taken from this deposit for testing purposes. (*See* Plate VB.)

ONTARIO

So far as is known at the present time, there is no anhydrite occurring as outcrops in the province of Ontario, but in several localities it has been found occasionally in the lower levels of some of the gypsum mines.

Dyer[1] after careful study of the gypsum deposits of southwestern Ontario has come to the conclusion that the calcium sulphate is divided vertically into three zones: in the first zone, from the surface to a depth of 225 feet, the material is entirely in the form of gypsum; the second zone, the zone of transition between 225 and 275 feet, consists of a mixture of anhydrite and gypsum; while the third zone, below 275 feet, the material is nearly all in the anhydrous form.

He also gives as his opinion that the greater part of the calcium sulphate was deposited in the first instance as the anhydrous variety, but towards the surface it was changed to gypsum by circulating meteoric waters.

Since all the gypsum mines so far developed in Ontario are opened only to shallow depths, it is, therefore, improbable that any large tonnage of anhydrite will be encountered in these workings and it will likely only be by sinking to depths greater than 275 feet in some locality where anhydrite has been recognized in a bore hole that a workable deposit of anhydrite will be exploited.

MANITOBA

Anhydrite has been found in quantity in Manitoba, both in the neighbourhood of Gypsumville and at Amaranth.

Gypsumville Deposits

In the quarries of the Gypsum Lime and Alabastine, Canada, Ltd., at Gypsumville, 170 miles north of Winnipeg, anhydrite occurs in the

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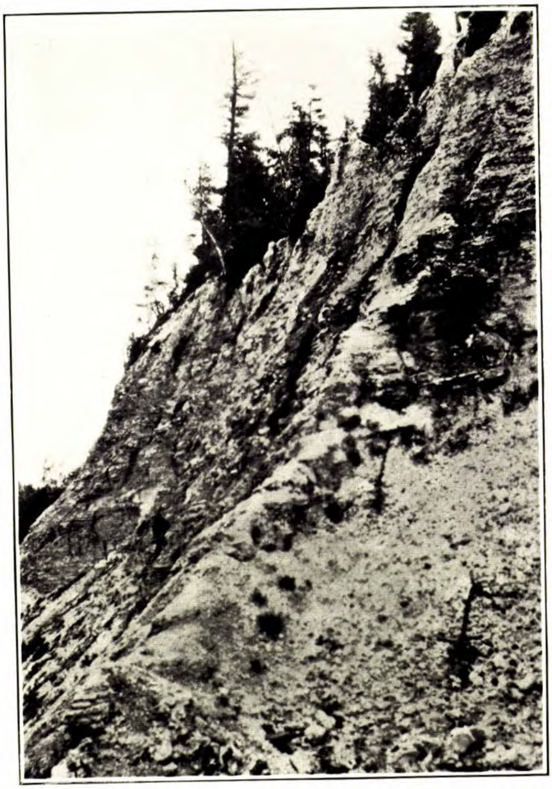
[1] Geology of the Gypsum Deposits of Southwestern Ontario, by W. S. Dyer, Ontario Department of Mines, Vol. XXXIV, Part II, 1925, p. 58.

3725

A. Contorted beds of anhydrite associated with limestone occurring on shore of Minas basin, below the village of Cheverie, Hants county, Nova Scotia.



3333

B. Anhydrite bluff. Wilson brook, Albert county, New Brunswick.

Figure 3. Sketch map of southwestern Ontario showing the distribution of gypsum and anhydrite.

bottom beds at the south end of the old quarry just to the northwest of the village where Wallace[1] found the following section in the face:

Surface capping (gypsite and soil)	1–3 feet
Red argillaceous gypsum	29 "
White foliated gypsum	75 "
Bluish grey anhydrite	25 "
Hard reddish gypseous rock	5 "

The immediately underlying beds are not exposed in this locality, but from the evidence of a core section they appear to be a reddish calcareous clay. The anhydrite forms heavy beds 2-4 feet thick, which show no evidence of disturbance. The overlying white gypsum beds are 2-4 inches thick, and are sharply folded. At the quarry there is a dip which is only of local significance, towards the north; consequently the anhydrite appears only at the south end of the quarry. The line of contact between the gypsum and anhydrite follows fairly closely the bedding plane, wherever the top of the anhydrite beds is exposed.

Anhydrite also is found in a number of other outcrops in the Gypsumville district, the area underlain by the gypsum-anhydrite formation in this locality, as far as at present known and indicated by outcrops, covering an aggregate of nearly 5½ square miles.

At the "White Elephant" property of the Gypsum Lime and Alabastine, Canada, Ltd., situated on sec. 3, tp. 33, range 8, west of the Principal meridian, occasional masses of anhydrite as well as selenite are encountered in the gypsum and Sample No. 64 was taken from the anhydrite from this deposit. This deposit is distant 6 miles from Gypsumville, the present terminal of the Gypsumville branch of the Canadian National railway.

On the Fry-Dulman property situated on sec. 10, tp. 33, range 8, west the Principal meridian, a small amount of development work has been done on a deposit of anhydrite with the object of ascertaining the suitability of the material as a decorative stone for interior finishings. Dr. Parks[2] has reported on this property as follows:

> The location is about 5½ miles eastward from Gypsumville but the swampy nature of the intervening country makes communication impossible except in winter. Accessibility to the deposit may be had in summer by a roundabout way via the north shore of lake St. Martin. There is no road northward from the lake to the property but it is possible to get through with a team and light wagon.
>
> In the vicinity of the deposit the country is rather rough, heavily drift-covered in part and clothed with timber. On the location a ravine cuts through the formation in a northeast and southwest direction. The northwest bank of the ravine has been stripped for a distance of 40 or 50 feet exposing a face of 17 feet. The face thus exposed strikes N. 30° E. and shows a light bluish-white, fine-grained anhydrite in beds of varying thickness but reasonable solidity. Irregular joints cut the formation and the anhydrite has been partially altered to gypsum along the joint planes. Considering the susceptibility of the stone to weathering and the superficial character of the workings, the shattering does not seem to be excessive. It is a reasonable assumption that more solid material would be encountered by more extensive development.
>
> Northwest of the margin of the ravine the country falls off gradually with a more pronounced slope west than north. On the area immediately bordering on the ravine, Mr. Fry has sunk three diamond drill holes to a maximum depth of 86 feet without passing out of the anhydrite. These holes indicate a fairly solid mass of

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[1] Gypsum and Anhydrite in Genetic Relationship, by R. C. Wallace, Ph.D., Geological Magazine, N.S., Decade VI, vol. I, pp. 272-3, June, 1914.

[2] Building and Ornamental Stones of Canada, vol. IV, Mines Branch, Dept. of Mines, Canada, Rept. No. 388, pp. 271-273 (1916).

anhydrite, whitish-blue and veined with brown towards the top and becoming bluer and less veined towards the bottom. It would appear from these holes that a considerable deposit of anhydrite is available and that it probably occurs in beds of sufficient solidity for quarrying mill blocks. The longest piece of drill core was about 10 inches, but it does not follow that the stone is thus limited in thickness. I am informed that the drills cut in a curved line and that the cores were broken in consequence.

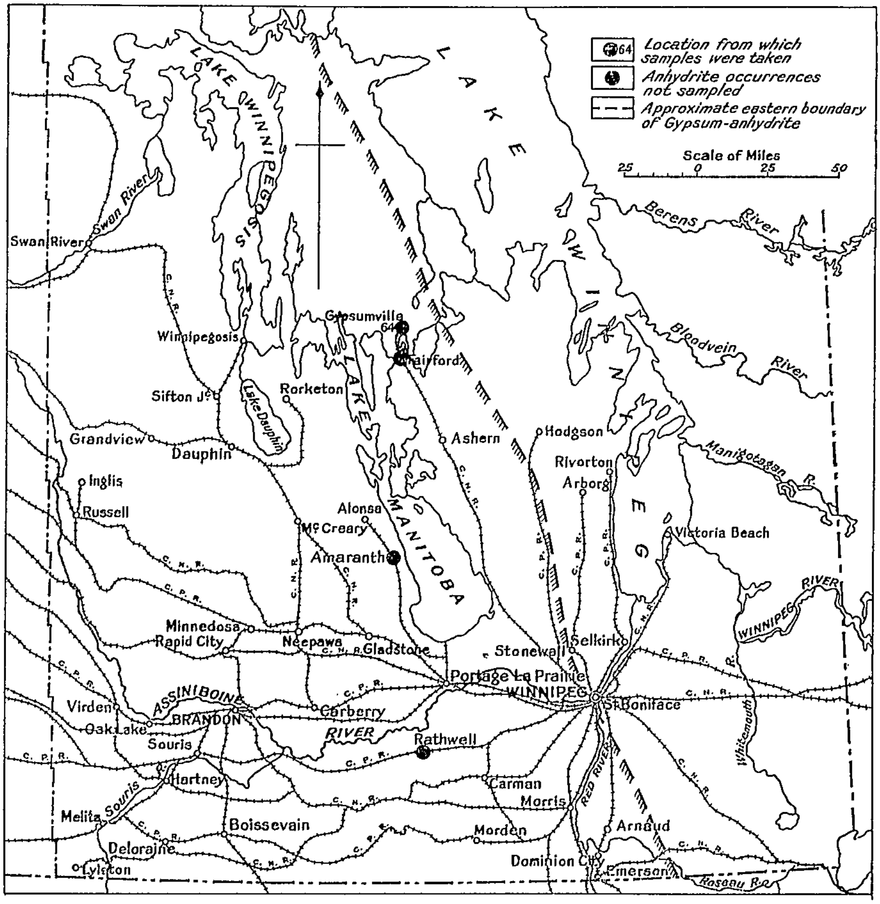

Figure 4. Anhydrite occurrences in Manitoba.

The holes were struck at the following points: (1)—16 paces, N. 15° W. from the face of the escarpment at the point where the stripping was done. No detailed record was kept but anhydrite is said to have been found to a considerable depth.

(2)—59 paces due west from the first hole. The surface here is about 25 feet lower.

(3)—72 paces N. 5° W. from the first hole. The surface here is 10 feet lower than at hole No. 1. The upper 15 feet showed broken stone below which solid material was found to a depth of 86 feet according to a statement of Mr. Fry. Portions of the core were obtained from different levels as below:

18 feet—Specimen No. 1167
26 feet— " " 1169
33 feet— " " 1170
41 feet— " " 1171
49 feet— " " 1168
60 feet— " " 1172
74 feet— " " 1166

The average stone exposed on the face is a bluish to whitish anhydrite (1164), sometimes banded, sometimes clouded, and towards the top brown-veined and spotted (1165).

The stone No. 1164 is a massive fine-grained crystalline anhydrite of light bluish colour; it varies somewhat in the tone of the blue.

No. 1165—(*a*) A distinctly blue type. The presence of occasional brown spots and bands detracts from the beauty of the material.

(*b*) A coarser grained bluish-white variety tinged with brown in places.

(*c*) Like 1165 (*a*) but mottled with white.

(*d*) A light blue and white type with distinct lines of pinkish-brown.

Nos. 1166-1172—These specimens prove the continuity of blue and white fine-grained anhydrite to the depth indicated.

Amaranth Deposit

A body of gypsum and anhydrite has, in the past few years, been opened up by a vertical shaft close to the northeast corner of sec. 26, tp. 18, range 10, west of the Principal meridian. The Western Gypsum Products, Ltd., of Winnipeg, have acquired five quarter sections in tp. 18, range 10, west of the Principal meridian, namely N.W. of 25, N.E. of 26, S.E. of 35, S.W. of 36, and S.E. of 36. The deposit is easily accessible, being 117 miles by road or 110 miles by rail (Canadian National railway) from Winnipeg.

On this deposit a two-compartment shaft extends to the bottom of the gypsum-anhydrite deposit at 130 feet. The thickness of the deposit is 38 feet. The lateral extent of the deposit has not yet been proven.

Brownell[1] who has made a study of this deposit describes it in part as follows:

> The gypsum bed may, for convenience, be divided into three portions:—(*a*) the "*upper gypsum layer*," consisting of the upper twenty-five feet of gypsum; (*b*) the "*anhydrite zone*," which is around four feet thick, between the two gypsum layers; and (*c*) the "*lower gypsum layer*" which constitutes the bottom nine feet.
>
> *The Anhydrite Zone.* Massive pale-blue vitreous anhydrite occurs abundantly in a horizontal zone between the upper and lower gypsum layers. The bottom of this zone constitutes the roof of the lower or main working level. The upper boundary of this zone is not so well determined, but from the one section obtained where the shaft cuts through it, the thickness of the zone is taken, for the present at least, to be approximately four feet.
>
> In the ladder-way of the shaft massive white gypsum is exposed on the west wall for five feet from the floor of the upper level to where anhydrite is first encountered. The first ten inches below the gypsum is massive blue anhydrite. Below this is twelve inches of mixed anhydrite and gypsum enclosing small irregular patches of limestone. A thin section made from a specimen taken here shows under the

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[1] Brownell, G. M.: "The Amaranth Gypsum Deposit," in Transactions of the Institute of Mining and Metallurgy for 1931, pp. 274-294.

microscope areas of anhydrite partially replaced by gypsum. The gypsum is working into the anhydrite areas along ragged edges and beginning to replace anhydrite in the interior. A narrow band of limestone traversing the section is bordered on either side by gypsum in such a manner as to indicate that replacement of the anhydrite is first taking place along the limestone contact.

A further twelve inches of massive blue anhydrite is exposed on the west wall, making a total thickness of nearly three feet composed largely of this mineral. On the north wall of the shaft, about a four-foot thickness is exposed down to the roof of the lower level. The roof of the lower level does not show a continuous exposure of anhydrite, but rather rounded boulder-like masses enclosed in gypsum. Such boulder-like occurrences are typical of anhydrite beds undergoing alteration to gypsum. Limestone occurs in the anhydrite as small irregular patches in exactly the same manner as seen in the upper gypsum layer.

According to Wallace[1] a bore hole put down at Rothwell, Manitoba, some 25 miles southwest of Portage-la-Prairie, encountered at a depth of 960 feet below the surface, a 62-foot bed of gypsum in which there was some anhydrite.

A glance at the sketch map of Manitoba, Figure 4, will show the localities in which anhydrite has been found in this province.

It can be seen, therefore, from the above description that anhydrite occurs in Manitoba in deposits conveniently situated with respect to transportation, and in large enough tonnages to supply any normal demand which may be reasonably expected for this mineral in the Prairie Provinces for many years to come.

ALBERTA

In Alberta, gypsum and anhydrite have been found at a number of localities, outcropping both on the surface and in drill holes. So far none of these deposits has been exploited either for gypsum or anhydrite, their distance from markets being the chief factor in preventing their being operated.

McMurray Deposits

Two wells were drilled by the Alberta Government in the vicinity of McMurray in 1919 and 1923, in both of which gypsum and anhydrite were encountered. Well No. 1 was located in the townsite of McMurray and was drilled to a depth of 685 feet, and at a depth of 500 feet the gypsum-anhydrite series was encountered. This series persisted in alternating beds of varying thickness down to a depth of 631 feet when the first salt horizon was penetrated. Well No. 2 was located by Dr. Allan, professor of geology, University of Alberta, 100 yards from the Alberta and Great Waterways railway at the junction of Deep creek and Clearwater river, in sec. 32, tp. 88, range 4, west of the 4th meridian. This hole was drilled to a depth of 789 feet and penetrated to granite. Beds of gypsum and anhydrite of varying thickness were first encountered at a depth of 415 feet and recurred at

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[1] "The Non-Metallic Mineral Resources of Manitoba." Industrial Development Board of Manitoba, 1927, p. 41.

intervals down to the contact of the Precambrian granite at a depth of 785 feet.[1] A series of analyses was made by J. A. Kelso, Director, Alberta Provincial Industrial Laboratories, from different beds of gypsum and anhydrite from Well No. 1 with the following results[2]:—

—	No. 1	No. 2	No. 3	No. 4
Depth in feet	534	546	564	662
Residue	1·02		2·02	4·22
Lime	32·81	17·36	33·88	37·42
Magnesia	5·14	6·66	0·98	1·25
Sulphuric anhydride	58·11	0·63	48·62	54·05
Ignition loss	2·72	25·62	14·01	0·72
Silica		34·20		
Iron oxide		2·00		
Alumina		9·20		
Alkalis, etc		4·33		
Sodium chloride				1·99

—	No. 5	No. 6	No. 7	No. 8	No. 9
Depth in feet	664½	665	666	671	676
Residue	5·62	5·20	1·02	4·72	2·01
Oxide of iron and alumina	5·98		4·02		
Lime	34·58	35·27	29·46	35·84	35·56
Magnesia	0·00	0·24	0·00	0·46	6·66
Sulphuric anhydride	49·07	49·16	41·88	52·46	50·67
Sodium chloride	0·38	0·58	20·90	5·02	0·32
Ignition loss	4·01	9·02	2·78	1·24	4·52

—	No. 10	No. 11	No. 12	No. 13
Depth in feet	681	684	670–673	685½
Residue	4·02		7·72	1·38
Lime	37·04	40·78	33·00	40·00
Magnesia	0·12	0·37	0·09	0·09
Sulphuric anhydride	54·62	58·34	47·09	57·44
Sodium chloride	1·02		4·72	
Ignition loss	3·01	0·42	7·30	1·07

From these analyses it can be seen that the greater part of the calcium sulphate penetrated occurs in the form of anhydrite.

Peace River Deposits

Camsell,[3] in describing the Peace River gypsum deposits, states that anhydrite is occasionally present in rounded nodules or in thin beds.

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[1] Complete logs of these two wells are given by J. A. Allan, Can. Inst. of Min. and Met. Bull. No. 206, June, 1929, p. 77.

[2] Second Annual Report on the Mineral Resources of Alberta, 1920, p. 110.

[3] Geol. Surv., Canada, Sum. Rept. 1916, pp. 139-140.

BRITISH COLUMBIA

In the province of British Columbia, gypsum deposits are known to occur at a number of localities, several of which have been operated to a greater or less extent, but at only one of them, namely the Falkland deposits of the Gypsum, Lime and Alabastine, Canada, Ltd., has anhydrite been found to any appreciable extent.

Falkland Deposits

The Falkland gypsum deposits, formerly known as the Salmon River deposits, are located in tp. 18, range 12, west of the 6th meridian. They are owned and operated by the Gypsum, Lime and Alabastine, Canada, Ltd., this company having purchased these deposits together with the calcining and board mill at Port Mann, B.C., from British Columbia Gypsum Company in 1927. The distance from Kamloops is approximately 40 miles in a southeasterly direction and the branch line of the Canadian National railway from Kamloops to Vernon furnishes transportation to the property.

The quarry is on the side of a hill facing south and has been opened up at an elevation approximately 500 feet above the level of the railway. The rock is a massive white to translucent gypsum with occasional bands of grey gypsum, and in places a few minute crystals of pyrite. The deposit has been opened up in three quarries, a working face of over 60 feet having been already obtained in No. 1, the floor of which has an elevation of 515 feet above the tracks. In this quarry anhydrite has been encountered in lenticular masses of varying extent, but the tonnage of this mineral present is not at present known. Sample No. 69 was taken from this locality for test purposes.

CHAPTER III

USES OF ANHYDRITE IN INDUSTRY

Anhydrite as a mineral of commerce is becoming better known each year, and as new uses are found it will probably become of increasing importance as time goes on.

Already it finds a market in several important industries in Europe and to a small extent on this continent, and even in Canada there has been a small but steadily increasing production of anhydrite from Nova Scotia, reaching in 1931 a total of over 40,000 tons.

A brief résumé of the several major uses of anhydrite which are at present consuming appreciable tonnages will be of interest.

AS A RETARDER IN PORTLAND CEMENT

At the present time Portland cement manufacturers employ up as high as 3 per cent of gypsum, added to the cement clinker and ground with it, in order to retard the set of the cement. Opinions as to the substitution of anhydrite for this purpose in place of gypsum are divided, some claiming that it is unsatisfactory whereas others claim that they actually prefer it.

The action of the gypsum in retarding of cement appears to be directly proportional to the SO_3 content of the gypsum and, as anhydrite contains a relatively higher proportion of SO_3, it should be more profitable to employ anhydrite. In order to obtain the retarding action the gypsum has to be intimately mixed with the cement clinker, and the more intimately the gypsum is mixed the greater the efficiency. If, therefore, anhydrite is used, there is less material to distribute uniformly through the clinker and greater care would have to be taken to produce the same results. This is probably one of the reasons for the objection to the use of anhydrite offered by certain cement plant operators. It is probable that a certain amount of anhydrite is present in many of the gypsums now used as cement retarder and there seems no reason why increasing amounts of anhydrite should not be used for this purpose. As high as 50 per cent of anhydrite in the retarder added (i.e. 1·5 per cent) has been used successfully at several cement plants.

FERTILIZER

Anhydrite has been used in large tonnages in Europe and the United States for fertilizer purposes, some consumers preferring it in place of gypsum, it being found especially satisfactory for leguminous forage crops such as clovers, alfalfas, etc., and also for peanuts. When first used, very little was known concerning its reactions in benefiting these crops since it was supposed to act only as an indirect fertilizer by acting on the double silicate of magnesia and potash in the soil, liberating the potash so that it was free to act as plant food. It has recently been shown that anhydrite with its calcium and sulphur probably acts directly in furnishing these nutrients to the plant as well as a general liberator of other plant foods. Where the sulphur content is the main requirement, anhydrite is preferable to gypsum on account of its higher SO_3 content and for the peanut crop it seems to be preferred. The greater proportion of the total production of anhydrite in Canada at the present time is employed in the southern Atlantic states for this purpose.

For this use the anhydrite is shipped in the lump form to the United States where it is finely ground and applied[1] by sprinkling on top of the peanut vines about the time the peanuts blossom. It is used at the rate of from 400 to 600 pounds per acre.

The peanut-growing areas in Virginia and North Carolina are possibly the largest users of calcium sulphate-containing material, and it is used to some extent in the peanut belt of Georgia.

Experiments by G. E. Colby[2] on the use of anhydrite or calcium sulphate on soils impregnated with black alkali are of interest since they show that the actions of anhydrite and gypsum on black alkali in moist soils are approximately the same, and the conclusion is drawn that anhydrite possesses the same value as a chemical remedy for black alkali as land plaster (gypsum). In parts of western Canada, notably in southern Alberta black alkali frequently occurs and according to the above experiments this harmful condition of the soil should readily lend itself to amenable treatment by the application of anhydrite.

Anhydrite is also suitable for use for mixing with farm manures and is said to save much of the volatile ammonia which is generally lost when straw is used for bedding in stables.

MANUFACTURE OF AMMONIUM SULPHATE

The use of anhydrite for the manufacture of ammonium sulphate has been successfully adopted both in Germany and England. In the latter country the Imperial Chemical Industries have a plant for this purpose in operation at Billingham, where they employ synthetic ammonia for the manufacture of ammonium sulphate.

The process consists briefly of converting the ammonia (in solution) into ammonium carbonate by the addition of carbon dioxide then mixing the carbonate solution with finely ground anhydrite. The reaction that takes place may be represented by the following equation:

$$(NH_4)_2CO_3 + CaSO_4 = (NH_4)_2SO_4 + CaCO_3$$

The calcium carbonate is removed from the ammonium sulphate solution by filtration and the latter recovered in crystal form by evaporation.

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[1] Personal communication kindly furnished by Dr. Oliver Bowles, Bureau of Mines, U.S. Department of Commerce, Washington, D.C.

[2] California Dept. Agr. Mo. Bull. 10 (1921) No. 1, pp. 39-41.

Although the solubility of anhydrite is relatively small, by close control and suitable manipulation of the plant, a sufficiently high concentration of the ammonium sulphate solution can be obtained to render the process economic.

For this use anhydrite should be finely ground so that 98 per cent or more will pass the 100-mesh screen and if the material is finer, even better results are obtained since the speed of the reaction between ammonium carbonate and calcium sulphate is influenced by the particle size of the anhydrite, inasmuch as the finer the anhydrite is ground the more readily soluble it becomes. Argillaceous impurities in the anhydrite are detrimental since they tend to hinder the filtering.

This industry is probably the greatest consumer of anhydrite at the present time.

MANUFACTURE OF CEMENT AND SULPHURIC ACID

As early as the middle of the 19th century, suggestions were made for the use of anhydrite as a source of sulphur in one or other of its various forms, but it was not until the war that any of the various processes achieved commercial success.

The idea underlying the process was to reduce the anhydrite with coke by firing in a kiln to form SO_2 and by suitable means converting the gas into sulphuric acid. The process, however, produced large quantities of calcium carbonate as a by-product and its disposal was a serious problem.

Recent modifications of the process as employed by the Imperial Chemical Industries at their plant at Billingham, England, have overcome this difficulty by utilizing the waste material to manufacture Portland cement by the addition of clay and sand to the original charge before firing.

The following notes on the process as followed at Billingham have been kindly furnished by Canadian Industries, Ltd., Montreal.

> The idea underlying this process is the reduction of calcium sulphate with coke to form SO_2.
>
> In order that the residue may be obtained in a saleable form, clay and sand are incorporated in the mixture in definite proportions, depending on their analyses, so that the final ratio of $CaO:Al_2O_3:SiO_2$ is that required by the specifications for Portland cement.
>
> The feed mixture may be either dry or wet and is roasted in a standard type of cement kiln.
>
> Sulphur dioxide is given off in the reactions taking place in the burning zone of the kiln, and the flue gases are passed through a Dust Precipitator to an acid plant for manufacture into sulphuric acid by the usual processes.
>
> Care must be taken to control the burning conditions so that the formation of sulphides is avoided, and so that the SO_3 content of the clinker is reduced to a point where it will meet with the cement specifications.
>
> The cement clinker is then ground in the usual manner.
>
> Either anhydrite or gypsum may be used as the raw material.

The use of anhydrite for this process instead of gypsum as the raw material would seem preferable, since smaller tonnages would be required to obtain the same result, and a higher content of SO_2 in the gases would be obtained on account of the absence of the water which is present in the gypsum.

PLASTERS

Plasters made from anhydrite are already on the market in England employing the process patented by Victor Lefebure. These plasters, known under the trade name of "Pioneer Plasters", are manufactured by the Imperial Chemical Industries and the results already achieved by them are distinctly promising.

At the present time the above-mentioned industries are the major users of the anhydrite world production. A number of other uses have been suggested for anhydrite such as a diluent for insecticides and fungicides, as a filler for paper and other products, as a polishing material, as a binder for making roads, as flux in certain metallurgical processes, and in the manufacture of crayons.

DILUENT FOR INSECTICIDES AND FUNGICIDES

As early as 1917 the writers carried on a series of experiments in conjunction with the Entomological Branch of the Department of Agriculture in order to find a suitable carrier or diluent for the several poisons used in combating insects attacking fruit trees. A number of non-metallic products were tested, among them calcium sulphate. This material when finely ground and properly mixed and applied by dusting to the trees, proved entirely satisfactory. While the calcium sulphate used in these tests was in the form of ground gypsum, anhydrite should prove as equally satisfactory. Calcium sulphate mixed with Paris green has proven very effective in combating the potato bug.

FILLER FOR PAPER AND COTTON

Finely ground and screened gypsum under the trade name of "Terra Alba" has been employed for many years as a filler and whitener for paper and cotton goods.

"Crown filler" or "pearl filler"—artificially prepared calcium sulphate—is also used quite extensively for the same purpose. It is probable that anhydrite could be utilized in a similar manner. (*See* Chapter IV, p. 33.)

METALLURGICAL FLUX

In connexion with the smelting of certain nickel ores mined in New Caledonia, crude gypsum is used as a flux. Thus, in smelting this ore, coke and gypsum are added to the charge, the latter furnishing the sulphur necessary for collecting the metal into a matte. It also acts as a base to counteract and slag the siliceous gangue. Anhydrite could probably be used for the same purpose.

In Germany calcium sulphate has been used as a flux for many years in the concentration of lead-copper matte in the reverberatory furnace.

In the Carmichael-Bradford blast-roasting process dehydrated gypsum (anhydrite) is added as flux to galena concentrate.

MISCELLANEOUS USES

Polishing Material. Small quantities of low-grade gypsum are used for certain polishing processes and there appears to be no reason why anhydrite could not also be employed for this purpose.

Road Making. In the vicinity of the gypsum deposits of Nova Scotia and New Brunswick many of the quarry roads have been surfaced with waste material from the quarries, material which in many cases is largely composed of anhydrite. The surfaces of such roads are noted for their smoothness and the readiness with which they become compacted. There is probably a setting action taking place due to the friction of the cart wheels rapidly pulverizing the anhydrite sufficiently fine to allow a certain amount of it to go into solution and form gypsum which acts as a binder for the rest of the mass.

Crayons, etc. White and coloured crayons used in blackboard and other work are now extensively made from gypsum. The uncalcined gypsum rock is finely ground in a disk pulverizer and combined with several other ingredients, principally as a binder, and the mixture is then pressed into required shapes and dried before packing. It should be possible to use anhydrite for this purpose.

CHAPTER IV

THE COMMERCIAL UTILIZATION OF ANHYDRITE IN CANADA

INTRODUCTION

The idea of commercially utilizing anhydrite has interested investigators for years, and many patents for processes in which the use of anhydrite has formed the major claims have been applied for in Canada, the United States, and Europe.

As anhydrite contains over 58 per cent sulphur trioxide, the early investigators regarded the mineral as a potential source of sulphuric acid. The difficulty, however, of successfully breaking the mineral down and recovering SO_2 gas commercially was for many years a great stumbling block, and it was only during the war that a process was developed which was a success both on a commercial as well as a technical scale. It is probable that the greater part of the sulphuric acid produced in Germany during the war years was obtained from anhydrite.

In the past few years a similar process has been adopted by the Imperial Chemical Industries at their plant at Billingham, England, at which they are now producing both sulphuric acid and cement. When market conditions warrant, the process may be applied in Canada.

The use of anhydrite for the manufacture of ammonium sulphate has also received attention and plants employing anhydrite for this purpose are now in successful operation both in England and in Europe. This again forms a potential use for anhydrite in Canada.

Recent investigations on anhydrite have focused attention on the possibility of producing cements and plasters similar in many of their properties to those made by calcining gypsum into plaster of Paris, and the results obtained have been decidedly promising.

PREVIOUS WORK[1]

The pioneer work in Canada on this phase of the anhydrite investigation has been carried on by Professor A. E. Flynn, professor of mining engineering at the Nova Scotia Technical College, Halifax, N.S., and his report entitled "Anhydrite Plasters and Cements" published by the Department of Public Work and Mines, Halifax, N.S., gives the results of a series of tests made on Nova Scotia anhydrite. His results are of great interest, since they indicate the possibilities of the mineral for such a purpose.

In the United States, the United States Bureau of Mines has devoted considerable attention to the study of anhydrite, principally dealing with

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[1] For a complete résumé of the investigational work that has been carried on with respect to anhydrite the reader is referred to "Industrial Uses of Anhydrite" by Chas. A. MacConkey, published by the National Research Council of Canada, Division of Research Information, Ottawa, March, 1931.

the possibility of accelerating the time of hydration, in the hope of finding a quick and cheap process by which anhydrite could be turned into gypsum and then used in the ordinary way.

The late H. E. Brookby of Chicago also did considerable work on the use of anhydrite as plaster and several U.S. patents were taken out by him. In his U.S. patent No. 1,668,548, he added to the finely ground anhydrite 10 per cent of plaster of Paris, 10 per cent of clay, 1 per cent of zinc sulphate ($ZnSO_4 \cdot 7H_2O$), 1 per cent of hyposulphite ($Na_2S_2O_4$), and 2 per cent of magnesium sulphate ($MgSO_4 \cdot 7H_2O$). With this mix Flynn[1] obtained a plaster with a tensile strength of 330 pounds per square inch. The plaster of Paris and clay were added to increase the workability and sand-carrying capacity of the plaster.

In England, as early as 1924, Victor Lefebure commenced a study of the possibility of producing a commercial plaster from anhydrite, and his work has resulted in the placing, on the English market, of a plaster made from anhydrite which is daily increasing in use. The Department of Mines, Ottawa, in the early stages of his experiments, furnished Lefebure with a number of samples of Canadian anhydrites and it is interesting to note that he found several of these made most suitable plasters of very satisfactory quality. Further supplementary tests in the present investigation were made on a number of Canadian anhydrites, using Lefebure's formula, in every case with excellent results.

Lefebure's process is covered in Canada by Canadian patent No. 293,763, under date of 8th October, 1929, entitled "Process for the Manufacture of Plasters from Anhydrite." Briefly his process consists of the addition of small percentages of certain inorganic salts to natural anhydrite, ground to a suitable fineness, and thus he is able to dispense with calcination, such as is necessary in the manufacture of plaster from gypsum, and nevertheless to cause the material to set to a hard mass, harder and stronger than ordinary plaster of Paris and approximating in strength to high class plasters such as those known as Keene's, Mack's, and Parian plasters.

Lefebure[2] in referring to the work that has already been accomplished with anhydrite in England states that the results so far, although thoroughly and repeatedly tested, are mainly empirical. On one particular use, for wall faces, he has bulk evidence, stretching over six or seven years on a large number of jobs of different types, representing more than a hundred thousand square yards of exposed surface. The matter is no longer in the experimental stage. Two things remain to be done and are being steadily pursued. In the first place the properties of the material suggest new commercial uses. These are being explored. Many of them have already passed to the stage of proved practical testing over adequate times on a large scale. Secondly, these developments have opened up a number of fundamental problems of a physical and chemical nature which really govern the successful use of all types of building binders. Very little work appears to have been done in the past on these problems and they are steadily being investigated as facilities allow.

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[1] Flynn. Op. cit., p. 16.

[2] Anhydrite, a New Industrial Mineral, by V. Lefebure. Unpublished manuscript furnished the writers, Jan., 1932.

FIELD AND LABORATORY WORK BY MINES BRANCH

For the investigation made in the Ore Dressing and Metallurgical Laboratories of the Mines Branch, a number of representative anhydrite samples were collected from deposits in Nova Scotia, New Brunswick, Manitoba, and British Columbia.

In all cases the samples collected were as representative as could possibly be obtained in the conditions under which they were taken. Where actual quarrying operations were being being carried on for gypsum in which anhydrite masses were also encountered and quarried, the samples were obtained by taking freshly broken material from all parts of the waste piles, taking care not to include any piece which showed gypsum in appreciable quantities. In the case where deposits were undeveloped, the obtaining of truly representative samples was extremely difficult, owing to the fact that most of the surface of such deposits was badly disintegrated and partly changed to gypsum. As far as possible such surface material was broken away with picks until a hard fresh face was obtained for sampling, but without the use of dynamite it was impossible, in every case, to obtain the material free from some gypsum and in consequence a number of the samples contain a higher percentage of gypsum than would normally be expected. It is, therefore, necessary, in studying the results obtained to take this fact into account. Such tests will naturally be more severe than if they were made on purer material as the gypsum in the anhydrite tends to increase the setting time and lower the tensile strength. It can reasonably be assumed, however, judging from the nature of the occurrence of the deposits as already indicated in a previous chapter, that as such deposits are opened up, the material obtained from fresh faces in the solid deposit will be considerably higher in anhydrite and freer from included gypsum. It may also be possible to obtain from anhydrite deposits, once they are properly opened up and a quarry face obtained free from sink holes and jointing, a uniformity of product over long periods of time, much more so than at present holds in some gypsum quarries where anhydrite masses and clay overburden frequently get mixed with the material.

Methods of Testing

Preparation of Samples

The average weight of the samples was about 200 pounds. The anhydrite was in pieces weighing 1½ to 3 pounds. Before crushing, a representative specimen was retained from each sample.

Crushing and Preliminary Grinding

Each sample was crushed first to 1 inch in a gyratory crusher. This product was reduced to -20 mesh or -100 mesh. To obtain the -20-mesh material, a small jaw crusher, small rolls, and disk pulverizer were used. For the -100-mesh material, one sample was reduced in hammer and burr mills, the others being ground in pebble mills.

Screen analyses were made of the ground products. The results are given in the following table.

TABLE I

Screen Analyses

Sample No.	1	3	4	5	6	7	8	9	10	41	58	64	69
	%	%	%	%	%	%	%	%	%	%	%	%	%
+100 mesh	27·4	2·0	.....	3·4	9·4	1·4	37·6	68·1	61·0	0·2	41·4	48·6	46·8
+150 "	2·6	3·6	1·4	2·8	6·6	3·0	2·8	1·8	2·4	0·2	2·0	3·0	3·0
+200 "	4·4	4·4	3·6	8·2	8·8	7·6	5·2	3·4	2·6	1·0	4·0	5·0	5·4
−200 "	65·6	90·0	95·0	85·6	75·2	88·0	54·4	26·7	34·0	98·6	52·6	43·4	44·8
−325 "	64·0	90·8	91·8	83·2	83·8	93·6	50·0	28·0	35·6	98·0	44·0	40·0	38·0

Chemical Analysis

The ground anhydrite was cut with a Jones riffle to obtain small samples for chemical analysis.

The standard methods of the American Society for Testing Materials, Serial Designation C 26-27, were used for the chemical analysis of the samples. The results are given in Table II.

Grinding

For the tests 2,000-gramme lots of the 20-mesh or 100-mesh anhydrite were ground in a pebble jar with 6,000 grammes of pebbles for 4 hours. Some of the anhydrites with a large percentage of gypsum had a tendency to stick to the interior surface of the jar. Screen analyses were made after grinding.

Catalysers

Small amounts of chemical salts added to ground anhydrite have been found to aid its setting when water is added to the mixture. In experiments, it was noted that the fine anhydrite mixed with water alone would harden or set after a time. Varying percentages of chemical salts or " agents " from 0·5 to 5·0 per cent and in one test, 10 per cent, were added either to the sample during grinding or else to the water in which the sample was mixed. The following agents were used:

1.	Aluminium sodium sulphate	$Al_2Na_2(SO_4)_4.24H_2O$
2.	Aluminium sulphate	$Al_2(SO_4)_3 \cdot 18H_2O$
3.	Calcium chloride	$CaCl_2$
4.	Magnesium chloride	$MgCl_2.6H_2O$
5.	Magnesium sulphate	$MgSO_4.7H_2O$
6.	Sodium sulphate	Na_2SO_4 (prepared by drying the salt from western Canada)
7.	Sodium pyrosulphate	$Na_2S_2O_7$
8.	Ammonium sulphate	$(NH_4)_2SO_4$
9.	Ammonium acid sulphate	NH_4HSO_4
10.	Volcanic ash	From Waldeck, Sask.
11.	Sodium tetraborate	$Na_2B_4O_7$
12.	Sodium pyrosulphate	$Na_2S_2O_7$
	Sodium sulphate	Na_2SO_4
13.	Sodium carbonate	Na_2CO_3

14.	Zinc sulphate	$ZnSO_4.7H_2O$
	Potassium sulphate	K_2SO_4
15.	Zinc sulphate	$ZnSO_4.7H_2O$
	Sodium sulphate	Na_2SO_4
16.	Zinc sulphate	$ZnSO_4.7H_2O$
	Sodium pyrosulphate	$Na_2S_2O_7$
17.	Zinc sulphate	$ZnSO_4.7H_2O$
	Calcium hydroxide	$Ca(OH)_2$
18.	Zinc sulphate	$ZnSO_4.7H_2O$
19.	Potassium sulphate	K_2SO_4
20.	Zinc sulphate	$ZnSO_4.7H_2O$
	Ammonium sulphate	$(NH_4)_2SO_4$

Briquettes

In this investigation, only the tensile strength of the plaster was determined. Five briquettes were made in standard moulds for each test. Six hundred grammes of the sample were shaken into the water through a No. 8 mesh sieve and mixed to the proper consistency. The briquettes were cast continuously by moving the vessel back and forth over the moulds while pouring.

The briquettes were dried at room temperature to constant weight, but for at least seven days before breaking. Some samples were more than seven days drying to constant weight. One anhydrite, No. 64, with the catalysers, sodium pyrosulphate, zinc sulphate-sodium sulphate, and zinc sulphate-ammonium sulphate, was especially long drying, the time for Test No. 120 being 58 days.

Owing to the difficulty of obtaining duplicate results on briquettes made at different times from the same mixture, it was thought that the temperature and humidity of the air in which they were dried was responsible for this. Tests No. 248, 249, and 250 were made in an attempt to prove this, but were not altogether conclusive.

Consistency

Distilled water was used to mix the plaster in all the tests. Sufficient water was mixed with the sample so that when a perpendicular face was made after thorough mixing, the plaster would not slump. The amount of water required varied from 19 to 68 cubic centimetres per 100 grammes of anhydrite.

The amount of water used has a direct bearing on the strength of the plaster. Tests No. 171 to 176 and No. 178 to 184 were made to show this. (*See* Figure 5.)

Time of Setting

The time of setting was determined by the glass plate method. One hundred grammes of the sample is mixed with the required amount of water and the resulting paste spread on a piece of common window glass about 8 inches square. The pat is made about 7/16 inch thick. The time of setting is taken as the elapsed time from when the sample is added to the water until it will leave the glass plate when the latter is flexed by the hands.

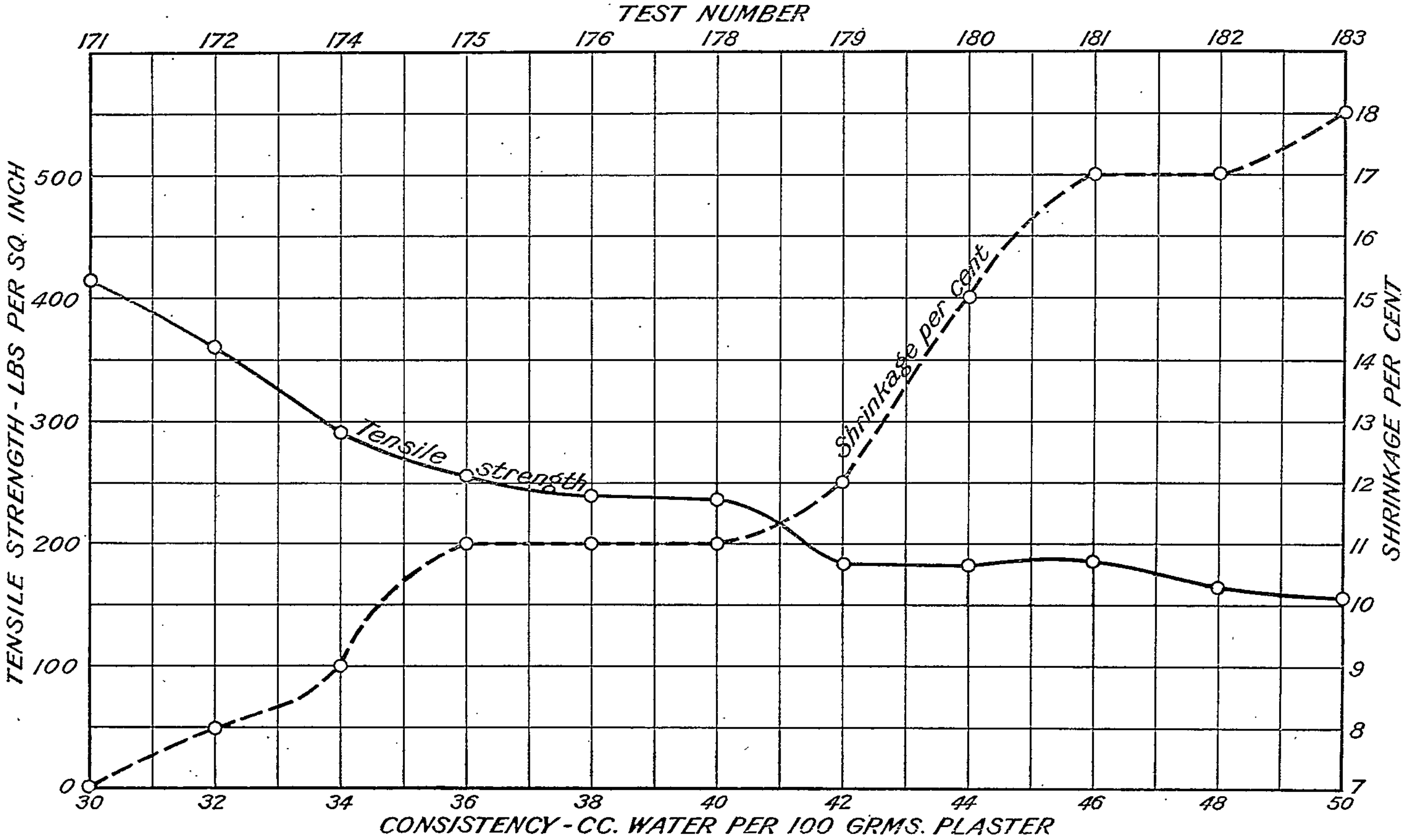

Figure 5. Graph showing decrease in tensile strength and increase in shrinkage with increasing water used in mix.

Water in Plaster

The water in the air-dried briquettes was determined. One gramme of the pulverized briquette was dried in a covered sillimanite crucible at 215° to 230°C. to constant weight. The percentages of water found are given in Table III.

Tensile Strength

The briquettes were broken in an Olsen-Boyd automatic cement tester manufactured by the Tinius Olsen Testing Machine Company. The average tensile strength of the 5 briquettes was taken as the tensile strength of the sample, except that if one or two briquettes varied more than 15 per cent from this average, they were discarded, and the tensile strength taken as the average of the remaining three.

Special Tests

In Tests No. 133 and 134, the samples made for Tests No. 88 and 122 were calcined at a dull red heat for one hour. It was hoped that this would increase the strength of the plaster made from this calcined material, but it had the opposite effect.

In Tests No. 187, 188, and 194, instead of water, a one per cent solution of hydrochloric acid was used to mix the plaster. This seemed to retard the setting.

The samples in Tests No. 195 and 196 were calcined for one hour at 860°C. A water determination at 230°C. on the calcined material showed it to be dead-burnt. After calcining, the anhydrite was ground in the usual way with the addition of an agent. The tensile strength was found to be lower than that of plaster made from the same anhydrite uncalcined.

In Tests No. 214 and 215, the 20-mesh anhydrite was soaked in a 10 per cent alum solution for 1½ hours. This was somewhat similar to the method for making Keene's cement. It was filtered, dried, and then calcined to a dull red heat, 580°C., for 2 hours. After calcining, it was ground in a pebble jar. Test No. 214 gave a good plaster, but No. 215 was not very strong.

Tests No. 216, 217, 218, 219, and 220 were made on anhydrite which had been dried in an oven at 230°C. This removed practically all the combined water. The plasters were quite unsatisfactory. When mixed with water, they commenced to set like plaster of Paris, but softened again.

In Tests No. 227 and 228, the anhydrite was ground for 8 hours to determine whether a finer material could be produced by the extra grinding. Screen analyses showed it to be no finer than that ground for 4 hours. The analyses were as follows:—

Test No.	53	227	93	228
+100 mesh	1·6	2·0	0·2	0·1
+150 "	1·2	3·0	0·1	0·2
+200 "	2·6	5·8	0·2	0·4
−200 "	94·6	89·2	99·5	99·3
−325 "	92·0	92·7	98·6	97·8
Time of grinding	4 hours	8 hours	4 hours	8 hours

For Test No. 229, the same sample as Test No. 197 was used. After the briquettes were cast in the moulds, the latter were immersed in water for nearly 24 hours, and then the water was siphoned off. The briquettes swelled in the water. They were soft for a depth of ¼ inch and then hard. They were left in the moulds for another day before removing. After drying there was some shrinkage from the original size. The object of this test was to determine if the anhydrite would hydrate more and shrink less when immersed in water. The shrinkage was less, and the water content slightly greater but considerably below that of gypsum.

Tests No. 248, 249, and 250 were made to show the effect of different drying conditions on the strength of the plaster. The "A" briquettes were dried in a closet over water and had not come to constant weight when broken. They had a low tensile strength. The "B" briquettes were dried in an oven at 45°C. In Test No. 248, this seemed to increase the strength. The "C" briquettes were dried under ordinary conditions of summer temperature and humidity, while the "D" briquettes were placed in a heated room with a lower humidity. In Test No. 249, with the agent magnesium sulphate, the "D" briquettes had the greatest strength.

Efflorescence

In a large percentage of the tests, an efflorescence formed on the surface of the plaster. This varied in amount with the percentage of chemical salt added to the anhydrite. In many cases, it was of a white, chalky nature and would flake off. When magnesium sulphate was the agent, the efflorescence was harder and more crusty, often forming in rings on the surface of the briquette. In other cases, no efflorescence was noticeable, but the surface of the plaster was very hard.

Shrinkage

In nearly all the tests some shrinkage was observed in the plaster. It was greatest in the plaster made from the samples with a very large gypsum content. Using 1½ per cent zinc sulphate and one per cent potassium sulphate together as the agent, there was very little shrinkage in most of the samples tested.

Porosity

In some tests, instead of the plasters shrinking they swelled due to the formation of bubbles of carbon dioxide gas. When these bubbles were retained in the plaster a cellular structure resulted. In some cases the bubbles did not persist, and the structure was laminated. The agents which caused swelling were aluminium sodium sulphate, sodium pyrosulphate, and ammonium acid sulphate. The carbon dioxide was probably formed by the action of these acid chemical salts on the carbonates in the sample. One would naturally think that the samples having the higher percentages of carbonates would swell the most with the addition of acid salts, but such was not the case. The samples in which there was over 2 per cent of carbonates did not swell but shrunk when plasters were made from them with the aid of acid salts. Sample No. 4 with only 0·62 per cent of carbonates produced the most cellular plasters.

DESCRIPTION OF SAMPLES TESTED

Sample No. 1

Locality. From property of Albert Manufacturing Company, Hillsborough, N.B. From freshly broken anhydrite. Developed property.

Texture. Massive, cryptocrystalline, breaking with a conchoidal fracture.

Colour. Bluish grey, opaque and earthy. Powder, white.

Sample No. 3

Locality. Ottawa Brook, Victoria county, N.S. From property of the Newark Plaster Company, taken from anhydrite faces in the quarry which has not been worked for several years. Developed property.

Texture. Massive, with thin veinlets of fibrous and translucent gypsum cutting anhydrite and also horizontal one-quarter inch gypsum bands.

Colour. Bluish white, opaque to translucent. Powder, white.

Sample No. 4

Locality. Ottawa Brook, Victoria county, Nova Scotia. From property of the Newark Plaster Company, taken from extensive stock pile of anhydrite at the shipping pier. Developed property.

Texture. Massive, mottled texture.

Colour. Bluish white to translucent with occasional light brownish to greyish seams. Powder, white.

Sample No. 5

Locality. Cain Mountain, Washabuck river, Victoria county, Nova Scotia. Undeveloped property. Donald MacLeod, owner.

Texture. Massive, mottled with irregular brownish seams showing banding.

Colour. Greyish white, earthy. Powder, white.

Sample No. 6

Locality. From cliffs of anhydrite on north side of road running from Baddeck to Ross Ferry, Victoria county, Nova Scotia, and 3 miles west of latter place, on the west side of Bevis creek. Undeveloped property.

Texture. Massive, mottled with irregular greyish patches.

Colour. Whitish grey, earthy. Powder, white.

Sample No. 7

Locality. From property of J. H. McLeod, at the head of Baddeck bay, Victoria county, Nova Scotia. Undeveloped property.

Texture. Massive, mottled white and bluish.

Colour. Bluish white to white, the bluish parts being semi-translucent. Powder, white.

Sample No. 8

Locality. From property of Canadian Gypsum Company, Windsor, Nova Scotia. From freshly broken anhydrite. Developed property.

Texture. Massive, mottled.

Colour. Bluish white to greyish white, the bluish white being semi-translucent and vitreous. Powder, white.

Sample No. 9

Locality. From property of Albert Manufacturing Company, Hillsborough, N.B. From freshly broken anhydrite. Developed property.

Texture. Massive, cryptocrystalline, conchoidal fracture, even texture.

Colour. Bluish grey, translucent and vitreous. Powder, white.

Sample No. 10

Locality. From Wilson Brook, Albert county, New Brunswick. Undeveloped property.

Texture. Massive, with brownish irregularly banded structure.

Colour. Bluish white, earthy. Powder, white.

Sample No. 41

Locality. Urbania, Nova Scotia. On the west bank of the Shubenacadie river, half way between Urbania and South Maitland. Undeveloped property.

Texture. Massive, even texture.

Colour. Greyish white, earthy. Powder, white.

Sample No. 58

Locality. Cheverie, Nova Scotia. From broken masses of anhydrite at shipping pier. Developed property.

Texture. Massive, mottled.

Colour. Greyish white to bluish white, earthy. Powder, white.

Sample No. 64

Locality. From White Elephant quarry, Gypsumville, Manitoba. From freshly broken anhydrite on waste pile. Developed property.

Texture. Massive, even texture.

Colour. Bluish white, semi-translucent and vitreous. Powder, white.

Sample No. 69

Locality. Falkland, British Columbia. No. 1 quarry dump. Developed property.

Texture. Massive, even texture.

Colour. Bluish, translucent, vitreous. Powder, white.

Results of Chemical Analyses

The results of the chemical analyses of the 13 samples tested are given in Table II.

TABLE II

Chemical Analyses[1] of Samples

Sample No.	1	3	4	5	6	7	8	9	10	41	58	64	69
Insoluble	0·46	0·42	0·32	0·80	0·44	0·26	0·46	0·44	0·26	0·40	0·50	0·28	3·00
Ferric oxide, Fe_2O_3	0·04	0·06	0·04	0·06	0·06	0·04	0·06	0·06	0·05	0·04	0·04	0·04	0·20
Alumina, Al_2O_3	0·08	0·06	0·08	0·02	0·02	0·04	0·08	0·08	0·05	0·02	0·06	0·04	0·07
Lime, CaO	40·21	39·09	40·94	39·96	37·68	40·10	38·07	40·68	39·77	37·32	40·79	38·84	37·65
Magnesia, MgO	0·04	0·49	0·23	0·10	0·16	0·10	0·16	0·03	0·03	0·18	0·07	0·03	0·22
Sulphur trioxide, SO_3	57·31	54·45	57·48	54·65	52·68	52·97	54·08	58·27	55·65	53·18	57·09	56·03	53·81
Water, H_2O	1·35	4·44	0·53	2·85	8·02	3·90	6·30	0·06	3·30	8·55	0·31	4·57	4·02
Carbon dioxide, CO_2	0·47	1·07	0·31	1·14	0·49	1·89	0·62	0·31	0·97	......	0·97	0·05	0·69
Pyrite, FeS_2	......	......	......	......	......	......	......	......	......	......	......	......	0·47
Total	99·96	100·08	99·93	99·58	99·55	99·30	99·83	99·93	100·08	99·69	99·83	99·88	100·13

Hypothetical Combination													
Anhydrite, $CaSO_4$	91·19	75·80	95·73	82·15	59·27	75·33	67·25	97·66	81·18	58·12	95·12	76·96	74·84
Gypsum—$CaSO_4 \cdot 2H_2O$	6·45	21·22	2·53	13·62	38·32	18·64	30·10	0·29	15·77	40·85	1·48	21·84	19·21
Calcium carbonate, $CaCO_3$	0·98	1·23	0·14	2·34	0·73	4·05	1·02	0·64	2·14	......	2·02	0·05	1·02
Magnesium carbonate, $MgCO_3$	0·08	1·02	0·48	0·21	0·33	0·21	0·33	0·06	0·06	......	0·15	0·06	0·46

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[1] Analyses by R. A. Rogers—with exception of No. 41.

Impurities

A study of these results brings out some interesting facts. The impurities occurring in Canadian anhydrites tested consist mainly of gypsum and limestone, with minor percentages of ferric oxide, alumina, and magnesia.

Gypsum

Probably the most important impurity in the anhydrite is the gypsum. Tests indicate that the presence of gypsum has a distinct bearing on the strength of the resulting plaster, the higher the gypsum content, the lower the tensile strength. It probably also has a direct bearing on the shrinkage of the set plaster, the shrinkage increasing in direct proportion to the amount of gypsum present. Gypsum, therefore, should be considered as a deleterious impurity and should be as low as possible. As already stated, the amount of gypsum present in any deposit will probably be considerably less than indicated by the samples taken, once the deposit is properly opened.

Limestone

This impurity in itself is probably inert, but when a catalyser such as aluminium sulphate is employed it tends to generate CO_2 in the setting plaster causing a swelling and producing a cellular structure. This reaction, according to the tests, seems to be counteracted in some cases by the presence of gypsum, so that some of the samples, comparatively high in lime carbonate but with also high gypsum content, did not show this reaction. On the whole, therefore, it is better to have this impurity as low as possible and where a cellular structure is required, as in the manufacture of a cellular plaster, to add to the batch the exact amount of limestone necessary.

Ferric Oxide

In all the samples tested the ferric oxide was low and probably had no direct effect on the resultant product. In larger amounts it would probably tend to throw the plaster slightly off colour and Flynn[1] found that the addition of 2 per cent of iron oxide gave a plaster with a tensile strength of less than 30 pounds per square inch.

Magnesia

The presence of magnesia in the samples is small and it is not known whether it is present in the form of dolomite or magnesite. It, in all probability, acts very similarly to limestone.

Alumina

In all cases the alumina content of the samples is small and insufficient to cause trouble. It should be remembered, however, that in quarrying a deposit of anhydrite which has a clay overburden, or one in which sink holes are prevalent, there is always the probability of getting some alumina in the form of clay mixed with the rock, and the greatest care therefore should be taken to avoid such a possibility.

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[1] A. E. Flynn. Op. cit., p. 18.

Results of Tests on Canadian Anhydrites

The results of tests made in the Mines Branch laboratories are tabulated in detail in Table III following.

TABLE III

Results of Tests

Sample No. 1: —20 mesh

Test No.	65	69	166	77
Screen Analysis—				
+100 mesh......per cent	0·1	10·6	0·2	18·0
+150 mesh...... "	0·03	4·0	0·2	3·2
+200 mesh...... "	0·5	8·8	0·8	5·4
—200 mesh...... "	99·4	76·6	98·8	73·4
—325 mesh...... "	99·6	76·0	98·3	76·0
Time of grinding...... hours	4	(5 min.)	4	4
Agent added......	......	......	In water	In pebble jar
Agent......	None	None	$Al_2Na_2(SO_4)_4$ $\cdot 24H_2O$	$Al_2Na_2(SO_4)_4$ $\cdot 24H_2O$
Agent......per cent	......	......	0·5	2·5
Water used...... $\frac{cc.}{100}$ gms.	27	23	32	23
Days in mould......	2	1	2	1
Age when broken...... days	7	7	7	8
Weight briquette...... gms.	109·4	109·9	99·5	108·1
Tensile strength......lb./sq. in.	180	46	373	217
Water in plaster when broken......per cent	7·44	3·00	7·85	11·88
Time of setting...... hours	>9	>8	>8	2½
Area shrinkage......per cent	3	6	10	Swelled
Efflorescence......	None	None	Slight	Slight
Remarks......	......	Chalky surface		Cellular, laminated

Sample No. 1: —20 mesh—Continued

Test No.	95	139	151	59	62
Screen Analysis—					
+100 mesh......per cent	0·2	0·1	0·01	0·07	5·4
+150 mesh...... "	0·1	0·1	0·2	0·04	3·4
+200 mesh...... "	0·4	0·3	0·2	0·08	10·0
—200 mesh...... "	99·3	99·5	99·6	99·8	81·2
—325 mesh...... "	99·1	99·7	99·3	99·7	82·0
Time of grinding...... hours	4	4	4	4	(5 min.)
Agent added......	In pebble jar	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent......	$MgSO_4 \cdot 7H_2O$	Na_2SO_4	Na_2SO_4	Na_2SO_4	Na_2SO_4
Agent......per cent	2·5	0·5	1·0	2·5	2·5
Water used...... $\frac{cc.}{100}$ gms.	26	32	33	32	24
Days in mould......	1	1	2	1	1
Age when broken...... days	8	8	8	7	7
Weight briquette...... gms.	106·9	102·4	102·1	105·1	116·4
Tensile strength......lb./sq. in.	226	389	360	374	245
Water in plaster when broken......per cent	9·26	11·04	11·80	13·58	9·79
Time of setting...... hours	7¾	4¾	2½	(54 min.)	1½
Area shrinkage......per cent	2	3	3	1	None
Efflorescence......	Considerable	Some	Some	Much	Much
Remarks......	......	......	......	......	......

Sample No. 1: –20 mesh—Continued

Test No.	123	96	97	98
Screen Analysis—				
+100 mesh...............per cent	0·2	0·4	0·4	0·2
+150 mesh............... "	0·1	0·2	0·2	0·03
+200 mesh............... "	0·1	0·4	0·2	0·2
–200 mesh............... "	99·6	99·0	99·2	99·6
–325 mesh............... "	99·8	99·3	99·5	99·6
Time of grinding.............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..................................	$Na_2S_2O_7$	$Na_2S_2O_7$	NH_4HSO_4	Volcanic ash
Agent........................per cent	0·5	2·5	0·5	2·0
Water used.................. $\frac{\text{cc.}}{100}$ gms.	32	32	30	30
Days in mould........................	1	1	1	1
Age when broken............. days	8	8	8,	7
Weight briquette............. gms.	100·5	107·2	103·3	99·6
Tensile strength............lb./sq. in.	339	343	306	160
Water in plaster when broken.per cent	10·51	14·57	10·52	7·57
Time of setting............... hours	$6\frac{1}{4}$	(39 min.)	>7	$>8\frac{3}{4}$
Area shrinkage...............per cent	3	None	3	6
Efflorescence.........................	Slight	Much	None	None
Remarks...............................	....	....	....	....

Sample No. 1: –20 mesh—Continued

Test No.	208	209	231	250[1]a
Screen Analysis—				
+100 mesh...............per cent	0·04	0·4	0·4	0·4
+150 mesh............... "	0·2	0·4	0·1	0·8
+200 mesh............... "	0·2	0·6	0·2	0·6
–200 mesh............... "	99·6	98·6	99·3	98·2
–325 mesh............... "	98·4	97·1	99·8	99·6
Time of grinding.............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..................................	Na_2CO_3	Na_2CO_3	$ZnSO_4 \cdot 7H_2O$ K_2SO_4	$ZnSO_4 \cdot 7H_2O$ K_2SO_4
Agent........................per cent	0·5	2·5	1·5 1·0	1·5 1·0
Water used.................. $\frac{\text{c.c.}}{100}$ gms.	30	30	34	34
Days in mould........................	1	1	$\frac{1}{12}$	$\frac{1}{12}$
Age when broken............. days	8	8	11	15
Weight briquette............. gms.	103·5	99·4	102·5	113·6
Tensile strength............lb./sq. in.	428	225	383	121
Water in plaster when broken.per cent	9·82	11·51	13·93	18·60
Time of setting............... hours	4	$1\frac{1}{4}$	(55 min.)	(55 min.)
Area shrinkage...............per cent	6	5	1	2
Efflorescence.........................	Some	Much	Very slight	Very slight
Remarks...............................	....	....	....	....

[1] Test No. 250 includes a, b, c, and d.
a Briquettes were dried in a moist closet.

Sample No. 1: −20 mesh—Continued

Test No.	250 b	250 b	250[1] c	250 d
Screen Analysis—				
+100 mesh...............per cent	0·4	0·4	0·4	0·4
+150 mesh.............. "	0·8	0·8	0·8	0·8
+200 mesh.............. "	0·6	0·6	0·6	0·6
−200 mesh.............. "	98·2	98·2	98·2	98·2
−325 mesh.............. "	99·6	99·6	99·6	99·6
Time of grinding............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..................................	$ZnSO_4 \cdot 7H_2O$ K_2SO_4	$ZnSO_4 \cdot 7H_2O$ K_2SO_4	$ZnSO_4 \cdot 7H_2O$ K_2SO_4	$ZnSO_4 \cdot 7H_2O$ K_2SO_4
Agent...................... per cent	1·5 1·0	1·5 1·0	1·5 1·0	1·5 1·0
Water used................. $\frac{\text{c.c.}}{100}$ gms.	34	33	34	34
Days in mould..........................	$\frac{1}{12}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
Age when broken............. days	7	7	8	8
Weight briquette............. gms.	98·8	100·0	102·3	100·0
Tensile strength............lb./sq. in.	296	265	302	337
Water in plaster when broken.per cent	11·30	11·02	13·67	13·06
Time of setting.............. hours	(55 min.)	(55 min.)	(55 min.)	(55 min.)
Area shrinkage..............per cent	2	2	1	2
Efflorescence..........................	None	None	Very slight	Very slight
Remarks............................	....	....	....	....

[1] Test No. 250 includes a, b, c and d.
b Briquettes were dried in an oven at 45° C.
c Average temperature 70° F.; average humidity 59 per cent.
d Average temperature 86° F.; average humidity 41 per cent.

Sample No. 1: −20 mesh—Continued

Test No.	236	236	236	239
Screen Analysis—				
+100 mesh...............per cent	0·4	0·4	0·4	0·8
+150 mesh.............. "	0·2	0·2	0·2	0·2
+200 mesh.............. "	0·4	0·4	0·4	0·4
−200 mesh.............. "	99·0	99·0	99·0	98·6
−325 mesh.............. "	98·0	98·0	98·0	99·3
Time of grinding............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..................................	$ZnSO_4 \cdot 7H_2O$ Na_2SO_4	$ZnSO_4 \cdot 7H_2O$ Na_2SO_4	$ZnSO_4 \cdot 7H_2O$ Na_2SO_4	$ZnSO_4 \cdot 7H_2O$ $Ca(OH)_2$
Agent.......................per cent	1·5 1·0	1·5 1·0	1·5 1·0	1·5 0·25
Water used................. $\frac{\text{cc.}}{100}$ gms.	33	33	33	30
Days in mould..........................	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	1
Age when broken......................	8	7	9	8
Weight briquette............. gms.	105·1	102·5	102·7	102·1
Tensile strength............lb./sq. in.	594	491	368	303
Water in plaster when broken..per cent	15·68	14·16	13·66	10·15
Time of setting.............. hours	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$7\frac{1}{4}$
Area shrinkage ....per cent	2	3	3	5
Efflorescence..........................	Considerable	Considerable	Hard crust	Very slight
Remarks............................	....	....	....	....

Sample No. 1: −20 mesh—Continued

Test No.	242	245	248[2] a	248 b
Screen Analysis—				
+100 mesh, per cent	0·2	0·2	0·4	0·4
+150 mesh, "	0·4	0·2	0·4	0·4
+200 mesh, "	0·8	0·4	0·4	0·4
−200 mesh, "	98·6	99·2	98·8	98·8
−325 mesh, "	98·0	99·4	99·4	99·4
Time of grinding, hours	4	4	4	4
Agent added	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent	$ZnSO_4 \cdot 7H_2O$	$ZnSO_4 \cdot 7H_2O$ $Na_2S_2O_7$	$ZnSO_4 \cdot 7H_2O$ $Na_2S_2O_7$	$ZnSO_4 \cdot 7H_2O$ $Na_2S_2O_7$
Agent, per cent	2·5	1·5 0·5	1·5 0·5	1·5 0·5
Water used, $\frac{\text{cc.}}{100}$ gms.	30	32	32	32
Days in mould	1	1	¼	¼
Age when broken, days	7	8	16	7
Weight briquette, gms.	104·2	103·9	110·6	104·6
Tensile strength, lb./sq. in.	379	494	166	551
Water in plaster when broken, per cent	11·74	14·22	17·28	13·03
Time of setting, hours	7	4½	4½	4½
Area shrinkage, per cent	4	4	1	2
Efflorescence	Very slight	None	None	None
Remarks				

Sample No. 1: −20 mesh—Concluded

Test No.	248 c	248 d	251	254
Screen Analysis—				
+100 mesh, per cent	0·4	0·4	0·2	0·6
+150 mesh, "	0·4	0·4	0·2	0·2
+200 mesh, "	0·4	0·4	1·0	0·4
−200 mesh, "	98·8	98·8	98·6	98·8
−325 mesh, "	99·4	99·4	98·5	99·6
Time of grinding, hours	4	4	4	4
Agent added	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent	$ZnSO_4 \cdot 7H_2O$ $Na_2S_2O_7$	$ZnSO_4 \cdot 7H_2O$ $Na_2S_2O_7$	K_2SO_4	$ZnSO_4 \cdot 7H_2O$ $(NH_4)_2SO_4$
Agent, per cent	1·5 0·5	1·5 0·5	2·5	1·5 1·0
Water used, $\frac{\text{cc.}}{100}$ gms.	32	32	38	31
Days in mould	¼	¼	1	1
Age when broken, days	7	8	8	8
Weight briquette, gms.	103·4	101·2	91·5	104·4
Tensile strength, lb./sq. in.	425	408	207	379
Water in plaster when broken, per cent	14·17	11·61	8·43	13·23
Time of setting, hours	4½	4½	3½	3
Area shrinkage, per cent	2	6	5	6
Efflorescence	None	None	Slightly chalky	Very slight
Remarks				Hard surface

[1] Test No. 248—a Briquettes were dried in a moist closet.
b Briquettes were dried in an oven at 45° C.
c Average temperature 70° F.; average humidity 58 per cent.
d Average temperature 86° F.; average humidity 41 per cent.

Sample No. 3: −100 mesh

Test No.	52	167	99	74	103
Screen Analysis—					
+100 mesh.......per cent	2·2	2·2	2·2	2·2	4·4
+150 mesh...... "	1·4	2·0	1·4	1·4	1·8
+200 mesh....... "	3·0	3·0	3·0	3·0	5·6
−200 mesh....... "	93·4	92·8	93·4	93·4	88·2
−325 mesh....... "	96·0	92·0	96·0	96·0	94·0
Time of grinding..... hours	4	4	4	4	4
Agent added................	....	In water	In water	In water	In pebble jar
Agent........................	None	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$	$MgCl_2 \cdot 6H_2O$	$MgSO_4 \cdot 7H_2O$
Agent................per cent	....	0·5	1·0	2·5	2·5
Water used......... $\frac{\text{cc.}}{100}$ gms.	32	34	32	27	27
Days in mould..............	2	2	2	1	1
Age when broken.... days	7	7	7	9	12
Weight briquette.... gms.	92·5	89·6	99·6	99·4	99·7
Tensile strength....lb./sq. in.	140	276	244	68	238
Water in plaster when broken.............per cent	8·94	8·50	14·49	9·15	9·47
Time of setting...... hours	>9	>8	4½	8¼	>8½
Area shrinkage........per cent	8	13	1	7	7
Efflorescence................	None	None	None	Slightly chalky	Some
Remarks....................	....	....	....	....	Warped

Sample No. 3: −100 mesh—Continued

Test No.	140	152	204	47
Screen Analysis—				
+100 mesh...............per cent	3·2	2·2	2·6	3·2
+150 mesh.............. "	2·6	2·0	2·4	2·2
+200 mesh.............. "	5·6	3·0	4·4	4·0
−200 mesh.............. "	88·6	92·8	90·6	90·6
−325 mesh.............. "	92·0	94·3	98·3	98·0
Time of grinding............. hours	4	4	4	4
Agent added.........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..............................	Na_2SO_4	Na_2SO_4	Na_2SO_4	Na_2SO_4
Agent.......................per cent	0·5	1·0	2·5	3·5
Water used................. $\frac{\text{cc.}}{100}$ gms.	32	34	33	35
Days in mould......................	1	2	1	1
Age when broken............ days	8	8	7	8
Weight briquette............ gms.	94·2	93·6	94·4	92·9
Tensile strength............lb./sq. in.	292	260	280	262
Water in plaster when broken..per cent	10·25	11·72	11·84	12·89
Time of setting.............. hours	6¼	4¾	3½	4¼
Area shrinkage...............per cent	8	7	8	6
Efflorescence........................	Slight	Some	Much	Much
Remarks..........................	....	....	....	....

Sample No. 3: – 100 mesh—Concluded

Test No.	124.	104	210	211	234
Screen Analysis—					
+100 mesh............per cent	2·4	4·0	3·4	2·4	3·0
+150 mesh........... "	1·4	1·4	3·0	3·0	2·0
+200 mesh........... "	2·2	4·4	4·8	4·6	4·8
–200 mesh........... "	94·0	90·2	88·8	90·0	90·2
–325 mesh........... "	96·0	96·0	92·3	93·7	96·0
Time of grinding....... hours	4	4	4	4	4
Agent added....................	In pebble jar	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..........................	$Na_2S_2O_7$	$Na_2S_2O_7$	Na_2CO_3	Na_2CO_3	$ZnSO_4 \cdot 7H_2O$ K_2SO_4
Agent...................per cent	0·5	2·5	0·5	2·5	1·5 1·0
Water used............ $\frac{cc.}{100}$ gms.	34	32	33	33	32
Days in mould..................	1	1	1	1/6	1/8
Age when broken....... days	8	7	8	7	9
Weight briquette....... gms.	91·2	74·1	94·3	94·9	101·4
Tensile strength......lb./sq. in.	160	96	255	265	479
Water in plaster when broken...............per cent	9·91	15·29	10·66	12·49	15·80
Time of setting......... hours	$>7\frac{1}{2}$	$4\frac{1}{4}$	$6\frac{3}{4}$	$2\frac{1}{4}$	$1\frac{1}{3}$
Area shrinkage..........per cent	6	Swelled	7	6	1
Efflorescence..................	None	None	Some	Much	Very slight
Remarks........................	....	Cellular	....	....	....

Sample No. 4: –100 mesh

Test No.	43	43	43	168
Screen Analysis—				
+100 mesh................per cent	0·003	0·003	....	0·02
+100 mesh............... "	0·01	0·01	0·03	0·2
+200 mesh............... "	0·04	0·04	0·11	1·0
–200 mesh............... "	99·95	99·95	99·9	98·8
–325 mesh............... "	99·6	99·6	99·6	97·6
Time of grinding.............. hours	4	4	4	4
Agent added..........................	....	....	....	In water
Agent................................	None	None	None	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$
Agent.........................per cent	....	....	....	0·5
Water used.................. $\frac{cc.}{100}$ gms.	30	30	30	33
Days in mould........................	3	2	2	1
Age when broken............. days	7	7	7	7
Weight briquette............. gms.	99·6	98·7	98·7	97·6
Tensile strength.............lb./sq. in.	194	145	192	390
Water in plaster when broken..per cent	6·13	5·25	5·45	9·96
Time of setting............... hours	$>8\frac{1}{2}$	$>8\frac{1}{2}$	$>8\frac{1}{2}$	>7
Area shrinkage................per cent	7	7	8	6
Efflorescence........................	None	None	None	None
Remarks..............................	....	....	....	....

Sample No. 4: —100 mesh—Continued

Test No.	50	75	1	206
Screen Analysis—				
+100 mesh . . . per cent	0·004	0·003		
+150 mesh . . . "	0·01	0·01	0·1	0·2
+200 mesh . . . "	0·08	0·04	0·9	0·4
—200 mesh . . . "	99·9	99·95	99·0	99·4
—325 mesh . . . "	99·4	99·6	97·2	98·5
Time of grinding . . . hours	4	4	5	4
Agent added . . .	In water	In water	In pebble jar	In pebble jar
Agent . . .	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$	$MgCl_2 \cdot 6H_2O$	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$
Agent . . . per cent	3·5	2·5	0·5	0·5
Water used . . . $\frac{cc.}{100}$ gms.	35	25	26	28
Days in mould . . .	1	1	3	1
Age when broken . . . days	7	9	7	8
Weight briquette . . . gms.	98·1	108·3	106·2	103·0
Tensile strength . . . lb./sq. in.	162	72	135	294
Water in plaster when broken . . per cent	16·44	6·96	5·28	5·80
Time of setting . . . hours	1½	>8	>8	>8
Area shrinkage . . . per cent	Swelled 25%	4	5	10
Efflorescence . . .	None	Slightly chalky	Some	Some
Remarks . . .	Cellular, small cells laminated			

Sample No. 4: —100 mesh—Continued

Test No.	2	3	4	5
Screen Analysis—				
+100 mesh . . . per cent	0·1	0·1	0·1	0·3
+150 mesh . . . "	0·1	0·1	0·2	0·1
+200 mesh . . . "	0·9	1·1	1·4	1·6
—200 mesh . . . "	98·9	98·7	98·3	98·0
—325 mesh . . . "	97·2	96·8	96·4	96·5
Time of grinding . . . hours	5	5	5	5
Agent added . . .	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent . . .	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$
Agent . . . per cent	1·0	1·5	2·0	2·5
Water used . . . $\frac{cc.}{100}$ gms.	26	26	25	25
Days in mould . . .	3	3	1	1
Age when broken . . . days	7	8	7	8
Weight briquette . . . gms.	105·1	105·2	106·3	106·6
Tensile strength . . . lb./sq. in.	136	146	146	160
Water in plaster when broken . . per cent	5·67	6·25	5·98	6·83
Time of setting . . . hours	>8¼	>8	>8¼	>8½
Area shrinkage . . . per cent	5	3	3	5
Efflorescence . . .	Some	Considerable	Much	Much
Remarks . . .	. . .	. . .	. . .	. . .

Sample No. 4: —100 mesh—Continued

Test No.	207	6	7	44
Screen Analysis—				
+100 mesh................per cent	0·2	0·2	0·3	0·003
+150 mesh.............. "	0·4	0·2	0·2	0·01
+200 mesh.............. "	1·6	1·4	1·8	0·04
—200 mesh.............. "	97·8	98·2	97·7	99·95
—325 mesh.............. "	95·8	96·5	96·2	99·6
Time of grinding............. hours	4	5	5	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In water
Agent................................	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$
Agent.........................per cent	2·5	3·0	3·5	3·5
Water used................. $\frac{cc.}{100}$ gms.	26	25	26	28
Days in mould........................	1	1	1	1
Age when broken............ days	8	8	10	10
Weight briquette............ gms.	106·6	106·1	104·2	106·6
Tensile strength............lb./sq. in.	296	161	159	252
Water in plaster when broken..per cent	7·43	6·69	7·21	9·64
Time of setting............... hours	>8½	>8¼	8¼	>8
Area shrinkage................per cent	6	5	4	2
Efflorescence........................	Much	Much	Much	Much
Remarks..............................	....	....	....	....

Sample No. 4: —100 mesh—Continued

Test No.	8	8	8	8
Screen Analysis—				
+100 mesh................per cent	0·6	0·6	0·2	0·4
+150 mesh.............. "	0·6	0·6	0·2	0·4
+200 mesh.............. "	2·2	2·2	0·8	1·0
—200 mesh.............. "	96·6	96·6	98·8	98·2
—325 mesh.............. "	95·8	95·8	98·7	98·1
Time of grinding............. hours	5	5	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent................................	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$
Agent.........................per cent	4·0	4·0	4·0	4·0
Water used................. $\frac{cc.}{100}$ gms.	24	23	26	27
Days in mould........................	1	1	2	1
Age when broken............ days	13	11	11	8
Weight briquette............ gms.	107·4	109·5	107·0	104·9
Tensile strength............lb./sq. in.	92	167	401	323
Water in plaster when broken..per cent	7·37	6·56	9·96	7·87
Time of setting............... hours	>7¾	>7¾	>7¾	>7¾
Area shrinkage................per cent	2	4	4	7
Efflorescence........................	Much	Much	Much	Much
Remarks..............................	....	....	....	....

Sample No. 4: *—100 mesh*—Continued

Test No.	8	9	10	11
Screen Analysis—				
+100 mesh................per cent	0·4	0·5	0·7	3·4
+150 mesh............... "	0·4	0·6	0·6	1·1
+200 mesh............... "	1·0	2·7	2·4	4·4
—200 mesh............... "	98·2	96·2	96·3	91·1
—325 mesh............... "	98·1	95·9	95·6	94·0
Time of grinding.............. hours	4	5	5	5
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent................................	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$
Agent.........................per cent	4·0	4·5	5·0	10·0
Water used.................. $\frac{\text{cc.}}{100}$ gms.	26	23	23	19
Days in mould........................	1	1	1	1
Age when broken............. days	8	13	12	12
Weight briquette............. gms.	105·9	110·4	111·0	121·1
Tensile strength.............lb./sq. in.	356	87	71	49
Water in plaster when broken..per cent	8·78	8·08	8·08	12·76
Time of setting............... hours	>7¾	8	6¼	5¾
Area shrinkage................per cent	7	2	2	2
Efflorescence........................	Much	Much	Much	Much
Remarks..............................	....	....	....	....

Sample No. 4: *—100 mesh*—Continued

Test No.	13	141	14	153
Screen Analysis—				
+100 mesh................per cent	0·2	....	0·2	0·02
+150 mesh............... "	0·03	0·01	0·01	0·03
+200 mesh............... "	0·4	0·4	0·12	0·35
—200 mesh............... "	99·4	99·6	99·7	99·6
—325 mesh............... "	98·6	98·7	99·1	98·9
Time of grinding.............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent................................	Na_2SO_4	Na_2SO_4	Na_2SO_4	Na_2SO_4
Agent.........................per cent	0·5	0·5	1·0	1·0
Water used.................. $\frac{\text{cc.}}{100}$ gms.	30	30	31	33
Days in mould........................	1	1	1	1
Age when broken............. days	7	7	7	8
Weight briquette............. gms.	103·4	103·7	103·6	99·3
Tensile strength.............lb./sq. in.	307	361	282	317
Water in plaster when broken..per cent	9·69	9·92	10·76	10·89
Time of setting............... hours	5	5	2¾	2¾
Area shrinkage................per cent	4	5	1	5
Efflorescence........................	Some	Some	Some	Considerable
Remarks..............................	....	....	....	....

Sample No. 4: *—100 mesh*—Continued

Test No.	15	16	17	18
Screen Analysis—				
+100 mesh................per cent	0·03	0·12	0·01	0·004
+150 mesh.............. "	0·01	0·04	0·01	0·006
+200 mesh.............. "	0·12	0·6	0·09	0·07
—200 mesh.............. "	99·8	99·2	99·9	99·9
—325 mesh.............. "	99·1	98·6	99·3	99·4
Time of grinding............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent................................	Na_2SO_4	Na_2SO_4	Na_2SO_4	Na_2SO_4
Agent.........................per cent	1·5	2·0	2·5	3·0
Water used................ $\frac{\text{cc.}}{100}$ gms.	32	32	32	30
Days in mould........................	1	1	1	1
Age when broken............ days	7	7	7	7
Weight briquette............ gms.	102·8	103·6	105·0	108·2
Tensile strength............lb./sq. in.	307	310	359	343
Water in plaster when broken..per cent	12·00	11·97	12·34	12·44
Time of setting.............. hours	1¾	1¾	1¼	1
Area shrinkage...............per cent	1	1	4	2
Efflorescence........................	Considerable	Much	Much	Much
Remarks..............................	....	....	....	....

Sample No. 4: *—100 mesh*—Continued

Test No.	19	45	20	21
Screen Analysis—				
+100 mesh................per cent	0·03	0·003	0·03	0·01
+150 mesh.............. "	0·02	0·01	0·10	0·04
+200 mesh.............. "	0·09	0·04	0·35	0·17
—200 mesh.............. "	99·9	99·95	99·5	99·8
—325 mesh.............. "	99·7	99·6	99·0	99·4
Time of grinding............. hours	4	4	4	4
Agent added..........................	In pebble jar	In water	In pebble jar	In pebble jar
Agent................................	Na_2SO_4	Na_2SO_4	Na_2SO_4	Na_2SO_4
Agent.........................per cent	3·5	3·5	4·0	4·5
Water used................ $\frac{\text{cc.}}{100}$ gms.	35	35	35	34
Days in mould........................	1	1	1	1
Age when broken............ days	7	8	7	7
Weight briquette............ gms.	100·4	104·2	99·9	100·6
Tensile strength............lb./sq. in.	308	276	262	221
Water in plaster when broken..per cent	13·87	14·28	12·98	12·78
Time of setting.............. hours	1	(48 mins.)	1	1¼
Area shrinkage...............per cent	4	2	3	4
Efflorescence........................	Much	Much	Much	Much
Remarks..............................	....	....	....	....

Sample No. 4: *−100 mesh*—Continued

Test No.	22	125	105	46
Screen Analysis—				
+100 mesh .... per cent	0·04	0·8	0·1	0·004
+150 mesh .... "	0·02	0·2	0·01	0·01
+200 mesh .... "	0·10	0·2	0·3	0·08
−200 mesh .... "	99·8	98·8	99·6	99·9
−325 mesh .... "	99·7	99·96	99·3	99·4
Time of grinding .... hours	4	4	4	4
Agent added	In pebble jar	In pebble jar	In pebble jar	In water
Agent	Na_2SO_4	$Na_2S_2O_7$	$Na_2S_2O_7$	NH_4HSO_4
Agent .... per cent	5·0	0·5	2·5	3·5
Water used .... $\frac{\text{cc.}}{100}$ gms.	35	32	30	35
Days in mould	1	1	1	1
Age when broken .... days	7	8	7	8
Weight briquette .... gms.	101·3	97·7	102·2	68·1
Tensile strength .... lb./sq. in.	214	261	343	101
Water in plaster when broken .. per cent	12·88	11·19	16·15	16·26
Time of setting .... hours	1	5	1½	2
Area shrinkage .... per cent	4	3	Swelled	Swelled 3%
Efflorescence	Much	None	Some	None
Remarks	....	....	Laminated	Very cellular

Sample No. 4: *−100 mesh*—Continued

Test No.	51	23	24	25
Screen Analysis—				
+100 mesh .... per cent	1·4	0·01	0·01	0·002
+150 mesh .... "	1·0	0·02	0·01	0·003
+200 mesh .... "	2·4	0·09	0·12	0·08
−200 mesh .... "	95·2	99·9	99·9	99·9
−325 mesh .... "	94·0	99·4	99·2	99·5
Time of grinding .... hours	4	4	4	4
Agent added	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent	NH_4HSO_4	Volcanic ash	Volcanic ash	Volcanic ash
Agent .... per cent	3·5	0·5	1·0	1·5
Water used .... $\frac{\text{cc.}}{100}$ gms.	28	30	32	30
Days in mould	1	1	3	3
Age when broken .... days	9	8	7	7
Weight briquette .... gms.	94·3	100·1	97·2	100·9
Tensile strength .... lb./sq. in.	120	145	161	170
Water in plaster when broken .. per cent	14·22	6·19	6·10	6·00
Time of setting .... hours	(39 mins.)	>8	>8	>8
Area shrinkage .... per cent	Swelled	6	8	8
Efflorescence	None	None	None	None
Remarks	Cellular			

Sample No. 4: —100 mesh—Continued

Test No.	26	27	28	29
Screen Analysis—				
+100 mesh....per cent	0·01	0·003	0·003	0·002
+150 mesh.... "	0·01	0·007	0·007	0·004
+200 mesh.... "	0·07	0·06	0·05	0·05
−200 mesh.... "	99·9	99·9	99·9	99·95
−325 mesh.... "	99·5	99·5	99·7	99·7
Time of grinding.... hours	4	4	4	4
Agent added....	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent....	Volcanic ash	Volcanic ash	Volcanic ash	Volcanic ash
Agent....per cent	2·0	2·5	3·0	3·5
Water used.... $\frac{\text{cc.}}{100}$ gms.	30	30	31	31
Days in mould....	3	2	2	2
Age when broken.... days	7	7	7	7
Weight briquette.... gms.	100·0	99·5	98·0	98·3
Tensile strength....lb./sq. in.	182	145	152	152
Water in plaster when broken..per cent	6·14	6·33	6·32	6·27
Time of setting.... hours	>8	>8	>8	>8
Area shrinkage....per cent	7	4	6	6
Efflorescence....	None	None	None	None
Remarks....	....	....	....	....

Sample No. 4: —100 mesh—Concluded

Test No.	30	31	32	32	32
Screen Analysis—					
+100 mesh....per cent	....	....	0·001	0·001	0·2
+150 mesh.... "	0·01	0·01	0·006	0·006	None
+200 mesh.... "	0·08	0·04	0·08	0·08	0·2
−200 mesh.... "	99·9	99·95	99·9	99·9	99·6
−325 mesh.... "	99·5	99·7	99·6	99·6	99·6
Time of grinding.... hours	4	4	4	4	4
Agent added....	In pebble jar	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent....	Volcanic ash	Volcanic ash	Volcanic ash	Volcanic ash	Volcanic ash
Agent....per cent	4·0	4·5	5·0	5·0	5·0
Water used.... $\frac{\text{cc.}}{100}$ gms.	31	32	32	30	30
Days in mould....	2	2	1	2	2
Age when broken.... days	7	7	7	7	7
Weight briquette.... gms.	98·1	97·8	95·7	97·8	98·6
Tensile strength....lb./sq. in.	155	160	136	155	182
Water in plaster when broken....per cent	6·28	6·29	6·17	5·50	5·73
Time of setting.... hours	>8	>8	>8	>8	>8
Area shrinkage....per cent	8	8	10	8	9
Efflorescence....	None	None	None	None	None
Remarks....	....	....	....	....	....

Sample No. 5: —100 mesh

Test No.	53	169	73	221	222
Screen Analysis—					
+100 mesh.........per cent	1·6	2·0	4·0	2·6	3·0
+150 mesh......... "	1·2	1·4	1·6	2·8	2·2
+200 mesh......... "	2·6	5·6	5·6	6·6	6·2
—200 mesh......... "	94·6	91·0	88·8	88·0	88·6
—325 mesh......... "	92·0	90·0	90·0	88·5	88·7
Time of grinding..... hours	4	4	4	4	4
Agent added................	....	In water	In pebble jar	In pebble jar	In pebble jar
Agent........................	None	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$	$Al_2(SO_4)_3 \cdot 18H_2O$	$Al_2(SO_4)_3 \cdot 18H_2O$
Agent...............per cent	....	0·5	2·5	0·5	2·5
Water used.......... cc./100 gms.	32	32	28	30	31
Days in mould..............	2	1	1	1	1
Age when broken.... days	7	7	7	8	8
Weight briquette.... gms.	94·3	94·5	105·3	95·6	96·1
Tensile strength....lb./sq. in.	239	271	327	264	227
Water in plaster when broken.............per cent	7·93	7·91	11·66	6·60	8·35
Time of setting...... hours	>9	>7	3	>8	>8
Area shrinkage........per cent	12	13	4	14	12
Efflorescence................	None	Slight	Slightly chalky	None	None
Remarks..................	....	....	....	....	....

Sample No. 5: —100 mesh—Continued

Test No.	71	111	142	154	205
Screen Analysis—					
+100 mesh...........per cent	1·6	2·4	1·2	1·2	2·6
+150 mesh........... "	1·2	0·8	2·0	1·2	2·2
+200 mesh........... "	2·6	5·2	4·8	3·8	7·2
—200 mesh........... "	94·6	91·6	92·0	93·8	88·0
—325 mesh........... "	92·0	90·0	90·0	90·8	87·8
Time of grinding......... hours	4	4	4	4	4
Agent added.....................	In water	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..........................	$MgCl_2 \cdot 6H_2O$	$MgSO_4 \cdot 7H_2O$	Na_2SO_4	Na_2SO_4	Na_2SO_4
Agent...................per cent	2·5	2·5	0·5	1·0	2·5
Water used............ cc./100 gms.	25	25	30	33	32
Days in mould....................	1	1	1	1	1
Age when broken......... days	10	10	7	8	7
Weight briquette......... gms.	105·7	104·2	100·6	96·3	95·7
Tensile strength........lb./sq. in.	104	377	400	419	489
Water in plaster when broken................per cent.	8·00	9·72	10·01	10·53	10·31
Time of setting........... hours	>8	>7	5¾	5½	3½
Area shrinkage...........per cent	7	7	9	12	13
Efflorescence.....................	Slightly chalky	Much	Some	Considerable	Much
Remarks.......................	....	....	....	....	....

Sample No. 5: —100 mesh—Continued

Test No.	195[1]	48	126	184	186
Screen Analysis—					
+100 mesh..........per cent	1·0	2·6	1·0	0·6	0·8
+150 mesh.......... "	1·6	1·8	0·4	0·8	1·6
+200 mesh.......... "	3·6	4·8	4·2	5·0	4·2
−200 mesh.......... "	93·8	90·8	94·4	93·6	93·4
−325 mesh.......... "	89·0	92·0	93·9	94·0	89·0
Time of grinding......... hours	4	4	4	4	4
Agent added....................	In pebble jar	In pebble jar	In pebble jar	In pebble jar	In water
Agent..........................	Na_2SO_4	Na_2SO_4	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$
Agent...................per cent	2·5	3·5	0·5	2·5	2·5
Water used............. $\frac{\text{cc.}}{100}$ gms.	32	35	32	26	26
Days in mould..................	1/6	1	1	1	1/6
Age when broken................	7	8	8	7	9
Weight briquette......... gms.	102·3	95·5	96·8	105·7	108·3
Tensile strength.......lb. /sq. in.	149	444	418	434	373
Water in plaster when broken..............per cent	6·94	11·94	10·06	10·65	9·44
Time of setting.......... hours	1½	2½	>7½	1	1
Area shrinkage...........per cent	2	14	9	7	6
Efflorescence..................	Much	Much	Slight	Much	Much
Remarks........................	....	....	....	....	....

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[1] Test No. 195 100-mesh anhydrite was calcined at 860° C. for 1 hour, then ground with agent for 4 hours.

Sample No. 5: —100 mesh—Continued

Test No.	173	185	81	171	172
Screen Analysis—					
+100 mesh..........per cent	3·8	0·8	1·6	3·8	3·8
+150 mesh.......... "	2·2	1·6	1·2	2·2	2·2
+200 mesh.......... "	6·8	4·2	2·6	6·8	6·8
−200 mesh.......... "	87·2	93·4	94·6	87·2	87·2
−325 mesh.......... "	90·0	89·0	92·0	90·0	90·0
Time of grinding......... hours	4	4	4	4	4
Agent added....................	In pebble jar	In water	In water	In pebble jar	In pebble jar
Agent..........................	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$
Agent...................per cent	2·5	2·5	2·5	2·5	2·5
Water used............. $\frac{\text{cc.}}{100}$ gms.	28	28	30	30	32
Days in mould..................	1	1/6	1	1	1
Age when broken......... days	8	9	8	8	8
Weight briquette......... gms.	101·8	105·6	105·2	100·9	98·8
Tensile strength.......lb. /sq. in.	483	381	582	414	360
Water in plaster when broken..............per cent	10·12	10·66	12·15	10·51	10·44
Time of setting.......... hours	1¼	1¼	1¾	2½	2¾
Area shrinkage...........per cent	7	7	8	7	8
Efflorescence..................	Much	Much	Much	Much	Much
Remarks........................	....	....	....	....	....

Sample No. 5: −100 mesh—Continued

Test No.	174	175	193	176	178
Screen Analysis—					
+100 mesh...........per cent	3·0	3·0	0·8	3·0	1·4
+150 mesh........... "	2·8	2·8	1·6	2·8	2·4
+200 mesh........... "	6·0	6·0	4·2	6·0	5·8
−200 mesh........... "	88·2	88·2	93·4	88·2	90·4
−325 mesh........... "	90·0	90·0	89·0	90·0	92·0
Time of grinding......... hours	4	4	4	4	4
Agent added......................	In pebble jar	In pebble jar	In water	In pebble jar	In pebble jar
Agent............................	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$
Agent....................per cent	2·5	2·5	2·5	2·5	2·5
Water used.............. cc./100 gms.	34	36	36	38	40
Days in mould...................	1	1	1	1	1
Age when broken......... days	7	7	8	7	7
Weight briquette......... gms.	97·2	94·0	95·2	91·1	87·5
Tensile strength.......lb. /sq. in.	291	255	353	239	238
Water in plaster when broken...............per cent	10·77	10·58	11·51	10·71	10·93
Time of setting........... hours	4½	5¾	5½	7½	>7¾
Area shrinkage...........per cent	9	11	10	11	11
Efflorescence.....................	Much	Much	Much	Much	Much
Remarks.......................	....	....	....	....	....

Sample No. 5: −100 mesh—Continued

Test No.	179	180	181	182	183
Screen Analysis—					
+100 mesh...........per cent	1·4	1·4	1·4	0·6	0·6
+150 mesh........... "	2·4	2·4	2·4	0·8	0·8
+200 mesh........... "	5·8	5·8	5·8	5·0	5·0
−200 mesh........... "	90·4	90·4	90·4	93·6	93·6
−325 mesh........... "	92·0	92·0	92·0	94·0	94·0
Time of grinding......... hours	4	4	4	4	4
Agent added......................	In pebble jar	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent............................	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$
Agent....................per cent	2·5	2·5	2·5	2·5	2·5
Water used.............. cc./100 gms.	42	44	46	48	50
Days in mould...................	1	1	1	1	1
Age when broken......... days	7	7	8	7	7
Weight briquette......... gms.	85·0	80·1	79·0	76·5	75·2
Tensile strength.......lb. /sq. in.	183	181	186	164	155
Water in plaster when broken...............per cent	10·85	10·84	10·53	11·12	10·96
Time of setting........... hours	>7¾	>8½	>8½	>8¾	>9
Area shrinkage...........per cent	12	15	17	17	18
Efflorescence.....................	Much	Much	Much	Much	Much
Remarks.......................	....	....	....	....	....

Sample No. 5: —100 mesh—Continued

Test No.	188[2]	187[2]	194[2]	190	56
Screen Analysis—					
+100 mesh..........per cent	1·0	1·0	1·0	1·6	7·4
+150 mesh.......... "	1·0	1·0	1·0	1·8	1·0
+200 mesh.......... "	3·2	3·2	3·2	4·0	3·8
—200 mesh.......... "	94·8	94·8	94·8	92·6	87·8
—325 mesh.......... "	90·4	90·4	90·4	89·4	96·0
Time of grinding......... hours	4	4	4	4	4
Agent added.....................	In water	In water	In water	In pebble jar	In pebble jar
Agent...........................	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$	$(NH_4)_2SO_4$	NH_4HSO_4
Agent...................per cent	2·5	2·5	2·5	2·5	3·5
Water used............. $\frac{\text{cc.}}{100}$ gms.	26	28	36	30	35
Days in mould..................	1/6	1/6	2	1	1
Age when broken......... days	9	9	7	14	10
Weight briquette......... gms.	108·6	105·6	96·4	97·3	90·1
Tensile strength.......lb. /sq. in.	478	389	350	587	328
Water in plaster when broken..............per cent	10·30	10·11	12·08	8·93	8·86
Time of setting........... hours	2	$1\frac{3}{4}$	$6\frac{1}{2}$	>8	>$8\frac{1}{2}$
Area shrinkage...........per cent	6	10	12	16	15
Efflorescence....................	Much	Much	Much	None	None
Remarks......................	....	....	....	Warped	

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[2] Tests No. 188, 187, 194-A 1 % solution of hydrochloric acid was used instead of water.

Sample No. 5: —100 mesh—Continued

Test No.	191	192	198	197	229[3]
Screen Analysis—					
+100 mesh..........per cent	1·0	2·2	2·4	2·8	2·8
+150 mesh.......... "	1·8	1·8	3·8	2·4	2·4
+200 mesh.......... "	3·2	5·2	7·0	6·8	6·8
—200 mesh.......... "	94·0	90·8	86·8	88·0	88·0
—325 mesh.......... "	89·0	86·2	87·4	88·4	88·4
Time of grinding......... hours	4	4	4	4	4
Agent added.....................	In pebble jar	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent...........................	$Na_2B_4O_7$	$Na_2B_4O_7$	Na_2CO_3	Na_2CO_3	Na_2CO_3
Agent...................per cent	0·5	2·5	0·5	2·5	2·5
Water used............. $\frac{\text{cc.}}{100}$ gms.	32	31	30	30	30
Days in mould..................	1	1	1	1	2
Age when broken......... days	8	8	8	8	11
Weight briquette......... gms.	91·9	92·7	98·3	96·2	99·6
Tensile strength.......lb. /sq. in.	25	27	437	391	361
Water in plaster when broken..............per cent	3·47	4·55	8·95	11·40	13·19
Time of setting........... hours	>7	>$6\frac{1}{2}$	>7	3	....
Area shrinkage...........per cent	13	8	11	12	6
Efflorescence....................	Slight	Slight	Considerable	Very much	Much
Remarks......................	....	....	....	....	....

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[3] In Test No. 229 after making briquettes, they were covered with water and allowed to remain so for 21 hours, then removed from water, and dried.

Sample No. 5: −100 mesh—Continued

Test No.	230	237	237	237	240
Screen Analysis—					
+100 mesh...........per cent	4·4	4·4	4·4	4·4	2·4
+150 mesh........... "	2·8	3·2	3·2	3·2	3·2
+200 mesh........... "	7·4	6·2	6·2	6·2	7·4
−200 mesh........... "	85·4	86·2	86·2	86·2	87·0
−325 mesh........... "	88·0	90·0	90·0	90·0	90·0
Time of grinding......... hours	4	4	4	4	4
Agent added.....................	In pebble jar	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..........................	$ZnSO_4 \cdot 7H_2O$ K_2SO_4	$ZnSO_4 \cdot 7H_2O$ Na_2SO_4	$ZnSO_4 \cdot 7H_2O$ Na_2SO_4	$ZnSO_4 \cdot 7H_2O$ Na_2SO_4	$ZnSO_4 \cdot 7H_2O$ $Ca(OH)_2$
Agent..................per cent	1·5 1·0	1·5 1·0	1·5 1·0	1·5 1·0	1·5 0·25
Water used............ $\frac{cc.}{100}$ gms.	32	33	33	32	32
Days in mould..................	2	1	1	⅛	1
Age when broken......... days	7	8	7	9	8
Weight briquette......... gms.	97·7	98·3	96·8	99·0	96·5
Tensile strength.......lb. /sq. in.	332	483	400	334	400
Water in plaster when broken...............per cent	11·58	12·88	11·80	11·39	9·60
Time of setting........... hours	1¾	2	2	2	>8¾
Area shrinkage.... ....per cent	4	10	9	8	11
Efflorescence....................	Very slight	Much	Much	Hard crust	None
Remarks........................	....	Warped	Warped	....	....

Sample No. 5: −100 mesh—Concluded

Test No.	243	246	252	255
Screen Analysis—				
+100 mesh................per cent	4·2	2·4	2·0	2·4
+150 mesh............... "	3·2	2·8	2·8	2·6
+200 mesh............... "	7·2	7·4	8·2	5·6
−200 mesh............... "	85·4	87·4	87·0	89·4
−325 mesh............... "	90·0	88·8	90·0	90·8
Time of grinding............ hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..............................	$ZnSO_4 \cdot 7H_2O$	$ZnSO_4 \cdot 7H_2O$ $Na_2S_2O_7$	K_2SO_4	$ZnSO_4 \cdot 7H_2O$ $(NH_4)_2SO_4$
Agent........................per cent	2·5	1·5 0·5	2·5	1·5 1·0
Water used................. $\frac{cc.}{100}$ gms.	30	33	35	33
Days in mould.......................	1	1	1	1
Age when broken............. days	7	8	8	9
Weight briquette............. gms.	98·0	97·4	91·4	94·4
Tensile strength.............lb./sq. in.	218	359	215	309
Water in plaster when broken.per cent	8·22	11·13	7·50	10·52
Time of setting.............. hours	>8	6¼	5¼	>7¾
Area shrinkage................per cent	12	10	8	14
Efflorescence.........................	None	Very slight	Slightly chalky	None
Remarks..............................	....	....	....	Hard crust

Sample No. 6: —100 mesh

Test No.	54	170	163	112
Screen Analysis—				
+100 mesh.................per cent	4·4	12·2	9·6	10·8
+150 mesh............... "	5·4	5·8	5·4	2·4
+200 mesh............... "	5·0	7·2	7·2	8·6
—200 mesh............... "	85·2	74·8	77·8	78·2
—325 mesh............... "	98·0	90·0	92·0	92·0
Time of grinding.............. hours	4	4	$4\frac{1}{4}$	4
Agent added..........................	....	In water	In pebble jar	In pebble jar
Agent................................	None	Al_2Na_2 $(SO_4)_4 \cdot 24H_2O$	Al_2Na_2 $(SO_4)_4 \cdot 24H_2O$	$MgSO_4 \cdot 7H_2O$
Agent.........................per cent	....	0·5	2·5	2·5
Water used.................. $\frac{\text{cc.}}{100}$ gms.	43	45	45	36
Days in mould........................	2	1	1	1
Age when broken............. days	7	7	8	10
Weight briquette............. gms.	78·7	76·7	78·7	85·3
Tensile strength.............lb./sq. in.	342	461	530	374
Water in plaster when broken.per cent	12·47	13·07	17·79	13·94
Time of setting............... hours	$>8\frac{1}{2}$	$>8\frac{1}{2}$	>7	>8
Area shrinkage................per cent	21	23	18	15
Efflorescence.........................	None	None	Slight	Much
Remarks..............................	....	....	Laminated	....

Sample No. 6: —100 mesh—Continued

Test No.	143	155	49	127
Screen Analysis—				
+100 mesh.................per cent	11·0	8·0	9·6	5·8
+150 mesh............... "	6·4	6·2	7·4	2·4
+200 mesh............... "	7·6	8·0	5·0	7·6
—200 mesh............... "	75·0	77·8	78·0	87·8
—325 mesh............... "	88·0	90·0	96·0	96·3
Time of grinding.............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent................................	Na_2SO_4	Na_2SO_4	Na_2SO_4	$Na_2S_2O_7$
Agent.........................per cent	0·5	1·0	3·5	0·5
Water used.................. $\frac{\text{cc.}}{100}$ gms.	44	45	44	45
Days in mould........................	1	1	1	1
Age when broken............. days	7	8	8	7
Weight briquette............. gms.	77·5	77·8	80·5	80·1
Tensile strength.............lb./sq. in.	411	260	415	398
Water in plaster when broken..per cent	13·95	14·50	15·71	13·81
Time of setting............... hours	>8	>8	>8	>8
Area shrinkage................per cent	21	19	23	20
Efflorescence.........................	Some	Considerable	Much	None
Remarks..............................	....	....	....	....

Sample No. 6: —100 mesh—Concluded

Test No.	106	100	257	257
Screen Analysis—				
+100 mesh.................per cent	14·0	4·4	9·0	9·0
+150 mesh............... “	3·8	5·4	7·2	7·2
+200 mesh............... “	8·8	5·0	8·8	8·8
—200 mesh............... “	73·4	85·2	75·0	75·0
—325 mesh............... “	92·0	98·0	93·8	93·8
Time of grinding.............. hours	4	4	4	4
Agent added...........................	In pebble jar	In water	In pebble jar	In pebble jar
Agent..................................	$Na_2S_2O_7$	NH_4HSO_4	$ZnSO_4 \cdot 7H_2O$ K_2SO_4	$ZnSO_4 \cdot 7H_2O$ K_2SO_4
Agent.........................per cent	2·5	1·0	1·5 1·0	1·5 1·0
Water used.................. $\frac{\text{cc.}}{100}$ gms.	45	50	45	45
Days in mould.........................	1	2	1	1
Age when broken............. days	15	10	8	13
Weight briquette............. gms.	82·6	75·8	82·7	80·3
Tensile strength.............lb./sq. in.	345	353	292	400
Water in plaster when broken..per cent	19·87	16·09	17·47	17·92
Time of setting............... hours	>8	>8	7	7
Area shrinkage................per cent	24	25	15	13
Efflorescence..........................	Some	None	None	None
Remarks.............................	Grey	....	Hard surface	Hard surface

Sample No. 7: —100 mesh

Test No.	33	34	35	36	37
Screen Analysis—					
+100 mesh...........per cent	0·4	1·2	1·2	0·4	1·2
+150 mesh........... “	0·6	1·2	0·6	0·8	0·6
+200 mesh........... “	2·4	3·0	4·4	1·6	1·2
—200 mesh........... “	96·6	94·6	93·8	97·2	97·0
—325 mesh........... “	98·3	98·9	99·0	98·8	99·5
Time of grinding......... hours	4	4	4	4	4
Agent added......................	In pebble jar	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent............................	NH_4HSO_4	NH_4HSO_4	NH_4HSO_4	NH_4HSO_4	NH_4HSO_4
Agent....................per cent	0·5	1·0	1·5	2·0	2·5
Water used............. $\frac{\text{cc.}}{100}$ gms.	35	35	35	35	35
Days in mould...................	3	3	3	2	2
Age when broken......... days	7	7	7	8	8
Weight briquette......... gms.	88·9	90·3	90·5	91·1	91·3
Tensile strength........lb./sq. in.	288	305	328	383	409
Water in plaster when broken...............per cent	8·89	9·41	10·28	11·45	11·80
Time of setting........... hours	>8	>8	>7¾	>7¾	>7½
Area shrinkage............per cent	16	15	14	13	13
Efflorescence....................	None	None	None	None	None
Remarks..........................	....	....	....	....	....

Sample No. 7: −100 mesh—Concluded

Test No.	38	39	40	41	42
Screen Analysis—					
+100 mesh per cent	1·0	0·8	1·4	1·0	1·6
+150 mesh "	1·2	1·6	0·8	0·8	0·6
+200 mesh "	2·8	1·8	2·0	2·6	1·4
−200 mesh "	95·0	95·8	95·8	95·6	96·4
−325 mesh "	99·3	99·0	98·6	98·1	98·9
Time of grinding hours	4	4	4	4	4
Agent added	In pebble jar	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent	NH_4HSO_4	NH_4HSO_4	NH_4HSO_4	NH_4HSO_4	NH_4HSO_4
Agent per cent	3·0	3·5	4·0	4·5	5·0
Water used $\frac{\text{cc.}}{100}$ gms.	35	35	35	35	35
Days in mould	1	1	1	1	1
Age when broken days	9	9	12	11	14
Weight briquette gms.	91·0	90·4	90·6	90·6	91·3
Tensile strength lb./sq. in.	390	421	419	431	375
Water in plaster when broken per cent	12·17	12·40	11·52	12·23	12·55
Time of setting hours	>7½	>8¼	>7¼	>7¼	>8
Area shrinkage per cent	14	14	15	15	15
Efflorescence	None	None	None	None	None
Remarks					

Sample No. 8: −20 mesh

Test No.	66	70	78	113
Screen Analysis—				
+100 mesh per cent	0·1	24·0	30·0	3·8
+150 mesh "	0·2	3·2	3·4	0·4
+200 mesh "	0·6	8·2	6·0	2·6
−200 mesh "	99·1	64·6	60·6	93·2
−325 mesh "	98·3	64·0	66·0	98·0
Time of grinding hours	4	(5 min.)	4	4
Agent added			In pebble jar	In pebble jar:
Agent	None	None	$Al_2Na_2(SO_4)_4\cdot 24H_2O$	$MgSO_4\cdot 7H_2O$
Agent per cent			2·5	2·5
Water used $\frac{\text{cc.}}{100}$ gms.	27	22	22	28
Days in mould	1	1	1	1
Age when broken days	8	8	7	10
Weight briquette gms.	102·5	104·1	104·6	97·4
Tensile strength lb./sq. in.	121	52	204	194
Water in plaster when broken per cent	8·90	6·97	14·02	11·20
Time of setting hours	>8	>8½	3	>8¼
Area shrinkage per cent	6	6	Swelled	6
Efflorescence	None	None	Slight	Much
Remarks		Chalky surface	Laminated	

Sample No. 8: —20 mesh—Continued

Test No.	144	156	60	63
Screen Analysis—				
+100 mesh..............per cent	0·6	0·8	0·4	21·0
+150 mesh.............. "	0·2	0·6	0·2	3·2
+200 mesh.............. "	0·6	1·6	0·4	7·8
—200 mesh.............. "	98·6	97·0	99·0	68·0
—325 mesh.............. "	97·6	97·3	98·0	64·0
Time of grinding............. hours	4	4	4	(5 min.)
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..................................	Na_2SO_4	Na_2SO_4	Na_2SO_4	Na_2SO_4
Agent.........................per cent	0·5	1·0	2·5	2·5
Water used.................. $\frac{\text{cc.}}{100}$ gms.	32	34	31	23
Days in mould........................	1	1	1	1
Age when broken............. days	8	8	8	8
Weight briquette............. gms.	96·9	92·3	97·8	108·5
Tensile strength............lb./sq. in.	218	223	259	147
Water in plaster when broken..per cent	10·78	11·40	12·83	9·56
Time of setting............... hours	5¼	3¾	1¾	5¾
Area shrinkage...............per cent	5	7	3	2
Efflorescence........................	Slight	Considerable	Much	Much
Remarks..............................	....	....	....	....

Sample No. 8: —20 mesh—Concluded

Test No.	128	107	101	235
Screen Analysis—				
+100 mesh................per cent	0·2	0·8	0·1	1·0
+150 mesh.............. "	0·4	0·2	0·2	0·6
+200 mesh.............. "	1·8	0·8	0·6	2·2
—200 mesh.............. "	97·6	98·2	99·1	96·2
—325 mesh.............. "	98·4	98·6	98·3	98·0
Time of grinding............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In water	In pebble jar
Agent..................................	$Na_2S_2O_7$	$Na_2S_2O_7$	NH_4HSO_4	$ZnSO_4 \cdot 7H_2O$ K_2SO_4
Agent.........................per cent	0·5	2·5	0·5	1·5 1·0
Water used.................. $\frac{\text{cc.}}{100}$ gms.	34	36	32	33
Days in mould........................	1	1	1	⅛
Age when broken............. days	8	9	8	9
Weight briquette............. gms.	93·4	95·1	95·9	98·0
Tensile strength............lb./sq. in.	252	301	233	370
Water in plaster when broken..per cent	11·54	16·16	11·72	15·63
Time of setting............... hours	6½	1½	7¾	1¼
Area shrinkage...............per cent	6	3	6	1
Efflorescence........................	Slight	Considerable	None	None
Remarks..............................	....	....	....	....

Sample No. 9: —20 mesh

Test No.	93	87	214[1]	223
Screen Analysis—				
+100 mesh...............per cent	0·2	23·8	0·06	0·04
+150 mesh.............. "	0·1	3·0	0·03	0·09
+200 mesh.............. "	0·2	5·8	0·07	0·2
−200 mesh.............. "	99·5	67·4	99·8	99·7
−325 mesh.............. "	98·6	66·0	99·0	97·5
Time of grinding............. hours	4	4	4	4
Agent added.........................	....	In pebble jar	....	In pebble jar
Agent...............................	None	$Al_2Na_2(SO_4)_4\cdot 24H_2O$	$Al_2(SO_4)_3\cdot 18H_2O$	$Al_2(SO_4)_3\cdot 18H_2O$
Agent........................per cent	....	2·5	....	0·5
Water used.................. $\frac{\text{cc.}}{100}$ gms.	30	20	30	30
Days in mould.......................	2	1	2	1
Age when broken............ days	7	7	7	8
Weight briquette............ gms.	101·8	106·2	106·5	100·3
Tensile strength............lb./sq. in.	121	252	369	137
Water in plaster when broken..per cent	5·93	11·80	9·94	4·94
Time of setting.............. hours	>8¾	4¼	>8½	>8
Area shrinkage...............per cent	5	Swelled	3	9
Efflorescence.......................	None	Slight	None	Slightly chalky
Remarks.............................	....	Cellular, laminated	....	....

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[1] Test No. 214—20-mesh anhydrite was soaked in 10% alum solution for 1½ hours, filtered and dried. Calcined to 580° C.—dull red for 2 hours, then ground for 4 hours.

Sample No. 9: —20 mesh—Continued

Test No.	224	114	145	157
Screen Analysis—				
+100 mesh...............per cent	0·01	1·0	0·1	0·2
+150 mesh.............. "	0·1	0·2	0·1	0·2
+200 mesh.............. "	0·4	0·6	0·8	0·4
−200 mesh.............. "	99·5	98·2	99·0	99·2
—325 mesh.............. "	97·5	99·4	98·4	97·0
Time of grinding............. hours	4	4	4	4
Agent added.........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent...............................	$Al_2(SO_4)_3\cdot 18H_2O$	$MgSO_4\cdot 7H_2O$	Na_2SO_4	Na_2SO_4
Agent........................per cent	2·5	2·5	0·5	1·0
Water used.................. $\frac{\text{cc.}}{100}$ gms.	30	26	32	31
Days in mould.......................	1	1	1	1
Age when broken............ days	8	9	8	8
Weight briquette............ gms.	94·5	107·0	100·4	103·0
Tensile strength............lb./sq. in.	142	215	345	310
Water in plaster when broken..per cent	9·33	7·39	8·62	8·79
Time of setting............. hours	>8	>8¼	>8½	3¾
Area shrinkage...............per cent	Swelled then shrunk slightly	3	5	4
Efflorescence.......................	Slight	Much	Slight	Considerable
Remarks.............................	Cellular, laminated	....	....	....

Sample No. 9: —20 mesh—Continued

Test No.	85	129	89	189	203
Screen Analysis—					
+100 mesh...........per cent	0·4	0·2	0·2	....	....
+150 mesh........... "	0·2	0·2	0·2	0·05	0·05
+200 mesh........... "	0·4	0·4	0·2	0·2	0·2
−200 mesh........... "	99·0	99·2	99·4	99·8	99·8
−325 mesh........... "	98·0	99·2	99·3	95·2	95·2
Time of grinding......... hours	4	4	4	4	4
Agent added.....................	In pebble jar	In pebble jar	In pebble jar	In water	In water
Agent............................	Na_2SO_4	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$
Agent.....................per cent	2·5	0·5	2·5	2·5	2·5
Water used............. $\frac{\text{cc.}}{100}$ gms.	28	32	30	30	32
Days in mould..................	1	1	1	$\frac{1}{6}$	$\frac{1}{6}$
Age when broken......... days	9	7	8	14	7
Weight briquette......... gms.	110·8	101·6	116·5	109·5	108·9
Tensile strength........lb./sq. in.	355	260	414	397	405
Water in plaster when broken...............per cent	11·27	8·60	17·17	15·72	14·94
Time of setting........... hours	1	>7	(49 min.)	(38 min.)	(40 min.)
Area shrinkage...........per cent	None	5	Swelled 4%	Swelled	Swelled
Efflorescence.....................	Much	Slight	Slight	Considerable	Considerable
Remarks.........................	....	....	Not cellular	Laminated, dense	Laminated, dense

Sample No. 9: —20 mesh—Concluded

Test No.	102	200	199	258
Screen Analysis—				
+100 mesh................per cent	0·2	0·2	1·2	2·8
+150 mesh............... "	0·1	0·2	0·4	3·4
+200 mesh............... "	0·2	1·2	0·8	12·2
−200 mesh............... "	99·5	98·4	97·6	81·6
−325 mesh............... "	98·6	94·8	97·7	94·0
Time of grinding............. hours	4	4	4	4
Agent added..........................	In water	In pebble jar	In pebble jar	In pebble jar
Agent.................................	NH_4HSO_4	Na_2CO_3	Na_2CO_3	$ZnSO_4 \cdot 7H_2O$ K_2SO_4
Agent.........................per cent	0·5	0·5	2·5	1·5 1·0
Water used................. $\frac{\text{cc.}}{100}$ gms.	33	30	30	66
Days in mould.......................	1	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{8}$
Age when broken............. days	7	7	7	10
Weight briquette............. gms.	99·5	103·7	104·5	74·0
Tensile strength.............lb./sq. in.	241	344	347	183
Water in plaster when broken.per cent	8·13	8·59	10·88	16·47
Time of setting............... hours	>8	$3\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$
Area shrinkage................per cent	5	3	3	5
Efflorescence.........................	None	Some	Much	None
Remarks..............................	....	....	....	Hard surface

Sample No. 10: —20 mesh

Test No.	94	218 [1]	88	133 [2]
Screen Analysis—				
+100 mesh per cent	0·8	0·03	42·2	42·2
+150 mesh “	0·03	0·2	1·4	1·4
+200 mesh “	0·6	0·8	4·6	4·6
—200 mesh “	98·6	99·0	51·8	51·8
—325 mesh “	98·9	98·6	60·0	60·0
Time of grinding hours	4	4	4	4
Agent added			In pebble jar	In pebble jar
Agent	None	None	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$
Agent per cent			2·5	2·5
Water used $\frac{\text{cc.}}{100}$ gms.	30	50	21	32
Days in mould	1	1	1	2
Age when broken days	7	8	7	8
Weight briquette gms.	98·7	74·7	113·0	98·4
Tensile strength lb./sq. in.	143	46	255	39
Water in plaster when broken per cent	6·79	5·30	10·95	1·39
Time of setting hours	>8	>24	4¼	26½
Area shrinkage per cent	8	6	2	17
Efflorescence	None	None	Slight	Much
Remarks				

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[1] Tests No. 216, 218—Sample was dried at 230° C.—expelling all water before grinding.
[2] Test No. 133—Sample from Test No. 88 calcined at dull red heat for one hour.

Sample No. 10: —20 mesh—Continued

Test No.	115	146	216 [1]	158
Screen Analysis—				
+100 mesh per cent	2·4	0·2	0·03	0·6
+150 mesh “	0·4	0·2	0·2	0·2
+200 mesh “	1·8	1·0	0·8	0·4
—200 mesh “	95·4	98·6	99·0	98·8
—325 mesh “	98·8	98·8	98·6	98·9
Time of grinding hours	4	4	4	4
Agent added	In pebble jar	In pebble jar	In water	In pebble jar
Agent	$MgSO_4 \cdot 7H_2O$	Na_2SO_4	Na_2SO_4	Na_2SO_4
Agent per cent	2·5	0·5	0·5	1·0
Water used $\frac{\text{cc.}}{100}$ gms.	28	32	50	34
Days in mould	1	1	2	1
Age when broken days	9	8	7	8
Weight briquette gms.	101·2	98·0	81·1	96·6
Tensile strength lb./sq. in.	247	303	103	279
Water in plaster when broken per cent	8·81	9·78	8·75	10·43
Time of setting hours	>8¼	4¼	3½	3
Area shrinkage per cent	2	4	7	5
Efflorescence	Much	Slight	Slight	Considerable
Remarks				

Sample No. 10: −20 mesh—Continued

Test No.	86	196 [3]	220 [1]	130
Screen Analysis—				
+100 mesh...............per cent	0·2	....	0·03	0·6
+150 mesh.............. "	0·2	0·2	0·2	0·6
+200 mesh.............. "	1·4	0·2	0·8	1·0
−200 mesh.............. "	98·2	99·6	99·0	97·8
−325 mesh.............. "	98·0	99·6	98·6	99·4
Time of grinding............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In water	In pebble jar
Agent..................................	Na_2SO_4	Na_2SO_4	Na_2SO_4	$Na_2S_2O_7$
Agent.........................per cent	2·5	2·5	2·5	0·5
Water used................. $\frac{\text{cc.}}{100}$ gms.	31	38	50	32
Days in mould........................	1	$\frac{1}{6}$	$\frac{1}{4}$	1
Age when broken............. days	9	7	7	8
Weight briquette............. gms.	102·0	93·7	82·9	98·4
Tensile strength.............lb./sq. in.	260	146	116	281
Water in plaster when broken..per cent	12·13	7·88	10·35	9·97
Time of setting............... hours	$1\frac{1}{4}$	$1\frac{3}{4}$	$3\frac{3}{4}$	$5\frac{1}{2}$
Area shrinkage................per cent	2	2	5	6
Efflorescence..........................	Much	Much	Much	Slight
Remarks..............................	....	....	....	....

[1] Test No. 220—Sample was dried at 230° C.—expelling all water before grinding.
[3] Test No. 196—Sample calcined at 860° C. for 45 minutes.

Sample No. 10: −20 mesh—Concluded

Test No.	90	212	213	232
Screen Analysis—				
+100 mesh...............per cent	0·8	0·2	0·6	0·6
+150 mesh.............. "	0·2	0·6	0·6	0·6
+200 mesh.............. "	0·8	2·6	1·8	2·0
−200 mesh.............. "	98·2	96·6	97·0	96·8
−325 mesh.............. "	98·8	93·8	95·0	98·0
Time of grinding............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..................................	$Na_2S_2O_7$	Na_2CO_3	Na_2CO_3	$ZnSO_4 \cdot 7H_2O$ K_2SO_4
Agent.........................per cent	2·5	0·5	2·5	1·5 1·0
Water used................. $\frac{\text{cc.}}{100}$ gms.	35	30	30	33
Days in mould........................	1	$\frac{1}{4}$	$\frac{1}{6}$	$\frac{1}{8}$
Age when broken............. days	8	7	7	9
Weight briquette............. gms.	98·1	100·1	97·5	99·2
Tensile strength.............lb./sq. in.	241	295	294	349
Water in plaster when broken..per cent	13·13	8·74	10·36	12·70
Time of setting............... hours	$2\frac{3}{4}$	5	$2\frac{1}{4}$	$1\frac{1}{4}$
Area shrinkage................per cent	2	5	6	1
Efflorescence..........................	Much	Some	Much	None
Remarks..............................	....	....	....	....

Sample No. 41: −100 mesh

Test No.	67	164	164	116
Screen Analysis—				
+100 mesh, per cent	0·2	1·4	1·4	6·2
+150 mesh, "	0·2	1·2	1·2	0·8
+200 mesh, "	1·0	1·6	1·6	3·8
−200 mesh, "	98·6	95·8	95·8	89·2
−325 mesh, "	98·0	98·0	98·0	97·9
Time of grinding, hours	Ground in burr mill	4¼	4¼	4
Agent added	....	In pebble jar	In pebble jar	In pebble jar
Agent	None	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$	$MgSO_4 \cdot 7H_2O$
Agent, per cent	....	2·5	2·5	2·5
Water used, $\frac{\text{cc.}}{100}$ gms.	37	45	40	35
Days in mould	2	1	2	2
Age when broken, days	7	8	7	9
Weight briquette, gms.	84·4	70·5	81·0	85·9
Tensile strength, lb./sq. in.	73	202	235	251
Water in plaster when broken, per cent	9·98	14·51	14·71	12·03
Time of setting, hours	>8½	>8	>8	>8
Area shrinkage, per cent	12	16	12	13
Efflorescence	None	Some	Some	Considerable
Remarks	Chalky surface	Small air cells	Small air cells	

Sample No. 41: −100 mesh—Concluded

Test No.	147	159	57	131	108
Screen Analysis—					
+100 mesh, per cent	4·0	1·8	1·6	2·0	2·0
+150 mesh, "	1·8	0·8	0·8	1·0	1·0
+200 mesh, "	3·8	0·8	1·4	1·8	2·6
−200 mesh, "	90·4	96·6	96·2	95·2	94·4
−325 mesh, "	98·7	98·7	98·0	98·4	98·0
Time of grinding, hours	4	4	4	4	4
Agent added	In pebble jar	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent	Na_2SO_4	Na_2SO_4	Na_2SO_4	$Na_2S_2O_7$	$Na_2S_2O_7$
Agent, per cent	0·5	1·0	2·5	0·5	2·5
Water used, $\frac{\text{cc.}}{100}$ gms.	40	43	38	40	40
Days in mould	2	1	1	1	1
Age when broken, days	7	7	8	8	9
Weight briquette, gms.	82·8	79·6	85·7	81·7	83·2
Tensile strength, lb./sq. in.	167	267	204	198	103
Water in plaster when broken, per cent	12·29	12·74	13·15	11·51	13·57
Time of setting, hours	>8½	>8	>8½	>8	>8½
Area shrinkage, per cent	13	15	9	12	7
Efflorescence	Slight	Considerable	Much	None	Some
Remarks	....	....	....	....	....

Sample No. 58: —20 mesh

Test No.	92	84	215 [1]	117	148
Screen Analysis—					
+100 mesh.........per cent	0·05	5·6	0·03	1·2	0·01
+150 mesh......... "	0·01	1·4	0·08	0·2	0·1
+200 mesh......... "	0·04	3·0	0·18	0·6	0·2
—200 mesh......... "	99·9	90·0	99·7	98·0	99·7
—325 mesh......... "	99·7	88·0	98·5	99·6	99·9
Time of grinding....... hours	4	4	4	4	4
Agent added..................	....	In pebble jar		In pebble jar	In pebble jar
Agent.........................	None	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$	$Al_2(SO_4)_3 \cdot 18H_2O$	$MgSO_4 \cdot 7H_2O$	Na_2SO_4
Agent.................per cent	....	2·5	....	2·5	0·5
Water used........... $\frac{\text{cc.}}{100}$ gms.	29	26	30	26	30
Days in mould................	2	1	2	1	2
Age when broken....... days	7	8	7	7	7
Weight briquette....... gms.	100·1	110·8	99·9	104·7	101·8
Tensile strength......lb./sq. in.	87	167	172	194	260
Water in plaster when broken.............per cent	5·16	9·05	4·86	6·61	7·48
Time of setting......... hours	>7½	3¼	>7½	>8¼	>7¾
Area shrinkage..........per cent	5	1	11	4	5
Efflorescence..................	None	Some	Slightly chalky	Much	Some
Remarks......................	....	....	....	....	....

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[1] Test No. 215: —20-mesh anhydrite was soaked in 10% alum solution for 1½ hours, filtered and dried. Calcined to 580° C.—dull red for 2 hours, then ground for 4 hours.

Sample No. 58: —20 mesh—Concluded

Test No.	160	83	132	109	259
Screen Analysis—					
+100 mesh.........per cent	0·2	0·09	0·02	0·04	0·2
+150 mesh......... "	0·2	0·04	0·03	0·04	0·2
+200 mesh......... "	0·1	0·13	0·1	0·1	0·6
—200 mesh......... "	99·5	99·7	99·9	99·8	99·0
—325 mesh......... "	99·4	99·5	99·9	99·6	96·0
Time of grinding....... hours	4	4	4	4	4
Agent added..................	In pebble jar	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent.........................	Na_2SO_4	Na_2SO_4	$Na_2S_2O_7$	$Na_2S_2O_7$	$ZnSO_4 \cdot 7H_2O$ K_2SO_4
Agent.................per cent	1·0	2·5	0·5	2·5	1·5 1·0
Water used........... $\frac{\text{cc.}}{100}$ gms.	31	30	32	30	32
Days in mould................	1	1	1	1	⅛
Age when broken....... days	7	10	8	8	10
Weight briquette....... gms.	102·7	105·6	97·5	103·3	100·4
Tensile strength......lb./sq. in.	233	243	197	238	200
Water in plaster when broken.............per cent	8·07	9·69	6·26	8·92	9·65
Time of setting......... hours	4½	1¾	>8	2¼	1¼
Area shrinkage.........per cent	4	None	6	2	2
Efflorescence..................	Considerable	Much	Slight	Much	None
Remarks......................	....	....	....	....	Hard surface

Sample No. 64: −20 mesh

Test No.	64	68	76	79
Screen Analysis—				
+100 mesh, per cent	0·8	34·2	0·6	12·0
+150 mesh, "	0·2	6·0	0·8	3·6
+200 mesh, "	0·8	7·2	4·2	8·4
−200 mesh, "	98·2	52·6	94·4	76·0
−325 mesh, "	98·0	52·0	92·0	76·0
Time of grinding, hours	4	(5 min.)	4	4
Agent added			In pebble jar	In pebble jar
Agent	None	None	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$	$CaCl_2$
Agent, per cent			2·5	2·5
Water used, $\frac{\text{cc.}}{100}$ gms.	27	20	28	22
Days in mould	1	1	1	1
Age when broken, days	8	7	10	9
Weight briquette, gms.	105·3	114·2	109·2	103·3
Tensile strength, lb./sq. in.	234	44	320	34
Water in plaster when broken, per cent	9·17	5·52	16·23	8·68
Time of setting, hours	>8¾	>9	1½	>8½
Area shrinkage, per cent	5	5	1	9
Efflorescence	None	None	None	Slightly chalky
Remarks				

Sample No. 64: −20 mesh—Continued

Test No.	72	118	149	217 [1]
Screen Analysis—				
+100 mesh, per cent	0·8	2·4	0·6	1·0
+150 mesh, "	0·2	0·2	0·4	2·2
+200 mesh, "	0·8	3·2	1·8	5·6
−200 mesh, "	98·2	94·2	97·2	91·2
−325 mesh, "	98·0	95·1	94·0	86·7
Time of grinding, hours	4	4	4	4
Agent added	In water	In pebble jar	In pebble jar	In water
Agent	$MgCl_2 \cdot 6H_2O$	$MgSO_4 \cdot 7H_2O$	Na_2SO_4	Na_2SO_4
Agent, per cent	2·5	2·5	0·5	0·5
Water used, $\frac{\text{cc.}}{100}$ gms.	28	27	30	68
Days in mould	1	1	2	1
Age when broken, days	10	7	7	8
Weight briquette, gms.	102·0	102·8	100·9	67·9
Tensile strength, lb./sq. in.	86	295	294	129
Water in plaster when broken, per cent	10·00	11·13	10·84	10·35
Time of setting, hours	7½	5¾	2¾	>7½
Area shrinkage, per cent	6	4	3	16
Efflorescence	Slightly chalky	Much	Some	Slightly chalky
Remarks				

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[1] Test No. 217—Sample was dried at 230° C., expelling all water before grinding.

Sample No. 64: −20 mesh—Continued

Test No.	161	58	61	219[1]	121
Screen Analysis—					
+100 mesh...........per cent	0·6	0·4	36·6	1·0	0·4
+150 mesh........... "	0·2	0·2	4·4	2·2	0·2
+200 mesh........... "	0·6	0·8	7·4	5·6	0·6
−200 mesh........... "	98·6	98·6	51·6	91·2	98·8
−325 mesh........... "	97·5	98·0	52·0	86·7	97·4
Time of grinding......... hours	4	4	(5 min.)	4	4
Agent added.....................	In pebble jar	In pebble jar	In pebble jar	In water	In pebble jar
Agent...........................	Na_2SO_4	Na_2SO_4	Na_2SO_4	Na_2SO_4	$Na_2S_2O_7$
Agent....................per cent	1·0	2·5	2·5	2·5	0·5
Water used............ $\frac{\text{cc.}}{100}$ gms.	33	32	20	50	32
Days in mould..................	1	1	1	$\frac{1}{4}$	1
Age when broken......... days	7	7	7	7	8
Weight briquette......... gms.	96·6	100·0	116·0	83·8	103·6
Tensile strength........lb./sq. in.	306	249	135	152	418
Water in plaster when broken...............per cent	11·71	12·51	8·62	10·89	15·56
Time of setting........... hours	$2\frac{3}{4}$	1	$5\frac{1}{4}$	$1\frac{3}{4}$	$5\frac{3}{4}$
Area shrinkage............per cent	4	2	None	6	None
Efflorescence....................	Considerable	Much	Much	Some	None
Remarks.......................	....	....	....	....	....

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[1] Test No. 219—Sample was dried at 230° C., expelling all water before grinding.

Sample No. 64: −20 mesh—Continued

Test No.	82	82	120	233
Screen Analysis—				
+100 mesh................per cent	0·8	0·8	0·4	1·8
+150 mesh.............. "	0·2	0·2	0·2	0·6
+200 mesh.............. "	0·8	0·8	2·0	3·0
−200 mesh.............. "	98·2	98·2	97·4	94·6
−325 mesh.............. "	98·0	98·0	97·0	96·0
Time of grinding............. hours	4	4	4	4
Agent added..........................	In water	In water	In pebble jar	In pebble jar
Agent................................	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$	$ZnSO_4 \cdot 7H_2O$ K_2SO_4
Agent........................per cent	2·5	2·5	2·5	1·5 1·0
Water used................. $\frac{\text{cc.}}{100}$ gms.	32	36	34	34
Days in mould......................	1	1	1	$\frac{1}{12}$
Age when broken............. days	10	39	58	12
Weight briquette............. gms.	108·0	87·6	90·4	100·7
Tensile strength.............lb./sq. in.	190	179	253	433
Water in plaster when broken.per cent	18·10	3·07	4·47	16·01
Time of setting............... hours	1	$1\frac{1}{4}$	$2\frac{1}{2}$	(52 min.)
Area shrinkage............ per cent	7	4	4	1
Efflorescence........................	Slight	Slight	Slight	Slight
Remarks..............................	....	....	....	....

Sample No. 64: —20 mesh—Continued

Test No.	238	238 a	241	244
Screen Analysis—				
+100 mesh...............per cent	1·6	1·0	1·8	1·2
+150 mesh.............. “	0·6	0·4	0·6	1·0
+200 mesh.............. “	0·8	1·4	2·8	3·2
—200 mesh.............. “	97·0	97·2	94·8	94·6
—325 mesh.............. “	98·0	98·6	98·0	98·0
Time of grinding.............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..................................	$ZnSO_4 \cdot 7H_2O$ Na_2SO_4	$ZnSO_4 \cdot 7H_2O$ Na_2SO_4	$ZnSO_4 \cdot 7H_2O$ $Ca(OH)_2$	$ZnSO_4 \cdot 7H_2O$
Agent..........................per cent	1·5 1·0	1·5 1·0	1·5 0·25	2·5
Water used.................. $\frac{\text{cc.}}{100}$ gms.	34	34	30	30
Days in mould........................	⅛	⅛	1	1
Age when broken............. days	18	13	7	9
Weight briquette............. gms.	103·2	103·4	100·9	105·2
Tensile strength.............lb./sq. in.	242	177	467	557
Water in plaster when broken.per cent	17·02	17·38	12·38	14·72
Time of setting............... hours	2¼	2¼	5½	5¼
Area shrinkage................per cent	5	7	9	7
Efflorescence..........................	None	None	Slight	Considerable
Remarks..............................	....	....	....	....

Sample No. 64: —20 mesh—Continued

Test No.	247	249[1] a	249 b	249 c
Screen Analysis—				
+100 mesh...............per cent	0·6	0·8	0·8	0·8
+150 mesh.............. “	0·2	0·4	0·4	0·4
+200 mesh.............. “	1·8	2·0	2·0	2·0
—200 mesh.............. “	97·4	96·8	96·8	96·8
—325 mesh.............. “	96·5	98·0	98·0	98·0
Time of grinding.............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..................................	$ZnSO_4 \cdot 7H_2O$ $Na_2S_2O_7$	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$
Agent..........................per cent	1·5 0·5	2·5	2·5	2·5
Water used.................. $\frac{\text{cc.}}{100}$ gms.	32	27	27	27
Days in mould........................	1	1	1	1
Age when broken............. days	8	17	8	11
Weight briquette............. gms.	104·9	116·7	103·8	105·0
Tensile strength.............lb./sq. in.	393	87	328	342
Water in plaster when broken..per cent	16·50	17·76	10·64	11·78
Time of setting............... hours	3	5¾	5¾	5¾
Area shrinkage................per cent	2	6	5	5
Efflorescence..........................	Slight	Considerable	Considerable	Considerable
Remarks..............................	....	....	....	....

[1] Test No. 249 a—Briquettes were dried in a moist closet.
b—Briquettes were dried in an oven at 45° C.
c—Average temperature 71° F.; average humidity 60 per cent.
d—Average temperature 86° F.; average humidity 40 per cent. (p. 75).

Sample No. 64: —20 mesh—Concluded

Test No.	249 d	253	256	256
Screen Analysis—				
+100 mesh per cent	$0 \cdot 8$	$0 \cdot 8$	$1 \cdot 8$	$1 \cdot 8$
+150 mesh "	$0 \cdot 4$	$0 \cdot 6$	$0 \cdot 6$	$0 \cdot 6$
+200 mesh "	$2 \cdot 0$	$1 \cdot 0$	$1 \cdot 4$	$1 \cdot 4$
—200 mesh "	$96 \cdot 8$	$97 \cdot 6$	$96 \cdot 2$	$96 \cdot 2$
—325 mesh "	$98 \cdot 0$	$99 \cdot 2$	$98 \cdot 9$	$98 \cdot 9$
Time of grinding hours	4	4	4	4
Agent added	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent	$MgSO_4 \cdot 7H_2O$	K_2SO_4	$ZnSO_4 \cdot 7H_2O$ $(NH_4)_2SO_4$	$ZnSO_4 \cdot 7H_2O$ $(NH_4)_2SO_4$
Agent per cent	$2 \cdot 5$	$2 \cdot 5$	$1 \cdot 5$ $1 \cdot 0$	$1 \cdot 5$ $1 \cdot 0$
Water used $\frac{cc.}{100}$ gms.	27	38	34	34
Days in mould	1	1	1	1
Age when broken days	7	8	8	21
Weight briquette gms.	$104 \cdot 3$	$89 \cdot 3$	$104 \cdot 8$	$102 \cdot 0$
Tensile strength lb./sq. in.	438	180	140	312
Water in plaster when broken per cent	$10 \cdot 41$	$9 \cdot 53$	$17 \cdot 88$	$18 \cdot 10$
Time of setting hours	5¾	4¾	2½	2½
Area shrinkage per cent	6	5	12	11
Efflorescence	Considerable	Slightly chalky	Hard crust	Hard crust
Remarks	....	....	Warped	....

Sample No. 69: —20 mesh

Test No.	91	165	225	226
Screen Analysis—				
+100 mesh per cent	$0 \cdot 6$	$0 \cdot 2$	$0 \cdot 1$	$0 \cdot 4$
+150 mesh "	$0 \cdot 2$	$0 \cdot 4$	$0 \cdot 4$	$0 \cdot 4$
+200 mesh "	$1 \cdot 0$	$1 \cdot 0$	$1 \cdot 6$	$1 \cdot 2$
—200 mesh "	$98 \cdot 2$	$98 \cdot 4$	$97 \cdot 9$	$98 \cdot 0$
—325 mesh "	$98 \cdot 0$	$98 \cdot 0$	$97 \cdot 1$	$95 \cdot 8$
Time of grinding hours	4	4¼	4	4
Agent added	....	In pebble jar	In pebble jar	In pebble jar
Agent	None	$Al_2Na_2(SO_4)_4 \cdot 24H_2O$	$Al_2(SO_4)_3 \cdot 18H_2O$	$Al_2(SO_4)_3 \cdot 18H_2O$
Agent per cent	....	$2 \cdot 5$	$0 \cdot 5$	$2 \cdot 5$
Water used $\frac{cc.}{100}$ gms.	29	32	29	28
Days in mould	1	1	1	1
Age when broken days	7	8	8	8
Weight briquette gms.	$100 \cdot 9$	$100 \cdot 7$	$99 \cdot 0$	$100 \cdot 2$
Tensile strength lb./sq. in.	258	259	177	150
Water in plaster when broken per cent	$10 \cdot 10$	$14 \cdot 95$	$9 \cdot 07$	$10 \cdot 85$
Time of setting hours	>9	6	>8	6
Area shrinkage per cent	7	1	Swelled then shrunk slightly	Swelled then shrunk slightly
Efflorescence	None	Slight	None	None
Remarks	....	Laminated	Laminated	Laminated

Sample No. 69: —20 mesh—Continued

Test No.	119	150	162	80
Screen Analysis—				
+100 mesh...............per cent	2·0	0·1	0·4	0·4
+150 mesh............... "	0·2	0·2	0·2	0·1
+200 mesh............... "	0·8	1·4	0·2	0·2
—200 mesh............... "	97·0	98·3	99·2	99·3
—325 mesh............... "	96·2	97·8	98·9	98·0
Time of grinding.............. hours	4	4	4	4
Agent added...........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent.....................................	$MgSO_4 \cdot 7H_2O$	Na_2SO_4	Na_2SO_4	Na_2SO_4
Agent.........................per cent	2·5	0·5	1·0	2·5
Water used.................. $\frac{cc.}{100}$ gms.	26	31	34	33
Days in mould.........................	1	2	1	3
Age when broken.............. days	8	8	7	9
Weight briquette.............. gms.	104·3	102·8	97·8	104·8
Tensile strength.............lb./sq. in.	338	419	481	458
Water in plaster when broken..per cent	10·87	13·05	13·55	16·03
Time of setting............... hours	5½	2¼	2¼	(34 min.)
Area shrinkage................per cent	5	2	5	4
Efflorescence.........................	Much	Some	Considerable	Much
Remarks...............................	....	....	....	....

Sample No. 69: —20 mesh—Continued

Test No.	122	134 [1]	135	136
Screen Analysis—				
+100 mesh...............per cent	0·4	0·4	0·2	0·6
+150 mesh............... "	0·2	0·2	0·2	1·8
+200 mesh............... "	0·2	0·2	1·0	5·4
—200 mesh............... "	99·2	99·2	98·6	92·2
—325 mesh............... "	99·0	99·0	97·9	87·7
Time of grinding.............. hours	4	4	4	4
Agent added...........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent.....................................	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$
Agent.........................per cent	0·5	0·5	1·0	1·5
Water used.................. $\frac{cc.}{100}$ gms.	32	29	32	32
Days in mould.........................	1	1	3	3
Age when broken.............. days	8	8	7	7
Weight briquette.............. gms.	102·6	106·9	104·3	95·4
Tensile strength.............lb./sq. in.	487	247	402	217
Water in plaster when broken.per cent	14·88	6·81	16·68	16·02
Time of setting............... hours	3	25	1¾	1¾
Area shrinkage................per cent	2	4	None	Swelled
Efflorescence.........................	None	None	Some	Considerable
Remarks...............................	....	....	....	Small cells, laminated

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[1] Test No. 134—650 gms. of sample from Test No. 122 calcined at a dull red heat for 1½ hours.

Sample No. 69: −20 mesh—Continued

Test No.	137	110	138
Screen Analysis—			
+100 mesh........................per cent	0·2	0·2	0·2
+150 mesh........................ "	0·2	0·03	0·2
+200 mesh........................ "	1·4	0·6	1·4
−200 mesh........................ "	98·2	99·2	98·2
−325 mesh........................ "	95·5	97·9	95·7
Time of grinding...................... hours	4	4	4
Agent added....................................	In pebble jar	In pebble jar	In pebble jar
Agent..	$Na_2S_2O_7$	$Na_2S_2O_7$	$Na_2S_2O_7$
Agent................................per cent	2·0	2·5	3·0
Water used.......................... $\frac{\text{cc.}}{100}$ gms.	31	32	30
Days in mould..................................	3	1	1
Age when broken...................... days	7	12	8
Weight briquette..................... gms.	97·1	102·0	106·2
Tensile strength......................lb./sq. in.	276	270	317
Water in plaster when broken..........per cent	16·72	16·59	15·26
Time of setting....................... hours	(56 min.)	(42 min.)	(34 min.)
Area shrinkage.........................per cent	Swelled	Swelled	Swelled 1%
Efflorescence...................................	Much	Much	Much
Remarks...	Small cells, laminated	Laminated, grey	Not cellular

Sample No. 69: −20 mesh—Concluded

Test No.	177	202	201	260
Screen Analysis—				
+100 mesh...............per cent	0·6	0·8	0·4	1·4
+150 mesh............... "	0·2	0·6	0·4	1·6
+200 mesh............... "	0·2	1·6	1·2	4·4
−200 mesh............... "	99·0	97·0	98·0	92·6
−325 mesh............... "	98·0	96·4	93·9	93·4
Time of grinding............. hours	4	4	4	4
Agent added..........................	In pebble jar	In pebble jar	In pebble jar	In pebble jar
Agent..................................	$Na_2S_2O_7$ Na_2SO_4	Na_2SO_3	Na_2CO_3	$ZnSO_4 \cdot 7H_2O$ K_2SO_4
Agent........................per cent	0·25 0·5	0·5	2·5	1·5 1·0
Water used................. $\frac{\text{cc.}}{100}$ gms.	36	30	30	32
Days in mould.........................	1	1	1	$\frac{1}{8}$
Age when broken............. days	8	7	7	10
Weight briquette............. gms.	99·3	100·3	102·1	102·9
Tensile strength.............lb./sq. in.	421	369	274	408
Water in plaster when broken.per cent	14·66	11·18	12·15	15·17
Time of setting............... hours	2½	4½	2¼	(39 min.)
Area shrinkage................per cent	3	5	2	2
Efflorescence..........................	Considerable	Some	Much	None
Remarks................................	....	....	....	Hard crust

Explanatory Notes to the Tables

1. *Screen Analyses.*[1] It will be noted that in a number of cases the percentage of material passing the 325-mesh screen is larger than that passing the 200 mesh. The reason for this is that the analysis for −325 mesh was made on a separate portion of 5 grammes, water being used to wash through the fines, while for the —200 mesh the screening was done dry.

2. *Test No. 258, on Sample No. 9.* In preparing a sample of anhydrite for testing as to its suitability for use as a paper filler, a portion was ground and passed through the Gayco air separator. The rejects oversize and cleanout of the Gayco from this test was used as the material for test No. 258. Judging from the high water content of the plaster specimen when broken and the large amount of water necessary to gauge the plaster, the gypsum content of this material was considerably higher than the original sample.

3. *Crushing and Grinding.* At the commencement of the investigation the first few samples to be prepared were ground to −100 mesh. Later on this seemed to be unnecessary so that the remaining samples were crushed to pass only the 20-mesh screen. It was found that in preparing the material for testing by grinding in pebble mills that −20-mesh material was reduced to the required size just as fast as the −100-mesh material.

CONCLUSIONS

From the results obtained in our tests a number of broad conclusions may be drawn. Large-scale semi-commercial tests should however be made to see whether bulk conditions hold the same as under laboratory control.

1. Anhydrite, when suitably ground, on the addition of water alone will take a "set" varying with the different samples; in one case a tensile strength of 342 pounds per square inch being obtained (Test No. 54), while the lowest gave a tensile strength of 44 pounds per square inch (Test No. 68). In all, 18 tests were made on anhydrite with water alone with the following results:—

One gave a tensile strength over 300 pounds per square inch.

Three gave a tensile strength between 200 and 300 pounds per square inch and six gave a tensile strength under 100 pounds per square inch.

2. The addition of certain inorganic salts to the anhydrite tends to accelerate the "set" of the anhydrite and in many cases to increase greatly the tensile strength of the resultant plaster. Earlier tests indicated that there was probably an upper limit for the amount of "catalyst" that should be added, above which, additional amounts of the reagent tended to decrease the strength and quality of the plaster produced. Broadly speaking, this upper limit was found to be between 3 and 4 per cent and that 2·5 per cent[2] on the whole gave the most satisfactory results. This latter figure was therefore adopted for the greater part of the later tests.

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[1] Tyler standard screens used in all tests.

[2] This percentage refers only to the catalyst added and does not refer to inert fillers such as sand, etc., which may be added in the same way and proportions as in ordinary gypsum plasters.

3. In our tests, the reagent was added to the anhydrite in one of two ways, either dry and ground together with the anhydrite to obtain an intimate mixture, or else by dissolving it in the mixing water. The latter method, with some reagents gave better, and with others, poorer results than those obtained when the dry salt was added before grinding. Since, however, in commercial practice it would be almost impossible to add the reagent in the mixing water it was thought better to make most of the tests by the method more suitable to commercial use.

4. The percentage of water required to be added to anhydrite plaster is consistently less than for gypsum plasters, being approximately half that required for the latter type. In consequence a denser and more impervious set plaster can be obtained with anhydrite plaster. As a concrete example, take all the tests made on Sample No. 4 in this report and compare the results with 10 gypsum plasters the tests on which were also made in this department.

	Water required for gauging Average	Wt. of briquettes
53 anhydrite tests	31 c.c.	102 gms.
10 gypsum tests	66 c.c.	70 gms.

This is probably one of the reasons why briquettes made from anhydrite plasters do not disintegrate with anything like the rapidity of similar briquettes made from gypsum plasters when soaked for any length of time.

5. Certain reagents give better results than others. For example, volcanic ash tended to make a uniformly weak plaster, slow setting and with a comparatively high shrinkage; magnesium sulphate gave very erratic results, a slow set and heavy efflorescence, while aluminium sodium sulphate, although giving fair strengths, caused in some cases a swelling of the plaster producing a cellular or laminated structure.

More consistent results were obtained when sodium sulphate or sodium pyrosulphate was used for the reagent and strong plasters were produced which, however, showed in nearly all cases varying amounts of efflorescence on the surface of the briquettes, accompanied by shrinkage.

The most satisfactory results in our tests were obtained by using two catalysts such as zinc sulphate and some other reagent such as sodium sulphate, sodium pyrosulphate, or potassium sulphate. In such tests good tensile strengths were obtained, and the efflorescence and shrinkage greatly diminished.

6. In none of our tests were we able to reach the theoretical water content of pure gypsum, namely, 20·9 per cent, although percentages over 16 per cent in the set plaster were frequently obtained. This point is of great importance since the more nearly the anhydrite reaches complete hydration the higher the strength of the resultant plaster. This fact is borne out by our tests, and although there are many of the tests that do not fall on the regular curve, due to employing different reagents and different plasters, as a general rule the tensile strength increases, the greater the hydration. In order to establish this point definitely for any one particular plaster a series of tests, over a period of a year, on briquettes mixed at the same time will have to be made.

7. Summing up the above results our tests show that plasters may be made from Canadian anhydrites by the addition of small amounts of

certain chemical salts. These plasters will set and as a rule have a density greater than, and a tensile strength comparable with, and in many cases exceeding that of ordinary plaster of Paris (calcined gypsum). The various anhydrites give different results with the same catalyst and the best reagent to use with the anhydrite from each deposit will have to be separately established.

Anhydrite plasters have many interesting features, such as great density, good tensile strengths, higher resistance to solution by water than gypsum plasters, good plasticity under the trowel, and require less water for gauging.

Objectionable features are the shrinkage and efflorescence which occur with many of the reagents but these difficulties may be largely overcome by using zinc sulphate and some other salt such as potassium sulphate together as the catalyser.

Much experimental work has still to be done on anhydrite plasters, which will take time, but judging from our tests and from other research work carried out in many places, the use of anhydrite for the manufacture of commercial plasters has distinct possibilities and it is hoped, by publishing the results we have obtained, that commercial firms may be sufficiently interested to continue the work and make the use of anhydrite for this purpose an accomplished fact.

TESTS AS A FILLER FOR PAPER AND COTTON

In order to determine whether anhydrite would not be equally as suitable for this purpose a portion of Sample No. 9 was ground so that 99·5 per cent passed the 325-mesh screen and this was submitted to Dr. J. H. Ross of the Forest Products Laboratory of Canada, Pulp and Paper Division, Montreal, for testing.

The following report on the anhydrite submitted to Dr. Ross embraces the results of tests made by G. D. O. Jones, Laboratory Assistant, and H. Chalk, McGill Summer Student, under Dr. Ross' direction.

This investigation was carried out by the Division for the Department of Mines, Ottawa, at the request of L. H. Cole who supplied the "anhydrite" used in the tests reported below.

Fillers are mineral materials which are incorporated in the paper, not generally to replace fibre but rather to give the sheet certain qualities desired in printing. The sheet, so treated, becomes more opaque and " absorbs " more readily the ink used in printing.

Calcium sulphate[1] is used in paper-making under a number of different trade names such as " pearl filler," " crown filler," " pearl hardening," " terra alba " etc., the peculiarities in the different forms resting in their mode of occurrence, percentage of water of crystallization, or method of preparation.

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[1] There appears to be great variation in the "trade" as to the interpretation of the meaning of these different trade names with respect to the composition and method of preparation of the products. For the purpose of this report the following definitions are adopted:—

Pearl Filler. Chemically, pearl filler is calcium sulphate ($CaSO_4$) in which there is no water of crystallization and only small amounts of mechanically combined water, generally less than one per cent. It is found in nature in the form of the mineral anhydrite and as such may contain small percentages of impurities such as gypsum, limestone, In this investigation the anhydrite was used as received without further grinding or sifting. The screen analysis of the material showed that 99·5 per cent passed 325 mesh. For a standard of comparison a commercial grade of china clay was used. It was not possible to carry out the tests on the small-scale paper machine installed in the laboratory, therefore a standard type of hand sheet-making apparatus was employed. Unfortunately, this procedure is not an exact duplication of conditions as they exist on the commercial paper machine but the sheets are made under ideal conditions for testing.

The pulp employed in these tests was a bleached sulphite wood pulp beaten moderately (30 minutes) in the laboratory test beater. Beating fibrillates the pulp and increases its capacity to retain the filler. For each series of sheets made a fixed quantity of beaten pulp and the desired amount of filler were agitated in a fixed amount of water. When the charge was thoroughly mixed definite quantities of the suspension were measured out and used in the preparation of the test sheets.

In order to determine the amount of filler which would be required per gramme of pulp for a desired filler content in the finished sheet a preliminary series was run. The results are given in Table IV.

TABLE IV

Grms. filler per 2 grms. pulp	Per cent in sheet	
	China clay	Anhydrite
25·0	39·3	38·1
50·0	52·2	51·4
100·0	74·4	70·1

In other words when 100 grammes of filler were added to 8 grammes of bone dry fibre suspended in 2,400 c.c. of water, the mixture agitated for 5 minutes, and a sheet made from 600 c.c. of the suspension, it was found that

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etc., but these should be as low as possible. When ground to a fine powder the resultant material is white. It is prepared by crushing, grinding, and bolting the natural anhydrite rock to pass the 200-mesh screen.

Crown Filler. Crown filler is an artificial (manufactured) product, prepared as a precipitate by the interaction of solutions of calcium chloride ($CaCl_2$) and sodium acid sulphate ($NaHSO_4$). Chemically, it is calcium sulphate with two molecules of water of crystallization ($CaSO_4 \cdot 2H_2O$). It is generally marketed as a wet powder or paste containing as high as 33 per cent of water of which between 20 and 21 per cent is chemically combined and the remainder mechanically mixed. On account of its finely divided state due to the method of manufacture by precipitation, it is more readily soluble than some of the other forms of calcium sulphate, but is also more expensive, nevertheless it is widely used on account of its extreme whiteness.

Pearl Hardening. Pearl hardening is another term used for crown filler.

Terra Alba. Terra alba is a term very loosely used in the paper trade to represent a number of different filler substances. For the purpose of this report it is taken to mean very white natural rock gypsum ($CaSO_4 \cdot 2H_2O$), ground and bolted to pass a 200-mesh screen. Chemically, therefore, it is identical with crown filler but on account of its mode of preparation it is not so finely divided and in consequence its physical properties are slightly different. Some prefer to call it simply ground gypsum. A good example of this material is the product which has been sold for many years as a paper filler by the Albert Manufacturing Company, Hillsborough, New Brunswick, under the name of "terra alba," being their whitest selected gypsum ground and bolted to the proper fineness.

the sheet, in the case of china clay contained 39·3 per cent of filler, while with anhydrite the filler content was 38·1 per cent. Using the results thus obtained for each filler and the zero value, smooth curves (Figure 6) may be drawn relating per cent of filler in the sheet per weight of filler in grammes added to two grammes of pulp. From these two curves, values were obtained from which to calculate the necessary amounts of filler to be added in order to give sheets with a graduated filler content.

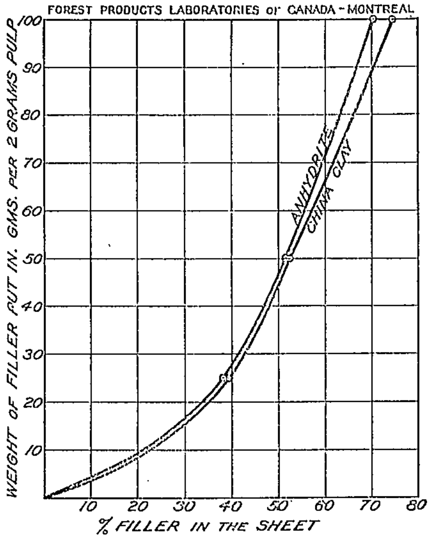

Figure 6. Graph showing percentage of filler in sheet per weight of filler in grammes added to two grammes of pulp.

Based on these curves definite quantities of filler were added to 8 grammes of bone dry fibre suspended in 2,400 c.c. of water in the disintegrator. The mixture was agitated for exactly 5 minutes when 600 c.c. was removed for each of the four test sheets to be made. These sheets were dried and a portion of one sheet from each test was taken for ash content, the results obtained being given in Table V.

TABLE V

Calculated percentage of filler in sheet	Grms. of filler employed per 2 grms. pulp		Resultant per cent of filler in sheet	
	China clay	Anhydrite	China clay	Anhydrite
10	3·6	4·1	12·03	10·65
20	8·4	9·2	25·13	16·56
30	15·3	16·3	33·41	28·40
40	25·7	28·0	43·55	39·35
50	44·4	47·0	53·88	51·75

These results indicate that more anhydrite than clay is required for the same amount of filler in the final sheet. This is no doubt due in part to the greater solubility of anhydrite in water. In actual practice this loss would be offset somewhat by the re-use of machine white-water where saturation with respect to anhydrite would occur.

The series of sheets were next conditioned at 70° F. and 65 relative humidity. They were then tested for tensile strength, bulk, per cent stretch and opacity, the results obtained being given in Table VI.

TABLE VI

Filler Used	Filler	Ream	Breaking length	Stretch	Bulk	Opacity
	per cent	weight	metres	per cent		per cent
China clay..........	0·00	32·40	2710	3·1	1·71	72·07
	12·03	37·75	1820	2·4	1·89	86·10
	25·13	42·12	1037	1·9	1·78	92·39
	33·41	48·70	838	1·6	1·81	96·38
	43·55	56·85	475	1·4	1·64	97·61
	53·88	69·70	245	1·4	1·46	98·95
Anhydrite...........	0·00	32·40	2710	3·1	1·71	72·07
	10·65	38·21	2100	2·8	1·74	79·86
	16·56	42·35	1532	2·1	1·66	82·92
	28·40	46·70	1300	2·0	1·81	85·35
	39·35	58·75	743	1·5	1·56	89·10
	51·75	70·70	389	1·5	1·37	91·49

The *Ream weight* of the paper is the weight in pounds of 500 sheets 25 x 40 inches.
The *Breaking length* is metres of paper of Ream weight 100 lb. which will be supported by a strip of this paper 1·5 cms. wide and is calculated from the tensile strength.
The *Stretch* is the elongation of a strip of the paper at rupture expressed in per cent.
The *Bulk* is the specific volume, or cc. of paper per gramme.
The *Opacity* is a contrast ratio and is expressed as a percentage of complete opacity.

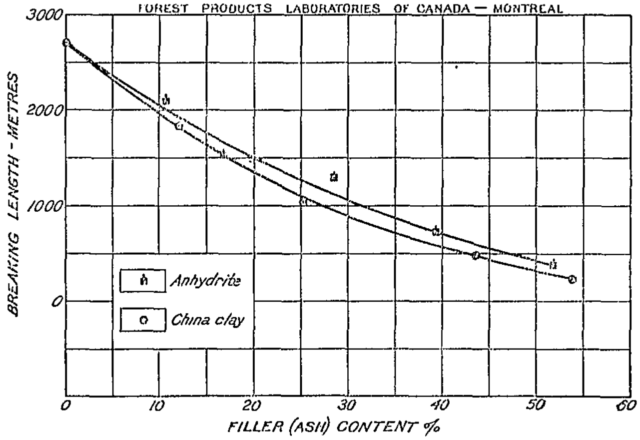

Figure 7. Graph showing relationship between tensile strength and percentage of filler in paper.

The results given in Table VI are similar to those found in practice. The tensile strength of the sheet falls off with the increase in the filler. This is shown graphically in Figure 7. Anhydrite decreases the tensile strength less than china clay for the same amount of filler in the sheet. This may be attributed to the more irregular granular shape of the anhydrite particles. A less bulky sheet is obtained when anhydrite is used. The lower opacity of the sheets loaded with anhydrite (Figure 8) is to be expected from commercial results with calcium sulphate.

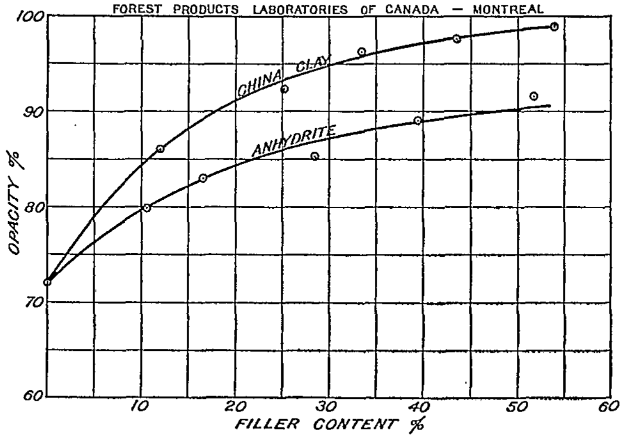

Figure 8. Graph showing comparison of opacity of sheets filled with anhydrite and china clay.

The fillers were next tested according to methods approved by the Non-Fibrous Materials Testing Committee of the Technical Association of the American Pulp and Paper Industry (Paper Trade Jour., XCV, July 7 (1932) No. 44-46).

Flotation.

	China clay	Anhydrite
Weight of original sample.	20 grammes	20 grammes
Weight of settled grit	0.1018 gramme	0.1680 gramme
Per cent grit.	0.51	0.84

Settling. (See attached curves, Figure 9.)

The sheets filled with " anhydrite " present a surface which has a gritty feel. Those into which an equivalent amount of clay has been incorporated are of much smoother texture. The conditions under which the sheets were made have contributed to the poor surface of the anhydrite filled sheets. The dilution of the stock in the sheet machine was such that there was a very considerable loss of filler with the water draining from the sheet. Under these circumstances there would be a tendency for the grit to be retained by the fibre in preference to the very fine material.

In this report the term " anhydrite " refers to the sample of anhydrous calcium sulphate supplied by the Department of Mines.

Summary

The retention by the pulp of anhydrite as compared with that of china clay was slightly inferior. There was less loss of tensile strength when anhydrite was used, though this is a matter of indifference to the printer who is interested primarily in the printing quality and the uniformity of his paper. The anhydrite, as is usual, contributed less opacity to the sheet than did china clay. The sample of anhydrite used in this investigation contained considerably more " grit " than did the clay with which it was compared. Under the conditions in which the sheets for test were made there was a tendency to retain a maximum of grit due to dilution of the pulp suspension. This imparted a rather rougher surface to the sheets loaded with anhydrite.

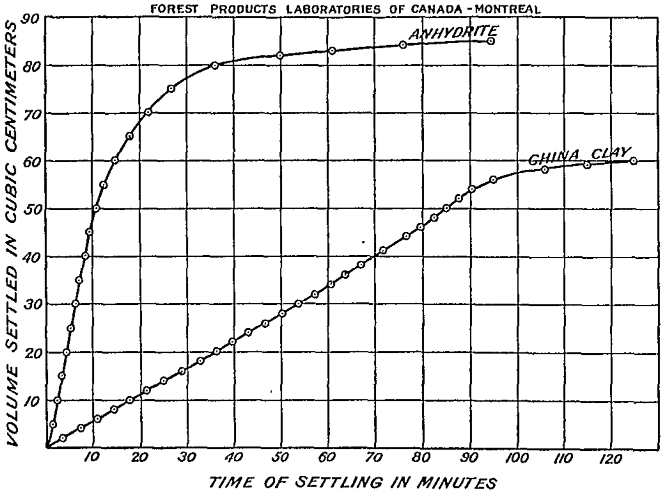

Figure 9. Settling test. (Anhydrite as a paper filler.)

Conclusions

" Anhydrite " may be used successfully as a filler or loading material for paper, but it does not give the qualities desired in printing in the same measure as a china clay. There is no doubt, however, that " anhydrite " could find a place in certain grades of paper.

GENERAL SUMMARY

Canada has extensive deposits of anhydrite well situated for development, and of good quality. With the rapidly extending use of this mineral in industry the prospects for a much greater production of anhydrite and for its utilization in important industrial processes would seem to be assured.

Such processes involving the use of anhydrite as a raw material have been developed on a large scale during recent years, notably in Europe, in connexion with the manufacture of sulphuric acid, Portland cement, and ammonium sulphate; anhydrite has also found a considerable market for use as a retarder in Portland cement, and various other industrial applications have been successfully tested on a commercial basis. For all of these, Canadian anhydrite is admirably suited and the appropriate industries will grow in Canada as and when the market needs for the corresponding products are manifested.

As a fertilizer Canadian anhydrite already has a market. Two other possible outlets, likely to lead to immediate markets, have formed the subjects of investigations described in detail in the preceding pages. These are for the manufacture of plasters and as a filler for paper. Encouraging results were obtained in the research on the suitability of Canadian anhydrite for plasters and it is to be hoped that commercial enterprise will avail itself of the opportunities so offered. As a filler for paper, although lacking some of the qualities of china clay, anhydrite has been found suitable in the manufacture of certain grades of paper.

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