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MINERALS FROM THE NEW NEPHELINE SYENITE
AREA, FRENCH RIVER, ONTARIO

By T. L. WALKER and A. L. PARSONS

Introduction

The valley of the French river was geologically surveyed by the late Dr. Robert Bell during the field seasons of 1891 and 1892. In 1897 his report and map¹ appeared. On the map wide areas were indicated as Laurentian gneiss. Recently, on behalf of the Geological Survey of Canada, Professor T. T. Quirke has carried on field work in the same region, and to his work we owe the discovery of a new nepheline syenite area which may be approximately indicated as being near longitude 80° 45' W., latitude 46° N. While the limits of the nepheline eruptive have not yet been definitely fixed by Professor Quirke's explorations, it may be indicated as lying for the most part in the township of Bigwood and constituting a north-south belt, about one quarter of a mile wide and five miles long, the southern end of which can be well studied, as exposed on the French river some four miles below French River station on the Canadian Pacific railway.

During the summer of 1925, the writers spent a few days examining the outcrops on the French river and gathering a series of minerals and rocks on which these observations are based.

The nepheline syenite is a gneissoid rock, grey in colour in contrast to the gneisses flanking it on the east and west, which are pinkish. Thin sections indicate that the rock is miaskite since the dark mineral is generally a very dark mica, probably lepidomelane, as shown by a partial chemical analysis. The feldspars, which are plagioclase, orthoclase, and microcline, appear to be unusually fresh. Nepheline

¹Geol. Sur. Can., Annual Report, Vol. IX, 1897.

is rarely recognized in hand specimens, though showing distinctly in thin sections. It is often bordered by a more or less continuous narrow rim of cancrinite. Reddish brown crystals of zircon are frequently found in considerable abundance in selected bands of the syenite. Sodalite has not been observed in the ordinary rock, though it appears in a quite subordinate manner in the pegmatitic knobs referred to below. Graphite in small scales is frequently observed in the field. Calcite is seen in most sections. An analysis of a typical specimen of the nepheline syenite by H. C. Rickaby gave the following results:

SiO ₂	55.90
TiO ₂.....	.05
Al ₂ O ₃	22.12
Fe ₂ O ₃.....	.96
FeO.....	4.33
MnO.....	.14
CaO.....	.44
MgO.....	.37
Na ₂ O.....	8.35
K ₂ O.....	6.42
H ₂ O.....	.57
CO ₂.....	.67
Total.....	100.32
S.G.....	2.661

Pegmatitic Masses

In the gneissoid miaskite there are coarse irregular rounded or lenticular masses often with a maximum diameter of one foot. Sometimes two of these merge and form an elliptical mass where the longer axis coincides with the strike. They resist weathering better than the surrounding rock and at times stand several inches above the general surface. They are brownish in colour and sometimes cavernous, owing to some constituent having been removed by weathering more rapidly than others. Against the syenite the boundaries are not sharp, since in polished slabs the coarse massive

portion passes gradually into the gneissoid rock (Pl. I, Fig. 1). In these masses many of the minerals are so well developed as to invite study.

Nepheline

The nepheline does not form crystals or even pure masses of appreciable size in the pegmatite knobs, but in a dyke of coarse pegmatite a few hundred feet to the east masses of salmon-coloured nepheline form the chief constituent. On weathered surfaces of the pegmatite the more rapid weathering of the nepheline as contrasted with the feldspar is well shown (Pl. I, Fig. 2). A microscopic examination of the nepheline shows a very slight alteration as betrayed by a few fine particles of a bright polarizing mineral. An analysis by H. C. Rickaby gave the following results:

SiO ₂	42.56	.709	
Al ₂ O ₃	35.80	.351	
CaO.....	.05	.001	
MgO.....	.20	.005	
Na ₂ O.....	14.86	.240	} .341
K ₂ O.....	5.75	.062	
H ₂ O.....	.67	.039	
CO ₂.....	.35	.008	
Total.....	100.24		
S.G.....	2.610		

The accompanying molecular ratios indicate that the nepheline agrees fairly well with the formula (Na, K, H) ₂O.Al₂O₃.2SiO₂.

Sodalite

This mineral is found in the round pegmatitic masses in subordinate amount. It is generally fine blue in colour. It was not possible to secure a sample for analysis, as the grains of pure sodalite are too small to select pieces of pure mineral. An attempt to purify a sample by use of heavy liquids was unsuccessful, owing to the presence in considerable amount of a secondary product which appears to possess almost identical specific gravity.

Lepidomelane

Six-sided crystals of a very black mica appear to have been the first constituent to crystallize as their boundaries project into masses of most of the other minerals. The sheets are at times three inches in diameter. This mineral possesses a very perfect cleavage, and is so dark in colour that only the very thinnest flakes transmit light. An analysis of this mica by H. C. Rickaby shows that it is lepidomelane.

SiO ₂	31.64
Ti ₂ O ₃.....	.33
Al ₂ O ₃	15.34
Fe ₂ O ₃	8.38
FeO.....	31.78
MnO.....	.28
MgO.....	.90
Na ₂ O.....	.67
K ₂ O.....	8.70
H ₂ O.....	1.93
F.....	.13
	<hr/>
Oxygen equiv. of F.....	100.08
	.05
Total.....	<hr/>
	100.03
	<hr/>
S.G.....	3.294

The dark mica contained in the analysed sample of nepheline syenite was separated, and found on partial analysis to agree with the above mica.

Cancrinite

Cancrinite occurs in the central portion of the pegmatite knobs in pure masses three or four inches in diameter. The cleavage is so well developed as to be continuous for several inches. In colour the mineral is a fine honey-yellow somewhat deeper than that from Litchfield. Usually the cancrinite is surrounded by a zone up to an inch and a half wide, that is pink or grey in colour, and appears to be an alteration product from the cancrinite. The margin between the two

is fairly sharp and jagged. Thin sections indicate that the secondary product is made up of two minerals, one with a very low birefringence, the other very high, and that there is a narrow zone on the margin where the original and secondary minerals are mingled,—remnants of cancrinite in the secondary area extinguish with the main mass of the cancrinite, and threads and strings of the younger minerals penetrate the original type usually with a tendency to follow the cleavage direction of the latter. These phenomena confirm the conclusion drawn from a macroscopic study of some of the larger specimens as to the primary nature of the cancrinite and the secondary character of the pink aggregates. Scattered through the cancrinite small amounts of the following minerals may be observed,—sodalite, plagioclase, microcline, apatite, magnetite, lepidomelane, molybdenite, and pyrrhotite. In some measure these minerals remain unchanged in the alteration zone above referred to. In the present occurrence it seems necessary to regard the cancrinite as a primary mineral.

A carefully prepared sample of the cancrinite was analysed by H. C. Rickaby with the following result:

SiO ₂	36.24
CO ₂	5.61
Al ₂ O ₃	28.78
Fe ₂ O ₃.....	.36
CaO.....	4.83
MgO.....	.26
MnO.....	.04
Na ₂ O.....	18.63
K ₂ O.....	.73
H ₂ O.....	4.64
Cl.....	Trace
	<hr/>
Total.....	100.12
	<hr/>
S.G.....	2.425

As the sample prepared for analysis, when examined microscopically, was seen to contain a small amount of the alteration products, the slight departure from the standard composition of this mineral is not surprising.

Across the river on the south shore in dark basic rocks small cavities are common owing to removal of calcite. Into these cavities project rude crystals of cancrinite. Some of them are fairly fresh, while in others the cancrinite has been changed to the characteristic secondary aggregate. On the outer surface these crystals are always rough and reddish owing to corrosion and the deposition of hematite. The largest crystal is over an inch in diameter and three inches long. On most crystals, planes in the prismatic zone are much fluted and appear to represent prisms of the first and second orders. The crystals are too rough for satisfactory measurement with the exception of the largest on which there is one pyramid for which the polar angle ρ was measured with the contact goniometer and found to be 24° . If this pyramid be assumed to be the unit pyramid of the first order the crystallographic constants for cancrinite become:

$$\rho_0 = .4452; c = .6678.$$

Crystallographic data for this mineral are available from the work of Törnebohm and Brögger. The former obtained $\rho = 26^\circ$ and the latter $26^\circ 59'$. The constants corresponding to these measurements are as follows:

$$\text{Törnebohm—}\rho_0 = .4877; c = .7316.$$

$$\text{Brögger—}\rho_0 = .5092; c = .7638.$$

Törnebohm's values were obtained from measurements on small crystals in thin sections, while those of Brögger were from rough crystals similar to the one measured from French river.

The Secondary Aggregate

Surrounding the masses of fine honey-yellow cancrinite, there invariably occurs a zone sometimes an inch and a half wide of porcellanic material, white to pink in colour. The border between the cancrinite and this material appears to be fairly sharp when examined with the hand lens, but on examination of thin sections it is seen that there is a neutral zone in which the cancrinite occurs as isolated remnants which extinguish at the same time, while towards the can-

crinite there is a tendency for the pink mineral to invade the cancrinite often following cleavage lines. These observations indicate that the cancrinite gives rise to the other mineral by alteration. The secondary mineral is not homogeneous as scattered through the main mass of the aggregate there is a considerable development of finely divided carbonate. The principal part of the aggregate shows low birefringence and low relief and is probably related to hydro-nephele or ranite. A carefully prepared sample on analysis by H. C. Rickaby gave the following result (I):

	I	II	III
SiO ₂	36.33	41.14	39.21
Al ₂ O ₃	28.88	32.70	31.79
Fe ₂ O ₃.....	.36	.40	.57
CaO.....	10.62	4.58	5.07
MgO.....	.48	.54	.....
MnO.....	.09	.10	.....
Na ₂ O.....	7.83	8.86	11.55
K ₂ O.....	2.35	2.65	.....
H ₂ O.....	8.47	9.60	11.71
CO ₂	5.15	.....	.....
Cl.....	Trace	.....	.....
Total.....	100.56	100.57	99.90

In specific gravity the selected sample seems to be heterogeneous since different portions are freely suspended in the liquid all the way from 2.40 to 2.46. The specific gravity of the sample analysed as determined by the pycnometer is 2.425.

In composition this aggregate, after calculating the carbon dioxide as calcite (II) resembles somewhat the secondary aggregate known as ranite (III).¹

Acmite

Radiating tufts and bunches of a fibrous mineral, yellow green in colour, suggesting epidote, are very common in the knobs. The fibres are at times nearly an inch long so that on the freshly broken surfaces of the rock patches an inch

¹Pajkull, S. R., Ber. Chem. Ges., Vol. 7, p. 1334.

and a half in diameter are not uncommon. A very pure sample was analysed by H. C. Rickaby with the following result:

SiO ₂	52.63	.877	÷4 = 219
Al ₂ O ₃	3.30	.032	
Ti ₂ O ₃.....	.35	.002	220
Fe ₂ O ₃	29.72	.186	
FeO.....	.64	.008	221
CaO.....	.18	.003	
MgO.....	.69	.017	221
MnO.....	Trace	.....
Na ₂ O.....	11.66	.188	221
K ₂ O.....	.54	.005	
H ₂ O.....	.26	.014	
Total.....	99.97		
S.G.....	3.487		

Dr. E. S. Larsen, who kindly examined a part of the sample prepared for analysis, reports as follows:

Optically negative 2V about 63°. Each optical axis shows strong dispersion, but the two optical axes seem to show the opposite dispersion due to the strong dispersion of the bisectrices. The dispersion of 2V is uncertain. This aegirite has a rather lower index of refraction than I had expected from a mineral so high in ferric iron.

$\alpha = 1.752$ Light yellow green
 $\beta = 1.788$ Bluish-yellow green
 $\gamma = 1.801$ Light green

The acmite does not appear in the cancrinite but in the more feldspathic portions of the mass. In chemical composition this mineral appears to be akin to acmite rather than aegirite, so that even in the absence of crystals suitable for geometrical study we think that the former name is preferable.

Zircon

Zircon occurs in relative abundance in the pegmatitic knobs where it seems to be one of the earliest minerals to crystallize and also in certain bands of the gneissoid nepheline

syenite. The crystals show the prisms of the first and second orders m (110) and a (100) in combination with two pyramids of the first order p (111) and u (221). There seems to be considerable variation in the relative development of the forms. Sometimes the only form present is p (111), (Fig. 1), at other times this form occurs with very small prisms (Fig. 2), while more rarely the crystals are

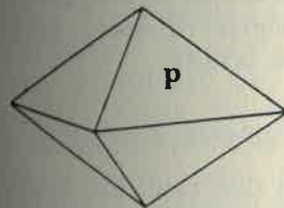


Fig. 1

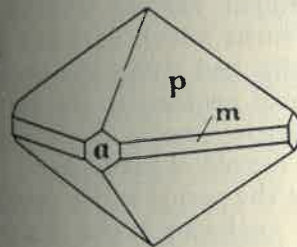


Fig. 2

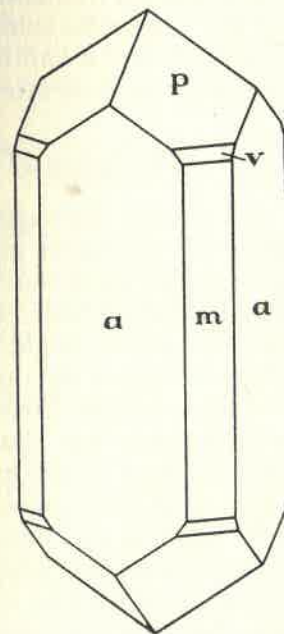


Fig. 3

distinctly prismatic and show all four forms in combination (Fig. 3). The crystals are brownish red in colour and usually show radial shattering in the surrounding minerals similar to that described by the writers for zircon from Hybla, Ontario.¹

Magnetite forms a subordinate part of the pegmatitic knobs. It often occurs in irregular stringers, suggesting that

¹Univ. of Toronto Studies, Geol. Ser. 16, p. 26.

it is one of the last minerals to form. At other times it appears as perfect octahedra surrounded by cancrinite. A chemical analysis shows that the mineral is normal magnetite devoid of titanium, nickel, and chromium.

In the pegmatitic masses apatite appears in the form of colourless glassy crystals about a millimeter in diameter and from one to two centimeters long. Pyrrhotite in small irregular masses is frequent, while molybdenite in the central parts of the pegmatite sometimes occurs as brilliant cleavage masses an inch and a half in diameter. Essonite in the form of grains is often associated with acmite.

The Origin of the Pegmatitic Knobs

If one accepts the suggestion that nepheline syenites are formed by the action of granitic magmas on sediments rich in lime, it would seem that the misakite mass owes its origin to the alteration of beds of impure Grenville limestone. In this case the knobs might be regarded as arising from the alteration of masses in the sediment varying somewhat in chemical composition from the rocks which enclosed them. It is a remarkable fact that in dip and strike the gneissoid miaskite conforms to the more acid gneisses to the east and west, and that the coarse massive knobs break sharply across the banding and are quite devoid of parallelism. They must have been formed later than the period which developed such marked parallelism in the enclosing rocks, regardless as to whether this structure is inherited from old sediments, or produced in the plutonic miaskite at the time of consolidation or by mechanical movement after consolidation. It appears to the writers that least difficulty is encountered if the knobs be regarded as pegmatitic injections into the already consolidated plutonic mass.

ZEOLITES AND RELATED MINERALS FROM LAKE NIPIGON, ONTARIO

By T. L. WALKER and A. L. PARSONS

During the past summer the writers spent two weeks in an examination of the Keweenawan traps around Lake Nipigon, more particularly in a search for zeolites and related minerals. These traps cover several thousand square miles and are exposed on most of the shore and islands of Lake Nipigon. All railway cuts for a distance of fifteen miles in the vicinity of Orient Bay were carefully examined and a trip was made around the lake so as to examine any recent falls of rocks from the cliffs. On this latter trip a surprisingly small quantity of zeolitic material was obtained, but in the railway cuts between Orient Bay station and Fairclough several good exposures were encountered which yielded the bulk of the material for this study.

The Diabase

The diabase is characterized by cliffs which are in their best development several hundred feet high. Usually on these precipitous cliffs the rock is solid and comparatively fresh. Along the railway between Orient Bay and Fairclough many of the rock cuts were weathered to a remarkable degree and in an unusual manner. When the rock cooled it developed shrinkage cracks, and next to these cracks the rock is finer grained than in the rest of the mass. In weathering everything, except these bands next to the cracks, decomposed so as to form a granular mass, while the rims remained fairly fresh.

Thin sections were prepared of fresh rock from the tunnel at McDiarmid and from the main shore of the south side of the lake near Gros Cap. In both cases ophitic texture was well developed, and the rock was a good olivine diabase.

All the minerals were remarkably fresh and unaltered. Analyses of both of these rocks were made by H. C. Rickaby as follows: I. McDiarmid, II. Main shore south of Gros Cap.

	I	II
SiO ₂	48.16	49.08
TiO ₂.....	.96	1.11
Al ₂ O ₃	16.52	16.36
Fe ₂ O ₃	1.44	1.28
FeO.....	10.88	10.44
CaO.....	9.97	10.41
MgO.....	9.35	8.32
MnO.....	.21	.22
Na ₂ O.....	2.12	2.41
K ₂ O.....	.47	.53
H ₂ O.....	.35	.32
P ₂ O ₅.....	.16	.17
CO ₂	Trace	Trace
S.....	Trace	Trace
Total.....	100.59	100.65

From the above analyses it is evident that there is a remarkable uniformity in the basalt in the Nipigon region as the samples were taken from places about twenty-five miles apart. The low percentage of water confirms the microscopic examination that the rock is composed of unaltered material. In view of the great age of these rocks, this freshness must be looked upon as one of its most striking features.

The zeolitic minerals which were observed are prehnite, pectolite, and analcite. To these may be added the nearly related mineral scapolite which occurred sparingly on joints near Gros Cap. These minerals are found almost entirely as fillings of crevices. In no case were amygdules observed which possibly indicates a condition that was unfavourable for the formation of the zeolites in contrast to the nearly related minerals pectolite and prehnite. In this connection it is to be noted that some mineralogists do not class analcite with the zeolites.

The first of these minerals to form is analcite, while the other two appear for the most part to have formed simul-

taneously starting to crystallize from different centres as both are found starting from the walls of the fissures.

The striking feature of the association is the almost complete absence of the zeolites proper. While there are numerous references in the literature to the occurrence of zeolites in the amygdaloidal traps of Lake Superior, so far as we are aware the only references to the occurrence of zeolitic minerals in the great compact nonamygdaloidal rock masses of the Thunder Bay district are the occurrence of analcite at Warneford¹ and of prehnite² on Pijitiwabic or Orient Bay. The only other near relative of the zeolites that has been recorded from the traps of the district is apophyllite, which was obtained in a silver vein on Spar Island in Lake Superior. The occurrence of prehnite, pectolite, and analcite with the almost complete absence of the zeolites proper yields an association which is decidedly different from most of the important zeolite localities of the world. Among zeolitic minerals these three, pectolite, prehnite, and analcite, are characterized by the smallest content of water. The physico-chemical conditions are evidently different in this case, and probably indicate a series that is formed at a higher temperature than the zeolites proper.

Pectolite

The most prominent mineral that was observed in the veins was a radiated white pectolite which was frequently tinged with red from the inclusion of a small quantity of hematite. The crystals are somewhat bladed with a pearly lustre and when terminating in cavities resemble the coxcomb type of barite. The terminations are however not suitable for goniometric measurement due to solution. The maximum length of the radiating crystals is about one inch. When broken there was a distinct luminescence. When examined under the microscope in yellow light $\alpha=1.601$, $\beta=1.604$, and $\gamma=1.633$, all $\pm.003$. An acute bisectrix is

¹Burrows, A., Ont. Bur. Mines, XXVI, Ann. Rep., p. 246.

²Wilson, A. W. G., Pr. Com.

almost normal to the good cleavage, and the mineral is positive. An analysis of carefully purified material by H. C. Rickaby follows:

SiO ₂	53.28	.888	
Al ₂ O ₃.....	.16	.002	
Fe ₂ O ₃.....	.48	.002	
MnO.....	.33	.005	
CaO.....	33.41	.596	2607
MgO.....	.26	.006	
Na ₂ O.....	9.14	.147	
K ₂ O.....	.25	.003	150
H ₂ O.....	2.70	.150	
Total.....	<u>100.01</u>		
S.G. (Pyc.).....	2.857		

This corresponds well with the formula for pectolite H₂O. Na₂O.4CaO.6SiO₂.

Prehnite

Associated with the pectolite is a creamy yellow to bluish green prehnite. Most of the material is of the creamy yellow type. The mineral occurs in radiated spherical or hemispherical masses and occasionally shows terminations which are in some cases a quarter of an inch in diameter. The length of the radiate crystals is greater than that of the pectolite and reaches a maximum of one and one half inches. No crystals suitable for measurement were found.

When examined by the immersion method $\alpha=1.612$, $\beta=1.617$, $\gamma=1.644$, all $\pm .003$. The acute bisectrix is perpendicular to the best cleavage, and the mineral is positive.

An analysis of pure material by H. C. Rickaby follows:

SiO ₂	42.78	.713	+3=238
Al ₂ O ₃	25.37	.249	
Fe ₂ O ₃.....	.87	.005	+1=254
CaO.....	26.95	.481	
MgO.....	Trace	.....	+2=243
Na ₂ O.....	.30	.005	
K ₂ O.....	Trace		
H ₂ O.....	4.18	.232	+1=232
Total.....	<u>100.45</u>		
S.G.....	2.900		

This corresponds well with the accepted formula for prehnite 2CaO.Al₂O₃.3SiO₂.H₂O.

Analcite

A few crystals of analcite were found associated with the pectolite and prehnite in the filling of crevices. The largest of these had been broken, but was part of a crystal nearly an inch and a half in diameter. The others showed the usual development of the trapezohedron (211).

Scapolite

On the main shore of the lake south of Gros Cap, on a recent fall of fresh trap, was a thin deposit of a white mineral which was only on a few joints. Optical examination showed it to be uniaxial negative with $\omega = 1.555$, $\epsilon = 1.546$ which is well within the range of the scapolites. The cleavage was prismatic and the extinction was straight.

APATITE, LEPIDOMELANE, AND ASSOCIATED
MINERALS FROM FARADAY TOWNSHIP,
HASTINGS COUNTY, ONTARIO

By T. L. WALKER and A. L. PARSONS

During the summer of 1925 some small pits were opened for mica on lot 32, concession XV of the township of Faraday, Hastings county, Ontario. As the character of the mica mined and the association of minerals found with it are somewhat unusual the writers undertook an examination of the deposits and of the material collected at the time of their visit in August, 1925.

On the southwestern slope of a hill composed of nepheline syenite there were outcrops of an extremely black mica along a band of very coarse rock containing considerable masses of calcite and a granitic plagioclase rock. In some places masses of calcite had been dissolved out so as to form caves, which were later filled with very fine black earth, probably derived from the decay of roots which had penetrated the gradually extending cavities. In August, 1925, the work of the prospectors had opened up a cave at least eight feet deep, three feet wide, and ten feet long. In this cave apparently all the less soluble minerals originally contained in the calcite filling were preserved scattered through the black peaty soil. Crystals of mica, apatite, and plagioclase and irregular masses of fluorite, magnetite, and pyrite were collected. Masses of coarse calcite at times projected into the cavity, suggesting that the local solution of the carbonate had given rise to the formation of the cave and that the scattered minerals had once formed part of a calcite-mica-apatite pegmatitic phase of the nepheline syenite.

Lepidomelane

The mica usually occurs in fine crystals which are often corroded as shown in Pl. II, Figs. 1 and 2. In the loose

material filling the cave there are all sizes of crystals from one inch to three feet in diameter. Owing to corrosion and covering with a rusty film of iron, they are not suitable for exact measurement, except such as may be made with the contact goniometer. As the crystal habit of lepidomelane is not well illustrated in the literature several crystals were measured. Figs. 4 and 5 present the common combination of forms and habit of the crystals. The forms observed on the crystals are: c (001), b (010), o (112), and μ (111).

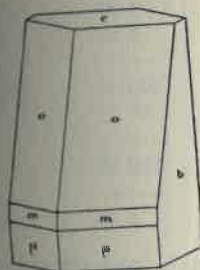


Fig. 4

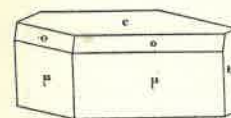


Fig. 6

The mica is deep black in colour and perfectly cleavable. Cleavage plates from crystals rarely show undulations, partings or inclusions of other minerals. In the thinnest cleavage plates the mineral is opaque, except on an occasional frayed border, where it is of a faint green when viewed in strong light. While such dark mica would not ordinarily find a market for electric purposes, it was learned that some of the larger sizes were readily disposed of at about half the price for similar sizes of amber phlogopite.

An analysis (I) by H. C. Rickaby indicates that the mica is lepidomelane rather than biotite or phlogopite. It resembles in some respects the lepidomelane analysed by Egelson¹ from the township of Monmouth some twenty miles to the west (II), where it occurs in essexite. It is also closely related to the lepidomelane from the nepheline syenite from Parry Sound district².

¹Adams, F. D., and Barlow, A. E., Mem. Geol. Sur. Canada, No. 6, p. 243, 1910.

²p. 7.

	I	II
SiO ₂	34.04	31.48
TiO ₂	1.48	2.50
Al ₂ O ₃	15.60	17.23
Fe ₂ O ₃	4.22	5.85
FeO.....	23.60	27.96
MgO.....	7.46	2.99
MnO.....	.99	1.61
K ₂ O.....	.....	1.33
Na ₂ O.....	8.89	4.17
H ₂ O.....	.88	1.68
F.....	1.26	3.94
	2.02	.....
Less oxygen equiv. of F.....	100.44	100.74
	.17	
Total.....	100.27	
S.G.....	3.16	3.25

The mineral from Faraday township is remarkable for the high content of fluorine and magnesia.

Apatite

The apatite occurs in well-formed prismatic crystals from half an inch to eighteen inches in length with a maximum diameter of four or five inches. The surfaces, while very brilliant, are often more or less corroded with rounded edges and corners, as has been frequently noted in the Canadian apatite crystals. In colour the mineral is a fine asparagus green, except when, due to the presence of foreign substances in cracks, the colour is brownish or brownish green. The crystals are very simple, exhibiting only three forms: *c* (0001), *m* (10 $\bar{1}$ 0), and *x* (10 $\bar{1}$ 1). Often the crystals are doubly terminated as shown in Fig. 6. It has long been known that in certain portions of the Canadian apatite field the crystals are always devoid of the basal pinacoid, while in other regions, especially in Renfrew county, the base is usually more prominent than the pyramid. In this respect the crystals described from Faraday township belong to the

basal or Renfrew type. This difference does not appear to depend upon the ratio of fluorine to chlorine, since our type is devoid of chlorine, and in habit resembles some Norwegian apatites which are said to be free from fluorine.

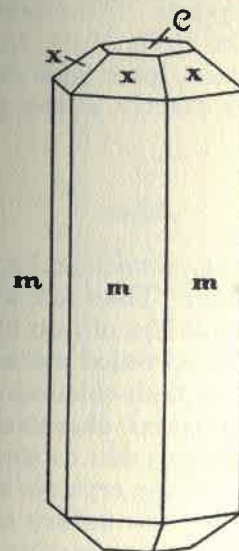


Fig. 6

An analysis by H. C. Rickaby gave the following result:

CaO.....	55.10
FeO.....	.36
MgO.....	.23
MnO.....	.12
Al ₂ O ₃.....	.12
P ₂ O ₅	41.24
F.....	3.65
CO ₂.....	.73
Insol.....	.22
	101.77
Less oxygen equiv. of F.....	1.54
Total.....	100.23
S.G.....	3.184

The sample for analysis was prepared by separation of the apatite by means of heavy solutions. Owing to the ready solubility of the mineral in acids, it was not possible to free it from the foreign substances which in thin films occupy fracture cracks in the crystals. This foreign material appears to be represented by the FeO, MnO, MgO, Al₂O₃, insoluble and 1.66% of calcite since, after such deduction, the P₂O₅, CaO and F are present exactly in the proportions required for pure fluor-apatite.

Albite

Along with the crystals of mica and apatite, a few crystals of feldspar were obtained. They are somewhat reddish on the outer surface, due to oxides of iron filling cleavage cracks and unevennesses in the corroded surface. The interior of the crystals is pinkish to flesh-coloured. At their base the crystals exhibit the striations characteristic of plagioclase and in addition deep grooves due to corrosion. A fragment from the interior of one of the crystals was crushed, and the powder used to determine the nature of the plagioclase by the immersion method. The extinction on basal plates was about three or four degrees; on brachy-pinacoidal cleavage plates, as measured against the basal cleavage lines, seventeen degrees; while all the indices were lower than 1.541. These observations show that the mineral is albite. Several of the crystals were about four inches long with proportions shown in Fig. 7.

The forms determined by measurements obtained by the contact goniometer are: *b* (010), *m* (110), *μ* (1 $\bar{1}$ 0), *z* (130), *c* (001), *y* (201), *p* (111), and *o* (1 $\bar{1}$ 1).

Other Minerals

The fluorite is purplish in colour and devoid of well-marked crystal form. It sometimes occurs as granular friable masses. The magnetite which exhibits perfect octahedral cleavage is present in masses up to three inches in

diameter. Of the minerals found in the cave pyrite is the least frequent. It forms small irregular masses up to two inches in diameter.

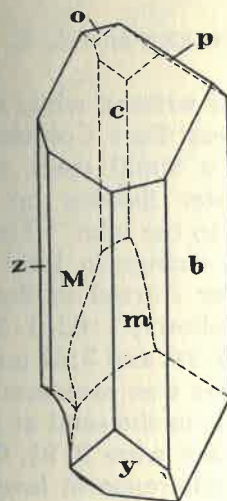


Fig. 7

In contrast to mica-apatite deposits common in Ontario and Quebec, the mineral association in Faraday lacks sphene, zircon, diopside, and scapolite, all of which are rarely absent in the apatite deposits further east, while lepidomelane takes the place of phlogopite. Possibly this difference in mineral association is connected with the nature of the igneous intrusion to which the deposits owe their formation. The deposit in Faraday township occurs on the border of a mass of nepheline syenite, while most of the apatite deposits are more closely associated with acid plutonics and pyroxenites, which probably represent the result of the action of the acid intrusive on old limestones. It may be noted also that many of the well-established occurrences of lepidomelane are closely associated with nepheline-bearing intrusives.

CHANGES IN WATER LEVEL AND FLOTATION AS FORCES OF EROSION

By T. L. WALKER and A. L. PARSONS

On July 6, 1925, the writers, while camped at the north end of Munroe Bay near Port Coldwell on Lake Superior (Fig. 8), noticed that a small creek reversed its current intermittently, the water flowing up stream for several minutes and then back to the lake. This reversal of current was accompanied by a change in level of the water. The moment when the water started to flow out was recorded for eleven changes as follows: 1:02, 1:15, 1:30, 1:46, 2:08, 2:24, 2:47, 2:59, 3:12, 3:24, and 3:37 p.m. The rise and fall for the last four changes was measured by putting a stick with inches marked on it in the sand at low water. The low and high points in inches were 2, $9\frac{1}{2}$, 0, 7, 3, 5, $3\frac{3}{4}$, and $7\frac{1}{2}$ so that the maximum difference in level was $9\frac{1}{2}$ inches and the minimum difference $1\frac{1}{4}$ inches. When these results were plotted it was seen that, in addition to a wave with an average length of 15 minutes, there was another with a much greater length, although there were not enough observations to determine the length of the longer wave. Loudon¹ has shown a definite tide in Lake Huron, and in his records, which were made by the tide gauge, there are also two well-defined sets of waves which appear to have average intervals of about five minutes and from fifteen to twenty minutes respectively. The longer wave appears to be comparable to the period observed by the writers. It is our hope that further observations may be made with a suitable tide gauge covering a period of several days. The reversal in current was noticed in a second creek, but no further measurements were made.

At about the same time large quantities of sand were seen

¹Loudon, W. J. Trans, R. Ast. Soc, Can. 1905, 131-140.

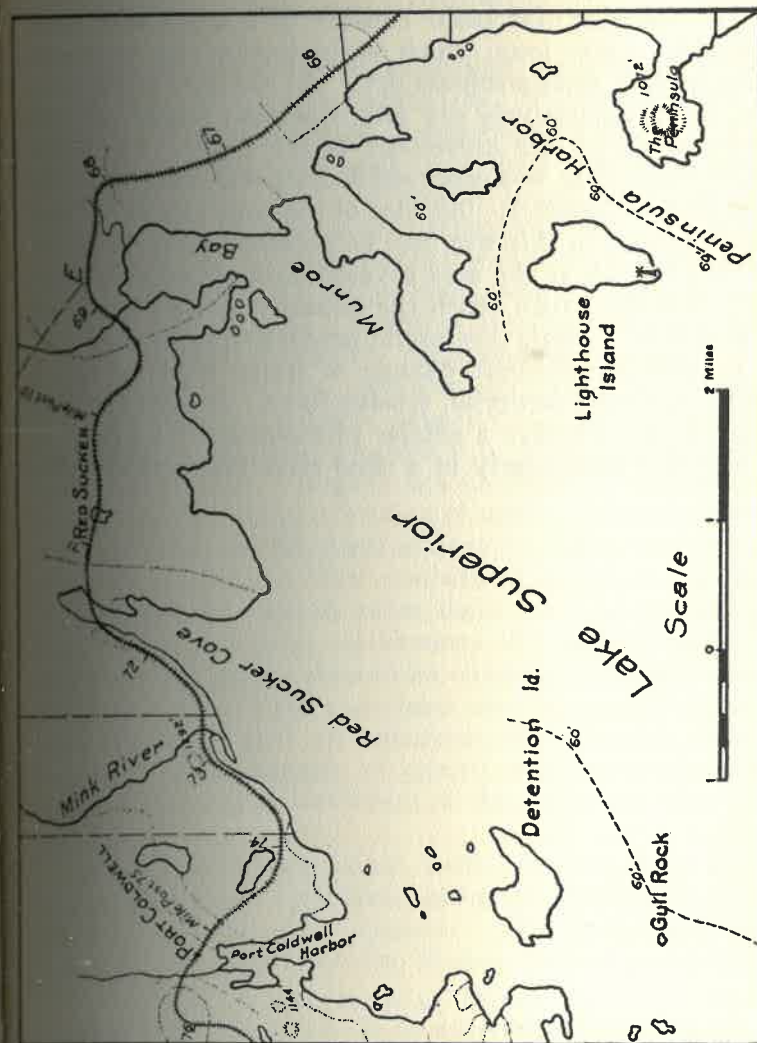


Fig. 8

floating on the surface of the water in small rafts several inches in diameter (Fig. 2).

The shore at this point consists of a broad sand beach about half a mile long, which as the level of the water went down became comparatively dry. As the level of the water rose, the comparatively dry grains of sand floated and were carried away by the movement of the water. The largest grain of sand that was observed floating was nearly a quarter of an inch in diameter. An idea of the large quantity of sand that is moved in this way can be obtained from the picture (Pl. IV, Fig. 1), as the area covered does not exceed a square yard. On the entire beach the quantity of sand that would be moved in a single day would amount to many tons.

In this intermittent change of water level we have a gentle, but most powerful, erosive force. It would be interesting to see whether a similar phenomenon were produced by the tide particularly in a tidal river above the salt line.

OXIDATION OF SULPHIDES

By FERGA CARMICHAEL

Although considerable experimental work has been done on the rate and order in which the various sulphides are attacked by acid solutions, comparatively little is to be found in the literature regarding their oxidation in the presence of water only. Winchell¹ found that powdered pyrite, when suspended on an aluminium screen over a glass vessel containing aerated distilled water which was kept in constant circulation by an air blast, was oxidized, although only very slightly, after a period of treatment of ten months. Grout² confirmed Winchell's conclusion with regard to the extreme slowness of the oxidation by exposing to the air for twelve months a weighed quantity of powdered pyrite on a crystallizing dish, and covering it as often as it became dry with distilled water. Buehler and Gottschalk,³ on the other hand, found the rate of oxidation of pyrite to be considerably more rapid than did Winchell or Grout. They obtained their results by washing a filter containing a weighed quantity of the powdered mineral twice daily for a period of three months with five cubic centimeters of distilled water. An analysis of the filtrate showed an oxidation of approximately three per cent. Work was done also on a number of the other sulphides and on mixtures of sulphides. It was found that the presence of pyrite and marcasite greatly increased the rate of oxidation of the materials with which they were mixed.

In the present experiment, work was done on a number of the commoner sulphides, although nothing has been attempted as yet upon mixtures. The method of attack was similar to that used by Walker and Parsons in their

¹Winchell, A. N., *Ec. Geol.*, Vol. II, pp. 290-294, 1907.

²Grout, F. F., *Ec. Geol.*, Vol. III, pp. 532-534, 1908.

³Buehler, H. A., and Gottschalk, V. H., *Ec. Geol.*, Vol. V, pp. 28-35, 1910.

work on arsenides.¹ Ten grams of mineral, which had been ground to pass through a twenty mesh sieve and rest upon a sixty mesh sieve, were put into a bottle containing 500 cc. of distilled water at room temperature and 2100 cc. of oxygen. The bottle was stoppered and clamped to prevent not only the escape of the oxygen, but also any leakage of air into the bottle. The bottle was then agitated continuously at room temperature for a period of thirteen days, atmospheric pressure being restored daily by the addition of fresh oxygen through a short glass tube and stop-cock in the stopper. The agitation was accomplished with the bottles in a vertical position by a reciprocating motion of the container which made one complete stroke of 15.4 centimeters per second. At the end of the thirteenth day the solution was filtered off and analysed. In the case of some of the sulphides, one product of the oxidation took the form of an insoluble slimy precipitate, which adhered to the sides of the bottle and to the unaltered sulphide residue. This precipitate was washed away from glass and residue by means of some dilute acid which had previously been found by experiment not to attack the original mineral. The precipitate which was thus taken into solution was analysed separately.

The chemical composition of the original mineral, the soluble oxidation product, and the insoluble oxidation product are shown for each mineral under the headings I, II, and III respectively.

Polydymite, Vermilion Mine, Sudbury, Ontario.

	I	II	III
Iron.....	11.88	.32	2.70
Nickel and Cobalt.....	47.42	8.99	
Copper.....	.88	.71	
Sulphur.....	39.94	5.53	.25
Insoluble.....	.44		
Total.....	100.56	15.55	2.95
		18.50	

¹Walker, T. L., and Parsons, A. L., Cont. Can. Min., 1925, Geol. Ser. No. 20, pp. 41-48.

Marcasite, Loughborough Township, Ontario.

	I	II
Iron.....	46.56	.11
Sulphur.....	53.40	.18
Insoluble.....	.05	
Total.....	100.01	.29

Pyrite, locality unknown.

	I	II
Iron.....	46.52	.07
Sulphur.....	52.70	.06
Insoluble.....	.40	
Total.....	99.62	.13

Pyrrhotite, Hybla, Ontario.

	I	II	III
Iron.....	60.16		.11
Nickel and Cobalt.....	.24		
Sulphur.....	38.76	.07	
Insoluble.....	.56		
Total.....	99.72	.07	.11
		.18	

Pyrrhotite, Crean Hill Mine, Sudbury, Ontario.

	I	II	III
Iron.....	54.28		.25
Nickel.....	6.64	.07	
Cobalt.....	Trace		
Sulphur.....	36.28	.06	
Insoluble.....	2.72		
Total.....	99.92	.13	.25
		.38	

Pentlandite, Creighton Mine, Sudbury, Ontario.

	I	II
Copper.....	2.76	
Iron.....	30.84	.01
Nickel.....	29.45	.12
Cobalt.....	1.93	.03
Sulphur.....	32.56	.10
Insoluble.....	.40	
Total.....	97.94	.26

Troilite, Del Norte Co., California.

	I	II
Iron (Ferrous).....	60.28	.32
Sulphur.....	33.54	.05
Insoluble.....	2.24	
Total.....	96.06	.37

Chalcopyrite, Ellenville, N.Y.

	I	II
Iron.....	27.28	Trace
Copper.....	31.28	None
Sulphur.....	35.10	.02
Insoluble.....	5.88	
Total.....	99.54	.02

Bornite, Whitehorse, Y.T.

	I	II
Iron.....	8.80	Trace
Copper.....	57.84	.01
Sulphur.....	22.00	Trace
Insoluble.....	9.54	
Total.....	98.18	.01

Chalcocite, Butte, Montana.

	I	II
Iron.....	.12	
Copper.....	75.84	.63
Sulphur.....	18.30	.02
Insoluble.....	4.54	
Total.....	98.80	.65

Stibnite, Japan.

	I	II
Iron.....	.24	
Antimony.....	56.15	.05
Sulphur.....	23.50	.02
Insoluble.....	16.75	
Total.....	96.64	.07

Sphalerite, Picos de Europa.

	I	II
Zinc.....	66.98	.04
Sulphur.....	32.35	.02
Insoluble.....	.22	
Total.....	99.55	.06

Galena, Kingdon Mine, Galetta, Ontario.

	I	II
Lead.....	85.74	None
Sulphur.....	13.98	.01
Insoluble.....	.08	
Total.....	99.80	.01

From these analyses, it is noteworthy that where the minerals have a sufficient excess of sulphur to form sulphuric acid, the oxidized iron is taken into solution, but where such an excess is not present the iron is precipitated in the form of the hydroxide.

It is evident that, under the conditions of the experiment, the sulphides have oxidized in the following order, starting with the most easily attacked:

	% Oxidized
Polydymite.....	18.50
Chalcocite.....	.65
Pyrrhotite (Crean Hill Mine).....	.38
Troilite.....	.37
Marcasite.....	.29
Pentlandite.....	.26
Pyrrhotite (Hybla, Ontario).....	.18
Pyrite.....	.13
Stibnite.....	.07
Sphalerite.....	.06
Chalcopyrite.....	.02
Bornite.....	.01
Galena.....	.01

This order of oxidation agrees well with the results of earlier workers, as is shown in the following table, in which

the minerals occurring in an order at variance with that of the present experiment have been placed in brackets:

Carmichael	Weigel ¹	Buehler and Gottschalk ²	Emmons and Laney ³
Polydymite.....			
Chalcocite.....			Chalcocite
Pyrrhotite (Ni 6.64%)..			
Troilite.....			
Marcasite.....			
Pentlandite.....			
Pyrrhotite.....	Pyrrhotite		Pyrrhotite
Pyrite.....	Pyrite	Pyrite	Pyrite
Stibnite.....		(Chalcopyrite)	
Sphalerite.....	Sphalerite (Chalcocite)	Sphalerite	
Chalcopyrite.....			
Bornite.....			
Galena.....	Galena	Galena	

During the course of the experiment particular interest was taken in the behaviour of the polydymite, not only because of its unusually rapid oxidation, but also because of an article which has recently appeared by Lindgren and Davy⁴ in which the suggestion is made that the so-called polydymite from the Vermilion mine, Sudbury, Ontario, differs from the type material from Grüneau, Westphalia, and is really a mixture of pentlandite and a new nickel disulphide, violarite. Instances have been recorded where it was possible to separate one of the constituents of an intimate mixture from the remaining minerals, as for example, the removal of calcite gangue by concentrated hydrochloric acid from goethite crystals by Goldschmidt and Parsons⁵

¹Weigel, O., *Zeit. f. phys. Chemie*, Vol. 58, 1907, pp. 293-300.

²*Loc. Cit.*

³Emmons, W. H., *Principles of Economic Geology*, p. 163.

⁴Lindgren, W., and Davy, W. M., *Ec. Geol.*, Vol. XIX, pp. 309-319, 1924.

⁵Goldschmidt, V., and Parsons, A. L., *Zeit. f. Kryst. usw.*, XLVII Band, 3 Heft, pp. 238-241.

and the separation of skutterudite from smaltite and chloanthite by means of nitric acid by Walker.¹ Ellsworth² separated cobaltite, breithauptite, and niccolite in a similar manner. Cobaltite was purified by the removal of the breithauptite and niccolite with aqua regia. Breithauptite inclusions were freed of the niccolite by means of concentrated nitric acid, while niccolite was removed from a niccolite-breithauptite mixture with hot dilute nitric acid. With these experiments in mind it was thought that some evidence of a tendency toward the concentration of violarite at the expense of the pentlandite might be exhibited by the polydymite during the process of oxidation. In order to test this theory, a bottle containing ten grams of polydymite³ ground to pass through a one-hundred-mesh sieve, with the usual 2100 cc. of oxygen and 500 cc. distilled water, was agitated continuously for fifty days. In this case a daily record was kept of the amount of oxygen used up in restoring atmospheric pressure, so that some idea of the rate of consumption of the mineral could be obtained. If we assume for purposes of calculation that the reaction occurring in the bottle was $Ni_4S_5 + 19O = 4NiO + 5SO_2$, then, for every cubic centimeter of oxygen used up, 0.00168 grams of the mineral would be consumed. At the end of fifty days it was assumed on the basis of this calculation that 5.55 grams of the original material had been oxidized and the agitation was discontinued. When the solution had been filtered off and the slimy precipitate dissolved in dilute hydrochloric acid, the insoluble residue was found to weigh 4.36 grams. From this residue 1.14 grams of sulphur was removed by means of carbon bisulphide. In the remaining 3.22 grams of insoluble residue it was hoped to find some indication of differential solution of the minerals contained in the original sample. Analyses of the residue (A), the oxidation product soluble in water (B), and the oxidation product soluble in dilute hydrochloric acid or carbon bisulphide (C) follow:

¹Walker, T. L., *Am. Min.*, Vol. 6, No. 3, pp. 54-56, 1921.

²Ellsworth, H. V., *Ont. Bur. Min.*, XXV Ann. Rep. Pt. I, p. 215, 1916

	A	B	C
Copper.....	.17	.85	
Iron.....	2.26	.17	10.15
Nickel.....	16.08	28.16	.22
Cobalt.....	.73	.08	Trace
Sulphur.....	11.86	16.32	12.21
Insoluble.....	.28		
Total.....	31.38	45.58	22.58
		99.54	

From the analysis of the residue it is evident that the molecular ratio of metal to sulphur is still about four to five, and hence no evidence of a concentration or differential solution of violarite is indicated.

Before concluding, the writer wishes to express her appreciation of the assistance given her and the interest taken in the work by Dr. T. L. Walker, Professor A. L. Parsons, and Mr. H. C. Rickaby.

CRYSTALLOGRAPHIC AND OPTICAL COMPARISON OF THE CHLORIDES OF LEAD ISOTOPES

By D. KERR-LAWSON

Since the discovery of the lead isotopes, it has been of interest to discover whether these substances and their compounds differ from each other, and from common lead and its compounds, in any properties other than those of density, atomic or molecular weight, and radioactivity. Richards¹ has supplemented his fine work in connexion with these latter characteristics by accurate determinations of the refractive indices and solubilities of the nitrates of uranium lead and common lead. He showed that both nitrates were cubic in crystallization and that at 20° centigrade their indices of refraction differed, if at all, by an amount less than one part in fifteen thousand, and also that their molal solubilities differed by an amount less than one part in eight thousand.

Upon the suggestion of Dr. T. L. Walker, of the Department of Mineralogy, University of Toronto, a comparison was made of the crystallographic constants and one of the indices of refraction, of the chlorides of common and isotopic leads. The chloride of lead is rhombic in crystallization, and a pyramidal face therefore makes intercepts on the three rectangular axes of reference, which are not simply and rationally related; moreover there are three principal indices of refraction, so that there is more scope for variation, both geometrically and optically, than in the case of the cubic nitrate. The first of the chloride samples was prepared from lead secured through the kindness of Professor T. W. Richards, of Harvard University, and represents the final decomposition product of Katanga uraninite. He states that, while the particular ingot from which the sample was

¹Richards, T. W., and Schumb, W. C., Jour. Am. Chem. Soc., Vol. XL, No. 9, Sept. 1918.

taken has not been analysed, it is from precisely the same source as that which yielded Hönigschmid and Birckenbach¹ an atomic weight of 206.05, and which yielded Richards and Putzeys a value of 206.1.

The second sample was ordinary lead chloride from the laboratory bottle, and labelled Baker's Analysed C.P. The analysis reported .002 per cent. iron and a trace of sodium, with no copper, lime, or lead acetate. The third sample was prepared from lead extracted from a specimen of thorite² from Brevig, Norway. From thirty grams of this mineral, about a quarter of a gram of lead was recovered.

The material from Katanga, which was received as metallic lead, was dissolved in strong nitric acid and plated out by electrolysis as lead peroxide. The deposit was dissolved in more nitric acid (1:1), to which a few drops of ethyl alcohol had been added. By repeated evaporation with concentrated hydrochloric acid, the nitrate was converted into chloride. The common lead chloride was used without further treatment. The lead chloride from the thorite was prepared by breaking up the mineral with hydrofluoric and sulphuric acids, driving off the silica, filtering out the lead as sulphate, dissolving the lead sulphate in ammonium nitrate, plating out by electrolysis, redissolving the deposit and replating, then proceeding as in the case of the uranium lead.

The method of growing the crystals consisted in the slow cooling of a saturated solution of the chloride in concentrated hydrochloric acid, as advocated by Schabus³ and Stöber.⁴ The solution was introduced into a Pyrex test tube, stoppered, and the whole placed in a thermos bottle containing water at its boiling point. At the end of forty-eight to sixty hours the temperature within had dropped to near that of the room and the crystals were then separated from the solution

¹Hönigschmid and Birckenbach, Ber. Deut. Ch. Ges., 56 B, 1857-9 (1923).

²The thorite in question yielded 10.36% U₃O₈ on analysis.

³Schabus, V., Berichte der Akad. der Wiss., Wien, 1850, (4), p. 456.

⁴Stöber, F., Bull. Acad. Belg. Brux., 1895, (3), 30, p. 345. Zeit. f. Krist., 28 p. 109.

and washed with ethyl alcohol. By this method beautiful water-clear crystals, adamantine in lustre, and almost diamond-like in appearance, are obtained. In size they run up to about two millimeters in their greatest dimension, and are admirably adapted to accurate goniometric measurement. The writer's experience indicates that in order to secure the best crystals the solution should contain very little, if any, solid lead chloride at the commencement of the slow cooling, and that the most symmetrically developed individuals are secured on a platinum filament suspended in the tube, and previously inoculated by touching in several places with a glass rod dipped in the hot saturated solution. This method of growing crystals has the advantage of requiring only small quantities of material. Not more than a



Fig. 9

quarter of a gram of lead was necessary to furnish a sufficient number of crystals for measurement. This yielded some ten cubic centimeters of saturated solution at 100° centigrade.

Figure 9 is a drawing showing the common habit and relative prominence of the chief forms exhibited by the crystals grown in this manner. Some variation occurs in the relative prominence of the forms in the same crop of crystals, particularly among those individuals which grow close to one another in the bottom of the tube. For a detailed study of the crystallization of the substance, the reader is referred to the excellent paper by Stöber,¹ who gives a number of drawings and also describes the twinning laws of the substance. Of importance to the present study, however, was the fact that the crystals were frequently found with domes

¹Loc. Cit.

and pyramids well developed on the upper side, while the lower side showed little or nothing other than the base. This peculiarity was utilized in measuring the refractive index for vibrations parallel to the brachy axis, by the method of minimum deviation, as the dome $u(012)$ makes a wedge angle of some $30^\circ 40'$ with the opposite base $c(00\bar{1})$. The forms observed on the crystals grown by this method were the base $c(00\bar{1})$; the brachydomes $u(012)$, $q(011)$, and $t(021)$; the macro dome $e(101)$; the pyramids $i(112)$ and $o(111)$; and the brachypinacoid $b(010)$. The base, the brachypinacoid, and the pyramid $i(112)$ were commonly well developed and gave fine reflections. This permitted the crystals to be oriented with some accuracy, and the axial ratios for each type of material were calculated from the

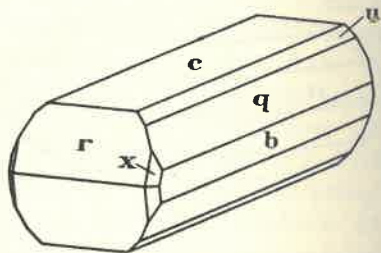


Fig. 10

angle ϕ of the unit pyramidal zones, and the angle ρ of the pyramid $i(112)$. The results obtained for these angles and the consequent axial ratios are shown in the following table. It is evident that, if the means be rounded off to the nearest minute, the angles are identical for the three types of material. In order to compute the axial ratios, the means have been taken to the nearest five seconds.

From the measurements it is apparent that, within the commonly accepted limit of accuracy of the Goldschmidt goniometer, these substances are crystallographically identical.

As previously stated, one of the indices of refraction was measured by the method of minimum deviation, using the prism formed by the brachydome $u(021)$ and the opposite base $c(00\bar{1})$. This gives the refractive index γ . It was

TABLE

Showing comparison of crystallographic constants

Katanga Lead 3 crystals		Common Lead 4 crystals		Thorite Lead 3 crystals	
ϕ	ρ	ϕ	ρ	ϕ	ρ
$50^\circ 15'$	$49^\circ 16'$	$59^\circ 16'$	$49^\circ 16'$	$59^\circ 13\frac{1}{2}'$	$49^\circ 16'$
15	16	15	16	$14\frac{1}{2}$	16
15	16	15	$15\frac{1}{2}$	$13\frac{1}{2}$	15
15	16	14	$15\frac{1}{2}$	$15\frac{1}{2}$	15
$14\frac{1}{2}$	15	15	15	$16\frac{1}{2}$	16
$15\frac{1}{2}$	16	$15\frac{1}{2}$	16	$13\frac{1}{2}$	16
15	16	15	17	$14\frac{1}{2}$	16
15	16	16	$14\frac{1}{2}$	$13\frac{1}{2}$	
15	16	15	$13\frac{1}{2}$	$13\frac{1}{2}$	$49^\circ 15' 45''$
15	16	15	$16\frac{1}{2}$	15	
15		15	$16\frac{1}{2}$	15	
16	$49^\circ 15' 55''$	15	15	16	
16		14	15	16	
15		14		15	
16		15	$49^\circ 15' 30''$	15	
14		16		13	
15		15			
15		12		$59^\circ 14' 35''$	
15		16			
14					
			$59^\circ 14' 55''$		
$50^\circ 15' 05''$					
$\rho_0 = 1.9959$		$\rho_0 = 1.9953$		$\rho_0 = 1.9954$	
$\phi_0 = 1.1875$		$\phi_0 = 1.1871$		$\phi_0 = 1.1869$	
$a:b:c = 0.5950:1:1.1875$		$a:b:c = 0.5949:1:1.1871$		$a:b:c = 0.5948:1:1.1869$	

Stöber's¹ values are: $a:b:c = 0.5952:1:1.1872$

found that ten readings of the wedge angle could be made with a range of a minute and ten determinations of the angle of minimum deviation with a range of three minutes. Each value quoted in the table below was computed from the mean of ten measurements of the wedge angle and ten measurements of the angle of minimum deviation.

¹Loc. Cit.

TABLE

Showing comparison of values obtained for index γ

Katanga Lead (At 20° C.)	Common Lead (At 20° C.)	Thorite Lead (At 20° C.)
1st wedge 2.2602 (Repeated on same wedge) 2.2604	1st wedge 2.2601 2nd wedge 2.2602	1st wedge 2.2602

Some preliminary experiments in which special attention was not paid to the temperature, but in which it was probably not far from 20° C., gave the following results:

Katanga Lead	Thorite Lead
1st wedge 2.2604	1st wedge 2.2605
2nd wedge 2.2604	2nd wedge 2.2602

The variations evident lie within the range of accuracy of the method.

Stöber¹ measured all three indices of refraction of lead chloride by the ingenious method of Brögger and Ramsay,² improved by himself³, according to which the natural wedges found on the crystal, when too obtuse in angle to refract light in air, are rendered available for the method of minimum deviation by immersion in methylene iodide, or other optically denser fluid. He gives for the index γ , for common lead, the value 2.2596. He obtained this from the wedge formed by the brachypinacoid $b(010)$ and the opposite dome $t(0\bar{2}1)$, which intersect to form a wedge angle of some 22° 50', so that for the determination of this particular index he did not use the liquid.

The nearest analogous pair of compounds not of isotopes, but having nearly the same molecular weight known to the writer, are the hexahydrates of nickel and cobalt dichlorides.

Formula	Molecular Weight	Crystallographic Constants
NiCl ₂ ·6H ₂ O	237.7	$a:b:c::1.4678:1:0.9462$ β 122° 30' ⁴
CoCl ₂ ·6H ₂ O	238.0	$a:b:c::1.4788:1:0.9452$ β 122° 19' ⁵

¹Loc. Cit.

²Ramsay, W., Zeit. f. Krist., XII, p. 209.

³Stöber, F., Bull. Acad. Belg. Brux., 1895, (3), 30, p. 520.

⁴Ch. de Marignac, Am. d. Mines, 1856, (5), 9, 3.

⁵Brooke, Annals of Philosophy, London, 1824, 23, p. 364.
Abstracted Groth, Chem. Krist. 1906, I, pp. 247-248.

If these crystallographic data are reliable, the differences in the axial ratios are much greater than in the case of the chlorides of isotopes of lead.

It may be of interest to state that lead chloride crystals of fair quality were also obtained from aqueous solution, by sealing suitable quantities of lead chloride and water in a strong Pyrex tube, and enclosing it in an iron cylinder with some water to take up the pressure. The cylinder was then placed in a box of sand and the whole set in a Freas oven, which was fitted with a clockwork arranged to turn the regulator down about 50° C. per 24 hours. The cooling was started after the oven and contents had stood for some hours at 175° C. The crystals obtained by this method from aqueous solution are somewhat inferior to those obtained from hydrochloric acid solution, from the point of view of accurate crystallographic measurement. They are of entirely different habit from the latter, having in general the appearance of Fig. 10. They are elongated in the brachy direction, and terminated in that direction by the macrodome $e(101)$. The only pyramid observed on these crystals was the form $t(121)$, and that was very poorly developed. The forms observed on them were the base $c(001)$; the brachypinacoid, $b(010)$; the brachydomes $u(012)$, $q(011)$; the macrodome, $e(101)$; and the pyramid, $t(121)$.

In conclusion, it may be stated that all the forms hitherto reported for lead chloride were observed on one or the other type of crystals, with the exception of the macropinacoid, $a(100)$.

Acknowledgements are due to Professor T. W. Richards, of Harvard University, who kindly furnished the sample of Katanga lead used; and to Professors T. L. Walker and A. L. Parsons, for valuable aid in the progress of the work.

THE MICROSTRUCTURE OF ANTHRACITE AND ANTHRAXOLITE

By SHERWIN F. KELLY

The microscopical structure of anthracite has been thoroughly studied in recent years by means of the heat-etching of polished sections.¹ It therefore seemed reasonable to suppose that, by using the same method on the anthraxolite from near Sudbury, some light could be shed on the nature of the latter substance.

The procedure adopted is that described by Professor Turner.² Pieces of varying size, up to three centimeters square, are ground flat, usually on two sides at right angles to each other. They are then polished on the polishing wheels used to prepare mineralographic specimens. Alundum flour is used on the first linen-covered wheel, and rouge on the second. On the third wheel, covered with velour, tin oxide is the abrasive. This leaves the specimen with a high, mirror-like polish.

It is then placed in an oven and heated to about 220° centigrade to drive off the moisture. After being kept at this temperature for an hour or so, warmed forceps are used to lift it out and hold it in front of a blow-pipe or blast-lamp flame. The flame is directed perpendicularly on to the polished surface, which is brought to a red heat and held there a few seconds. The warming and etching may have to be repeated several times to get good results.

The specimen is now ready for examination, using a microscope fitted with a prism for reflecting light vertically down upon the surface, which then reflects it back up the tube to the eyepiece. Professor Turner says:³ "All ordinary

¹Turner, H. G., *Trans. Am. Inst. Min. Eng.*, Vol. 71, 1925, p. 127. Turner, H. G., and Randall, H. R., *Jour. Geol.* 31, 306, 1923.

²*Loc. Cit.*

³*Loc. Cit.*

anthracite, on close examination, is found to be more or less laminated. . . . In general, brilliant jet-black layers alternate with bright black or gray bands, in which are embedded thin sheets of dull material resembling charcoal. . . . The brilliant layers of anthracite, when examined under the microscope, are found to be derived from pieces of wood, such as limbs, stems, twigs, and roots. Wood structure has been preserved in many of them, although it is absolutely lacking in the majority. . . . The bright coal, or attritus . . . is a complex granular ground-mass, composed of a great number of constituents. . . . Some of the easily recognized things embedded in this ground mass are spores, megaspores, cuticles, former resinous matter, pith, plant fibres, plant cells and parts of cells, finely macerated woody matter, and mineral grains. . . . The carbonized matter of coal has been called 'charcoal', 'mother of coal', and 'fusain'. . . . Most of it shows good plant structure, being structureless in rare cases only."

In the two papers cited Professor Turner has published numerous photomicrographs of the excellent results he has obtained by this method. For purposes of comparison and illustration, two photographs of coal obtained by the author are reproduced:

Pl. III, Fig. 1 shows a section at right angles to the bedding of the coal, magnified 112 diameters (as are all the sections, unless otherwise stated). At "A" there is some wood-fibre, slightly crushed, and cut obliquely to the fibres. Next to it at "B" there is a cross section of a much less crushed stem. The laminated material on either border is made up of bands of anthraxylon (the brilliant jet-black layers of coal) and plant debris, or attritus.

Pl. III, Fig. 2 is cut nearly parallel to the bedding and is made up almost entirely of crushed wood-fibre such as that at "A" in Fig. 1. At A and B are plant structures apparently formed subsequently to the degeneration of the wood, for they retain a delicacy of outline that could scarcely have survived the destruction of the ground-mass. In all likelihood they represent the cross-section of rootlets or stems which grew in the decaying wood.

EXPLANATION OF PLATES

PLATE I

Fig. 1.—Section of sodalite-cancrinite knob in nepheline syenite, French river, Ontario. ($\frac{1}{2}$ nat.).

Fig. 2.—Weathered surface of nepheline syenite, French river, Ontario. ($\frac{3}{8}$ nat.).

PLATE II

Fig. 1.—Lepidomelane showing natural etching of basal plane, Faraday township, Hastings county, Ontario. (nat. scale).

Fig. 2.—Lepidomelane showing natural etching of prismatic face of the crystal shown in figure 1, (nat. size).

PLATE III

Fig. 1.—Section of anthracite at right angles to the bedding, showing crushed wood-fiber at "A", and a less crushed stem at "B". (112 diameters).

Fig. 2.—Section of anthracite cut parallel to the bedding, showing structures (A and B) formed subsequent to the degeneration of the wood. (112 diameters).

Fig. 3.—Section showing light pitted anthraxolite in gray quartz from the Sudbury district, Ontario. (112 diameters).

Fig. 4.—Anthraxolite from the Sudbury district, Ontario. (112 diameters).

Fig. 5.—Section of anthraxolite from the Sudbury district, Ontario, cut at right angles to figure 4, showing two irregular areas. (112 diameters).

Fig. 6.—Section of the more distinctive irregular area shown in figure 5. (450 diameters).

PLATE IV

Fig. 3.—Floating sand, Munroe Bay, Lake Superior.



FIG. 1



FIG. 2



FIG. 1



FIG. 2



Fig. 1

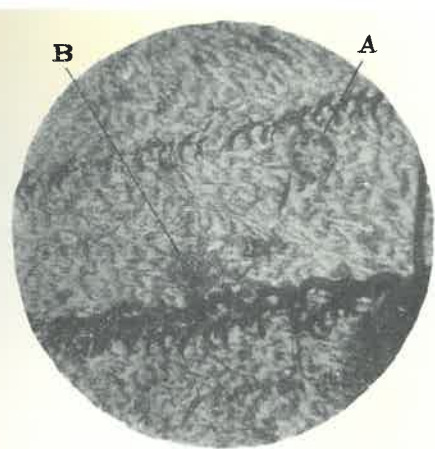


Fig. 2



Fig. 3

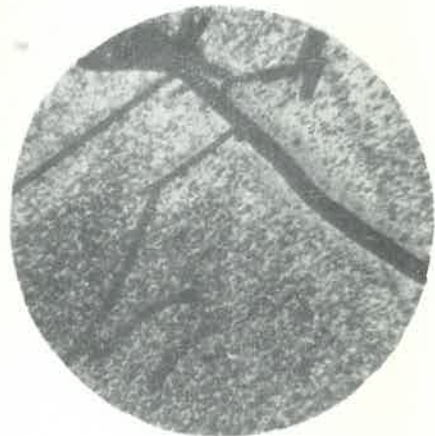


Fig. 4



Fig. 5

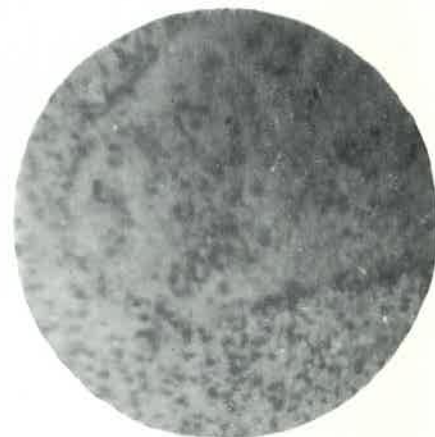


Fig. 6

PLATE IV.



FIG. 1