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A RE-EXAMINATION OF BYTOWNITE AND HURONITE

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

Bytownite and huronite were described by T. Thomson in his mineralogy,¹ and in the intervening years there has been much speculation as to the real nature of the substances that were analysed. Thirty years after their description, what appears to be a mention of the original material was published in Melbourne, Australia². In the prefatory note we have this statement:

"The minerals enumerated in this Catalogue were, with a few exceptions, obtained by Mr. Vazie Simons from the collection of the distinguished mineralogist, Dr. Thomas Thomson, by whom they were used when he was engaged in writing his well-known work on Mineralogy . . . each specimen is numbered, and has a card attached to it, on which is written in legible letters the name, locality, etc."

In the catalogue, after the composition of the mineral, a capital T apparently indicates the Thomson collection.

The following entries are of interest in the present study:

449 Bytownite.—Silicate of Alumina, Lime, Iron, Magnesia, and Soda, T.—Bytown, Upper Canada.

453 Huronite.—Hydrous Silicate of Alumina, Iron, Lime, and Magnesia, T.—Lake Huron, America.

Through the good offices of Dr. Charles Anderson, Director of the Australian Museum, the writers were put in touch with Dr. James A. Kershaw, Director of the National Museum, Melbourne, Australia, who very kindly divided the

¹T. Thomson, *Outlines of Mineralogy and Geology*, 1836.

²W. V. Simons, *A Catalogue of Foreign Minerals in the Mining Department*, Melbourne, Victoria, 1866.

specimens of Thomson's material, and forwarded a portion of each to us, so that a re-examination might be made.

Bytownite

In 1836 Thomson examined a specimen which had been sent him by Dr. Holmes of Montreal, who had broken it from a boulder which he found at Bytown, afterwards Ottawa. From an analysis of the specimen Thomson decided that the mineral was new and called it bytownite. In his classification the new mineral was preceded by tourmaline and followed by vermiculite, because all three were classed as "triple aluminous salts", while the feldspars which were by him regarded as "double anhydrous aluminous salts" were quite remote in the system of classification. Two very concordant analyses were made by Thomson, the average of which is shown in I.

Fifteen years later, in 1851, T. Sterry Hunt¹ examined and analysed a specimen which he received from Dr. Holmes of Montreal, who informed him that it was a part of a specimen pronounced to be bytownite by Thomson. The new analysis (II) was very different from the original in the proportions of silica, lime, and soda. On the basis of his analysis Hunt suggested that bytownite was identical with anorthite. When in 1864, Tschermak solved the riddle of the feldspars by his suggestion that all those containing lime or soda or both could be represented as isomorphous mixtures of the two end members albite and anorthite, he also gave an indication as to the names most appropriate for the different mixtures of albite and anorthite. Those in which the ratios lay between Ab_1An_2 and Ab_1An_6 were to be known as bytownite, the analysis of the Bytown material by Hunt which corresponds to $Ab_{27}An_{73}$ being regarded as typical.

The specimen kindly supplied to us by Dr. Kershaw is cleavable, granular, medium grained, and in colour resembles certain crushed anorthosites in which the granulated portion is white, while the crystal remnants of the feldspar are dark

¹T. Sterry Hunt, Phil. Mag., 1, 1851, p. 332.

purplish. With the lens some small splashes of black silicates may be detected. A thin section indicates that, with the exception of a few small fragments of secondary hornblende, and a small amount of finely divided calcite, the whole mass is composed of plagioclase, most of which is finely granulated, with a few ungranulated remnants of plagioclase crystals showing much bending and strain. In general, the rock appears to be crushed and granulated anorthosite, (Pl. III, Fig. 1). The specific gravity of the specimen as determined by the balance was found to be 2.70.

	I	II
SiO ₂	47.57	47.40
Al ₂ O ₃	29.65	30.45
Fe ₂ O ₃	3.58	—
FeO	—	.80
MgO	.20	.87
CaO	9.06	14.24
Na ₂ O	7.60	2.82
K ₂ O	—	.38
H ₂ O	1.98	2.00
	<hr/>	<hr/>
	99.64	98.96
S. G.	2.80	2.73

A portion of the small specimen was prepared for analysis as follows. It was crushed so that the powder passed through a 40-mesh screen, and one part of the powder was treated with dilute hydrochloric acid to remove the calcite and then with a magnet to remove any magnetite which might be present (III). The other portion of the powder, being freed from the finest dust after treatment with hydrochloric acid, was separated by methylene iodide. A very little of the heaviest and lightest was rejected, and the remainder divided into three portions of different densities. After the densities of these portions were determined they were analysed separately by H. C. Rickaby as shown in (IV)-(VI).

	III	IV	V	VI
SiO ₂	54.30	54.68	54.80	53.47
Al ₂ O ₃	27.49	28.07	28.36	28.59
Fe ₂ O ₃	1.27	.70	.89	1.18
CaO	10.21	10.32	10.35	10.80
MgO	.50	.39	.40	.52
Na ₂ O	4.77	4.76	4.90	4.77
K ₂ O	.84	1.32	1.02	.94
H ₂ O	.79	.40	—	.37
Total	100.17	100.64	100.72	100.64
S. G.	2.70	2.681	2.690	2.709

On the basis of the molecular ratios of the different constituents as indicated by the analyses it appears that the percentage composition expressed in terms of the three feldspar types is as follows:

	II	III	IV	V	VI
Ab	69.9	50.60	51.15	51.15	53.65
Ab	23.58	40.35	40.35	41.40	40.35
Or	2.23	5.00	7.78	6.11	5.56
Or+Ab	25.81	45.35	48.13	47.51	45.91

The position of the feldspar in each of these analyses in terms of the ratio $Ab:An$ and also $(Ab+Or):An$ is as follows:

II	Ab ₂₅ An ₇₅ ,	(Ab+Or) ₂₇ An ₇₃ ,	S. G. 2.73
III	Ab ₄₄ An ₅₆ ,	(Ab+Or) ₄₇ An ₅₃ ,	S. G. 2.70
IV	Ab ₄₄ An ₅₆ ,	(Ab+Or) ₄₈ An ₅₂ ,	S. G. 2.681
V	Ab ₄₅ An ₅₅ ,	(Ab+Or) ₄₈ An ₅₂ ,	S. G. 2.690
VI	Ab ₄₃ An ₅₇ ,	(Ab+Or) ₄₆ An ₅₄ ,	S. G. 2.709

Unfortunately, it does not seem possible to calculate the ratios of $Ab:An$ from Thomson's original fairly concordant analyses.

The powder of the sample prepared for analysis *V* was examined in immersion liquids with the following result: $\alpha = 1.555$, $\beta = 1.560$, $\gamma = 1.564$, (all ± 0.003). The extinction on basal cleavage plates was found to be 13° , while cleavages showing no twinning (010) when examined in convergent light showed the emergence of an optic axis on the border

of the field. These observations indicate that the plagioclase is a comparatively acid labradorite such as $Ab_{45}An_{55}$, a conclusion which agrees well with the chemical evidence.

From this series of analyses it becomes apparent that the specimen which Dr. Holmes gave to Hunt really represents quite a different type of feldspar from that contained in Thomson's collection, which probably was part of the original type specimen. In this way the name bytownite is now applied to a plagioclase much more basic than the original of Thomson.

Huronite

The original specimen of huronite was also furnished by Dr. Holmes. Thomson says: "Its locality was from the neighborhood of Lake Huron. It exists in boulder stones, nearly spherical, in a black matter like hornblende. In this black matter the huronite is imbedded in nearly spherical masses, attached to the surrounding black matter very firmly, without any visible cement." He classed it under quadruple aluminous salts which he considered to be probably either mixtures or combinations of two or more simpler minerals in proportions which might be indicated if the composition of the simpler minerals were known. His aim was "to describe the properties and determine the constituents of these compound minerals with as much accuracy as possible."

The specimen which was kindly furnished by Dr. Kershaw cannot be distinguished in the hand specimen in any respect from the huronite which occurs on the road from Elk Lake to Gowganda, Ontario¹. It is pale creamy yellow in colour and about 3 in hardness.

For purposes of comparison a portion of the material was purified so far as possible by methods which were available in Thomson's time; and the analysis I, which was made by H. C. Rickaby, is shown with Thomson's original analysis II, and the analysis III of huronite from Elk Lake-Gowganda road.

¹T. L. Walker, Univ. of Toronto Studies, Geol. Ser., No. 16, p. 55.

	I	II	III
SiO ₂	46.70	45.80	46.98
Al ₂ O ₃	31.60	33.92	30.18
Fe ₂ O ₃	1.41		.95
FeO	.57	4.32	.42
CaO	6.90	8.04	9.38
MgO	.64	1.72	.39
MnO	.05		.04
K ₂ O	6.96		6.40
Na ₂ O	1.45		1.36
H ₂ O	3.63	4.16	4.05
CO ₂	.40		.27
TiO ₂	Trace		
	<hr/> 100.31	<hr/> 97.96	<hr/> 100.42
S. G.	2.832	2.8625	2.819

In neither case does the analysis of the original huronite yield simple ratios. It represents a mixture that is slightly more acid than an ortho-silicate. A thin section was found to consist of about seventy-five percent. of fine grained muscovite, which in index liquids gave indices ranging from 1.57 to 1.59. With the muscovite was a much finer grained mineral with a higher index of refraction and the characteristic appearance of zoisite. In the mineral powder some grains were found to have indices greater than 1.67 which with the known constituents in the analysis confirms the determination of zoisite. A single grain of limonite as a pseudomorph, probably after pyrite, was seen.

A recalculation of analysis I follows:

	Calcite	Magnetite	Albite	Zoisite	Muscovite
SiO ₂	778		138	195	445
Al ₂ O ₃	309		023	097	189
Fe ₂ O ₃	009	009			
FeO	008	008			
CaO	123	009		114	
MgO	016			016	
MnO	001	001			
K ₂ O	074				
Na ₂ O	023		023		074
H ₂ O	202			032	170
CO ₂	009	009			

The error in calculation is cumulative, so that the muscovite varies from the theoretical, but is well within the range of muscovite analyses.

BERYL AND ASSOCIATED MINERALS FROM LYNDOKH TOWNSHIP, RENFREW COUNTY, ONTARIO

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

The occurrence of beryl on lot 23C, concession XV, Lyndoch township, Renfrew county, Ontario, has been known for a long time, but heretofore terminated crystals have not been available for measurement. The material for the present study was secured from T. B. Caldwell, Esq., Perth, Ontario, who worked the deposit in the summer of 1926 in the hope of developing a commercial deposit of beryl.

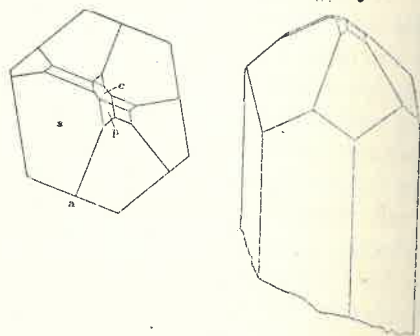


Fig. 1

The beryl occurs in a pegmatite dyke, and is associated with green microcline, albite, white and pale rose quartz, garnet, black tourmaline, columbite, and magnetite. A little more than two tons of beryl were obtained. In this lot were about a dozen terminated crystals which resemble in habit those on the Urulga river, Siberia. The largest of the terminated crystals is nineteen and a half by four and one-half inches. The pyramidal faces are very imperfect and not suited for measurement. The crystal is, however, interesting on account of its size, though in no way rivalling those obtained at Grafton, N.H., or Amelia Court House, Va.

The best crystal is represented in Fig. 1. The forms present are $a(10\bar{1}0)$, $p(10\bar{1}1)$, $s(11\bar{2}1)$, and $c(0001)$. The edges and faces of this crystal are unusually well formed. Portions of the crystal which are only slightly shattered are gem quality aquamarine.

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

SiO ₂	64.40	1.073	÷ 12 = .0894
Al ₂ O ₃	18.08	.177	} 183 ÷ 2 = .0915
Fe ₂ O ₃	.97	.006	
BeO	14.38	.573		÷ 6 = .0955
CaO	.18	.003	} .0855 ÷ 1 = .0855
MgO	.33	.008	
MnO	.04	.0005	
K ₂ O	.18	.002	
Li ₂ O	.18	.006	
Na ₂ O	.35	.006	
H ₂ O	1.08	.060	
Total	100.17		

S. G. (Pyc.) 2.726

This corresponds best with Penfield's formula for beryl, $(R_2R)0.6BeO.2Al_2O_3.12SiO_2$.

The association of minerals at this locality was described by W. G. Miller¹, who lists beryl, green feldspar, quartz, black mica, plagioclase, a mineral of the columbite group, black tourmaline, pink flourspar and magnetite. A more complete description was given by the writers² of the columbite which occurs in hemispherical radiating masses up to one inch in diameter.

Microcline. Masses up to forty pounds in weight were collected which are pale green in colour, but where slightly altered are of a flesh red tint. On the best cleavage surface a perthitic structure is seen, so that the material is best described as a microcline-perthite.

¹W. G. Miller, Ont. Bur. Mines, VII Ann. Rep., pp. 234-237.

²T. L. Walker, and A. L. Parsons, Univ. Toronto Studies, Geol. Ser., No. 16, pp. 33-35.

Albite. Tabular white and flesh red albite, which corresponds well with the description of cleavelandite, is in intimate association with some of the beryl crystals. No crystals were observed. The plates vary in thickness from two millimetres downward; and optically it is well within the albite range.

Tourmaline. Triangular prisms of black tourmaline are quite abundant. No terminations were found, but broken crystals up to six inches in length and an inch and a half on a side were observed.

Garnet. One large distorted garnet crystal and a few fragments were obtained. This has not yet been identified absolutely, but appears to be almandite.

Quartz. Both white and pale rose quartz are found on the dump, but no special association was noted to account for the variation in colour.

Magnetite. Granular to platy magnetite occurs in considerable abundance, associated with flesh red feldspar.

Mica and Fluorite. The mica and fluorite mentioned by Miller were not observed in the material on the dump, so that they are presumably rare.

NOTES ON CANADIAN MINERALS—TREMOLITE, CLINOHUMITE, STROMEYERITE, NATRON, AND HEXAHYDRITE

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

I. Tremolite Crystals from Faraday Township, Ontario.

Some rather unusual crystals of tremolite were recently obtained on lot 27, concession B, of Faraday township, Hastings county, Ontario, which seem to merit a description on account of their size, their purity, and the peculiarity of their mode of occurrence. The crystals occurred near a heap of stones on a limestone ridge in a meadow. The limestone was covered with sod and a thin layer of soil, and all the detached crystals of tremolite were found either in the grass roots or the thin layer of soil beneath, so that it would appear that the weathering of the crystals from the limestone had been caused by rain water combined with organic agencies since the glacial period.

Measuring parallel to the c , a , and b axes respectively, the dimensions for two of the largest detached crystals are $80 \times 60 \times 42$ mm. and $100 \times 58 \times 38$ mm. Another large crystal $68 \times 46 \times 36$ mm. was secured earlier which, while less perfectly developed, is nearly of gem quality and of a light drab colour in the faces of the prismatic zone using the Dana orientation¹. The forms present in order of magnitude are $b(010)$, $m(110)$, $r(011)$, $a(100)$, $e(130)$, and $c(001)$ with the new form $\gamma(132)$ as a single face. The relative development is shown in the accompanying figure which was drawn to scale and represents the first crystal mentioned (Fig. 2).

The largest crystal that was found forms part of a group and is $110 \times 60 \times 76$ mm., but is not so well developed as the

¹E. S. Dana, System of Mineralogy, 6th Ed., 1892.

detached crystals. The $m(110)$ face on this measures 80×60 mm.

Four small crystals were measured on the reflecting goniometer. The following forms were recognized: (410), (430), (110), (230), (250), (130), (150), (010), (011). Of these (410), (230), and (250) are new.

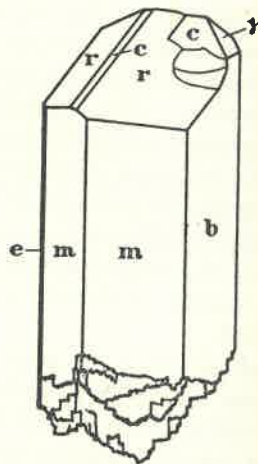


Fig. 2

The associated minerals are albite and microcline in crystalline limestone.

In a few cases, the crystals exhibit parting parallel to the base due to twinning on the base. A section parallel to $b(010)$ also showed twinning on a (100) and an extinction angle of $16^{\circ}30'$ to $17^{\circ}00'$.

An analysis by H. C. Rickaby follows:

SiO ₂	57.36	955	}	.957
TiO ₂	.14	002		
Al ₂ O ₃	1.04	010(×3)		
Fe ₂ O ₃	.21	001(×3)	}	.948
FeO	.72	010		
CaO	12.41	221		
MgO	25.22	631	}	
Na ₂ O	1.49	024		
K ₂ O	.47	005		
H ₂ O	.44	024		
Total	99.50			
S. G.	2.96			

While the ratio of base to acid is 1: 1 the mineral is evidently not simple. The ratio of lime to magnesia is nearly the theoretical for the formula given by Dana, $3MgO \cdot CaO \cdot 4SiO_2$. The residue is, however, large, and evidently indicates the presence of an amphibole molecule rich in soda. The analysis compares well with those of other tremolites.

II. Clinohumite from Chaffey's Locks, Ontario.

In August, 1924 the writers collected from a railway cut near the station at Chaffey's Locks, Ontario some samples of an exceedingly fresh member of the chondrodite group which was embedded in crystalline limestone. The mineral occurs in rounded grains and from a crystallographic point of view gave no clue as to its identity.

Until the work of Penfield and Howe¹, the three known members of the group, chondrodite, humite, and clinohumite, were supposed to have the same chemical composition, but to differ in crystallization. They showed that the group formed a series and predicted a fourth member. Soon afterwards this predicted mineral was announced under the name prolectite by H. Sjögren² from crystallographic work on two fragments. More recent work by P. Geijer³ has shown that

¹Penfield and Howe, Am. Jour. Sc., Series IV, Vol. 47, 1890, p. 188.

²H. Sjögren, Bull. G. Inst. Upsala, 1, 1892, p. 40: 2, 1894, p. 99.

³P. Geijer, Geol. För. Förh., Stockholm, Vol. 48, 1926, pp. 86-89.

prolectite is identical with chondrodite, but in the same publication a mineral having the predicted chemical composition, although different physical properties, was announced by Geijer under the name norbergite¹.

Inasmuch as no attempt has hitherto been made to differentiate the members of this group in Canadian occurrences, it seemed desirable to examine the material optically and chemically. The mineral is fine amber yellow with vitreous lustre. By the immersion method it was found to be biaxial, and in nearly all sections one optic axis was visible because of a good cleavage nearly normal to an axis: $\alpha = 1.628$, $\beta = 1.642$, all ± 003 . These values are somewhat lower than the indices given by Larsen² for clinohumite.

A carefully prepared sample was analysed by H. C. Rickaby with the following results:

SiO ₂	37.42	.623
TiO ₂	1.14	.013
Fe ₂ O ₃	.46	.003
FeO	1.27	.018
MgO	53.32	1.407
MnO	.10	.001
H ₂ O	.56	.031
F	5.04	.265
	102.31	
Oxygen Equiv.	2.12	
	100.19	
S. G.	3.17	

This corresponds well with the formula for clinohumite $Mg[Mg(F, OH)]_2 SiO_4 \cdot 3Mg_2 SiO_4$.

III. Stromeyerite from Cobalt and Gowganda, Ontario.

The present study seems desirable, not only as a record

¹*Op. cit.*, pp. 84-85.

²E. S. Larsen, U.S.G.S., Bull. 679, p. 222.

of the occurrence of this mineral in two of the important silver districts of Ontario, but as a means of calling attention to certain peculiarities of stromeyerite which are not mentioned in the standard works on mineralogy.

In the Cobalt district stromeyerite has been found, so far as known, only at the Foster mine, as recorded by R. A. Johnston³, though no analysis has hitherto appeared. Apparently no other specimens were found, and Johnston's determination was repeatedly called in question. By good fortune several specimens from the Foster mine had been secured by the Royal Ontario Museum of Mineralogy, which were regarded as chalcocite or bornite because of the great similarity of the colour of this mineral to the tarnish of bornite.

Stromeyerite was also found in June, 1926, on the stockpile of the Morrison mine at Gowganda, when a supply for investigation was obtained. A single specimen has been obtained from the Miller Lake-O'Brien mine near Gowganda.

In all cases the mineral is massive, brittle, showing a smooth conchoidal fracture and a molybdenite blue colour, which is more pronounced when the material is wet. It is probably this blue colour, which is the most striking characteristic of the mineral, that has prevented its recognition in the past, as it resembles somewhat the tarnish on bornite and is in part due to the formation of covellite.

A mineralographic examination by Professor Ellis Thomson of the material prepared for analysis from the Morrison mine proved it to be homogeneous; and the analysis (I) and that of stromeyerite from the Foster mine (II) by H. C. Rickaby follow:

	I	II
Cu	31.46	31.00
Ag	51.80	53.31
Fe	.30	Trace
S	16.08	16.02
Insol.	.32	
	99.96	100.33
S. G.	6.26	

³R. A. Johnston, Geol. Surv. Can., Summ. Rep., 1907, p. 98.

In both cases the material is almost theoretically pure stromeyerite.

This is the first time that stromeyerite has been recognized in the Gowganda district, and is the first published analysis of the mineral from Cobalt. It represents peculiar equilibrium relations between copper and silver and may prove a valuable index mineral in the further development of the silver regions. In the better known mines to the west of the Morrison, copper minerals are not common, but in some of the mines to the east chalcopryrite and bornite are associated with native silver. The stromeyerite seems to occupy a field between these, rich in both copper and silver, but poor in sulphides of iron.

On one of the specimens from the Foster mine there was a definite coating of covellite. The blue colour of the covellite tarnish has undoubtedly been attributed to bornite without further examinations.

IV *Natron from Clinton, British Columbia.*

The mineral that is the subject of the present study was secured in August, 1926, from A. M. Hinkes of Clinton, British Columbia, who stated that he had obtained it during the preceding winter from a soda lake near Clinton. The soda lakes of this locality have been described by L. Reinecke¹ who gives an analysis of natron which was taken from beneath the brine on Goodenough lake. Inasmuch as natron is supposed to occur in nature only in solution² or mixed with other carbonates of soda, it seems worth while to call attention to these deposits where crystallized natron of exceptional purity may be obtained.

The material for the present study, when broken, is nearly colourless and exhibits a good vitreous lustre, but on the surface, which has been exposed for some time to the air, it has become white and chalky, as it is converted into one of the lower hydrates. The glassy material was examined in

¹L. Reinecke, Geol. Surv. Can., Mem. 118, pp. 57-63.

²Dana, System of Min., 6th Ed., p. 301.

index liquids and all indices were found to be less than 1.47. It is coarsely crystalline and no crystals suitable for measurement were observed. Small cavities were seen in some of the broken surfaces.

Carefully selected fresh samples were used for analysis without grinding, so as to obviate any loss of water in the preparation of the material. The analysis by H. C. Rickaby follows:

Na ₂ O	21.23	.342
CO ₂	15.46	.351
H ₂ O	63.59	3.513
Cl	Trace	
Mg	Trace	
Insol.	Trace	
	100.28	
S. G.	1.34	

The analysis shows that the material is nearly pure natron.

V. *Hexahydrate from Oroville, Washington, U.S.A.*

During the past summer specimens of hexahydrate ($MgSO_4 \cdot 6H_2O$) which was originally described by R. A. A. Johnston¹ were secured near Oroville, Washington. The material was specially selected from portions of the deposit which were particularly exposed to dehydration, where the strongest contrast was exhibited between the glassy unaltered epsomite and the partially dehydrated material which is the subject of this study. The epsomite deposit fills a dried-up lake bottom several acres in extent, and is covered by a deposit of mud which in August was dry and hard. An inclined shaft gives access to the workings, which are principally in a large open pit. No exact measurements of the deposit or workings were made, but the thickness of the mud capping is about ten feet and that of the epsomite is over twenty feet. The epsomite is in large crystals up to four

¹R. A. A. Johnston, Geol. Surv. Can., Ann. Rep., 1910, pp. 256-257.

inches in diameter and a foot or more in length. Where it was exposed to the heat of the sun and the dry atmosphere the surface had turned white and chalky or porcellanic, but where it was somewhat protected it was colourless and glassy in appearance.

The samples were put immediately in glass jars and sealed so as to eliminate the possibility of alteration by loss of water.

About two hundred feet from the shaft a prospecting trench had been dug, but in the wet season this had filled with a magnesium sulphate brine which had given rise to a fine grained crystalline mass of epsomite. During the summer the upper inch of the epsomite had turned chalky and in every way resembles the material in the open pit. On breaking the crust, however, it was seen that each chalky grain had a central nucleus of glassy epsomite so that pure material for analysis could not be separated from the mass.

Several years ago one of the writers described epsomite from near Ashcroft, B.C.¹ A reserve specimen of this material has in the meantime turned chalky and has been the subject of two analyses, one of which showed it to be the hexahydrated magnesium sulphate, while the other showed an almost perfect heptahydrate ratio. The first of these analyses was made in May, 1926, after the specimen had been exposed to the drying conditions prevailing in a steam heated building during the winter; the second in the following autumn, after the material had been exposed in the mineralogical laboratory during the summer. It would appear that, with the humid conditions which prevailed in Toronto in the summer of 1926, the material again took on the extra molecule of water.

The following analyses are (I) of epsomite from Basque, near Ashcroft, B.C., (II) the same partially dehydrated in May, 1926, (III) the same in October, 1926, (IV) hexahydrate from Oroville, Washington from the open pit, (V) hexahydrate mixed with epsomite from trench at Oroville, and

¹T. L. Walker, Epsomite Lakes near Ashcroft, B.C., Univ. Toronto Studies, Geol. Ser., 1921, No. 12, pp. 43-46.

(VI) hexahydrate from the Bonaparte River, B.C. I was analysed by E. W. Tood¹, II-V by H. C. Rickaby, and VI by R. A. A. Johnston².

	I	II	III	IV	V	VI
MgO	16.26	17.98	16.40	17.88	17.44	17.15
Na ₂ O						
K ₂ O	.055					
Al ₂ O ₃	.05	.01	.04	.10	.02	
Fe ₂ O ₃						
SO ₃	32.41	35.00	32.34	34.64	34.30	34.52
Cl	.003					
H ₂ O	51.32	(46.99)	51.30	47.32	48.17	46.42
Insol.	.005	.02	.02	.03	.03	1.78
	100.103	100.00	100.10	99.97	99.96	99.87
S. G.				1.71 (Pyc)		1.757

A calculation of the molecular ratios shows that analyses II, IV and VI are nearly theoretically pure hexahydrate. I and III are nearly pure epsomite, while V is intermediate between the two extremes. The theoretical water content in hexahydrate is 47.37 per cent., and that of epsomite 51.2 per cent.

Prior to the visit to Oroville, a trip was made in August to the epsomite deposit near Basque in the hope that a layer of hexahydrate might be found on the surface as a result of the extremely dry condition of the past summer in British Columbia. No trace of hexahydrate was found on the lake, but a stock pile of epsomite on the bank was coated to a depth of 1 to 2 inches with this material. On the lake the brine level was in all places within two inches of the surface, so that there was little opportunity for the formation of hexahydrate at the expense of epsomite.

¹T. L. Walker, Univ. Toronto Studies, Geol. Ser., No. 12, p. 44.

²Loc. cit.

THE DEHYDRATION OF GYPSUM

By A. L. PARSONS

The dehydration of gypsum, because of its necessity in the manufacture of plaster-of-Paris has been the subject of numerous studies which show many anomalous features.

It is more or less well known that, when gypsum is heated at a low temperature (105°—135°C), it is completely dehydrated and the resulting anhydrous calcium sulphate when mixed with water sets. It is better known that in the commercial manufacture of plaster-of-Paris with rapidly increasing temperatures the gypsum boils, then settles, boils and settles a second time, and at a higher temperature becomes completely dehydrated. It is commonly supposed that the product at the second settle is $2CaSO_4 \cdot H_2O$. This material also sets when mixed with water.

When gypsum is heated with water this latter compound ($2CaSO_4 \cdot H_2O$) is formed and at a slightly higher temperature the anhydrous calcium sulphate. This change appears to be a reversible reaction, but has no bearing on the manufacture of plaster-of-Paris, though probably of extreme importance in explaining the setting of this material.

In order to ascertain the rate of dehydration at low temperatures samples of rock gypsum from Hillsboro, New Brunswick (I), and Caledonia, Ontario (II), and of selenite from Galetta, Ontario (III), were heated for twenty-two hour periods in a Freas electric oven; and the loss of water at different temperatures is given in the following table. The samples were not ground, as it was thought that there might be loss of water in grinding.

	I	II	III
84°C	2.47	.65	.03
95°C	12.21	14.87	4.52
105°C	19.29	20.01	13.85
115°C	19.77	20.09	19.89

	I	II	III
125°C	20.01	20.35	20.28
135°C	20.06	20.43	20.39
145°C	20.15	20.50	20.54
165°C	20.21	20.55	20.68

The samples were not analysed for purity, but if they are pure gypsum then less than one per cent. of water remains after heating at 115°C. A strange lag is also noticeable in the dehydration of the crystallized selenite from Galetta.

Through the courtesy of R. E. Haire, Esq., Manager of the Ontario Gypsum Company Limited, samples were obtained in all stages in the manufacture of plaster-of-Paris, and special samples were prepared to give the second settle and the dead burned gypsum. These were analysed for water and SO_3 , with the following results:

	SO_3	H_2O
I Crude	34.60	16.43
II Preheated lump	36.08	16.86
III Preheated ground	33.24	14.99
IV First settle	40.86	5.84
V First settle reground	38.60	6.55
VI Finished plaster from storage	37.56	6.13
VII Second settle (Laboratory)	38.70	4.73
VIII Dead burned (Laboratory)	39.08	1.81

In no case does the chemical evidence show $2CaSO_4 \cdot H_2O$, though the second settle approaches this.

In order to determine the nature of the dehydration products, samples 3, 4, 6, 7, and 8 were examined under the microscope in index liquids (oils). Details of the observations follow:

Sample number 3, which had been preheated at 180° to 190° Fahr. and ground, showed numerous plates of gypsum usually parallel to the clino-pinacoid (010), together with much fine grained material with a higher index of refraction. Some of the plates showed a central nucleus of unaltered gypsum, which was surrounded by a layer of dehydrated (or partially dehydrated) material. This latter tends to develop a fibrous structure. The gypsum was never found

with an index greater than 1.53, but the altered material was close to 1.5509, one index being slightly higher, the other slightly lower.

Sample number 4, which was taken from the kettle at the first settle at a temperature of 280° to 300° Fahr., showed that all the plates had undergone dehydration and the indices of refraction were the same as for the dehydrated portion of number 3. In general, the plates exhibited a fibrous structure, though in some cases there are two or more sets of fibres. There is no uniform angle between such sets, but in some cases there was a suggestion of an hour glass structure with an inner portion which has a lower index of refraction and probably represents a central nucleus of gypsum.

Sample number 6 was taken from the storage bin and is the same as number 4, except that it has been reground so that it is much finer in grain than the preceding and showed no particles of unaltered gypsum. Two types of fibres were seen, one where both indices were slightly lower than 1.5509 but higher than 1.5441, the other showing one value slightly lower than 1.5509 and one slightly higher. Presumably these are differently oriented fibres as mentioned above under number 4.

Sample number 7 is a second settle plaster which was specially prepared in the laboratory and shows no difference in optical properties from the first settle plaster (No. 6).

Sample number 8 is a dead burned plaster which was specially prepared and shows one index slightly greater than 1.5509 and one slightly less. In all respects it agrees in optical properties with the dehydration products in the other samples.

In all the samples grains of calcite were visible and easily recognized by their higher indices of refraction, but there was no marked difference in the abundance of calcite grains in the various samples. In all cases a substance was present, having indices of refraction very nearly 1.5509, which is neither gypsum nor calcite.

In general, the minute fibres fail to show complete extinction, but exhibit a progressive or undulatory extinction which

would indicate either strain or an inclusion of one substance in another. It has been shown in the case of spencerite¹ that when the first dehydration product is superposed on an unaltered nucleus of spencerite the optic planes of the two substances are at right angles to each other, and when the thicknesses of the two are in a certain ratio an uniaxial zone is to be seen. It is also well known that when selenite is heated the optic angle decreases to zero and then increases in a plane perpendicular to the original optic plane. The temperatures given for these optical changes² in view of the results obtained by analyses of gypsum that has been heated would suggest a loss of water and a probable superposition of bassanite on gypsum. The irregular extinction of the plaster-of-Paris fibres would be easily explained in the same way.

The present work goes to show that gypsum when heated in air loses all its water in a single stage and yields a second form of anhydrous calcium sulphate which corresponds to the mineral bassanite. This does not mean that the entire mass of a grain of gypsum is completely changed at once. The outer portion loses its water first and as the reaction proceeds additional layers give off their water. From the fact that in the commercial manufacture of plaster-of-Paris there are two stages of boiling it would appear either that heat is not conducted so well by bassanite as by gypsum or that a pressure is developed that retards the dehydration.

The present study shows conclusively that plaster-of-Paris is not a definite chemical compound, but an intimate mixture of bassanite and gypsum in proportions varying between three of bassanite to one of gypsum and two of bassanite to one of gypsum.

In all cases that have come to the attention of the writer, where the compound $2CaSO_4 \cdot H_2O$ has been definitely proven, it has been prepared by wet methods.

¹T. L. Walker and A. L. Parsons, Univ. Toronto Studies, Geol. Ser., No. 12, pp. 58-62.

²Dana, System, 6th Ed., 1892, p. 935.

THE CONTACT PHENOMENA OF THE NEPHELINE SYENITES OF PORT COLDWELL, ONTARIO.

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

In 1910 H. L. Kerr¹ published an account of the nepheline rocks of Port Coldwell, Ontario. In his report he called attention to a great variety of syenites, which along with smaller areas of nepheline syenite constitute a group of genetically related rocks. The nepheline syenite, as is often the case, occurs in irregular areas and patches of all sizes, so that it was difficult to represent the boundaries on the scale of map used. In regard to the relation between the nepheline syenites and the other rocks of the region Mr. Kerr says:

"Whenever the nepheline syenites were seen and it was possible to estimate the relative ages of the various rocks, the former were always found to be the youngest. Small dikes and off-shoots of the nepheline rock penetrate any and all other of the associated rocks with which it is in contact. This does not apply to the later eruptives which cut not only the nepheline syenites, but all the other rocks of the massif in numerous fine-grained dikes, the discussion of which will be deferred to a later part of this paper."²

The oldest rocks of the region are certain dark basic rocks described as picrites, which are brecciated and intruded by all the other types.

The writers spent some weeks in this region in 1925 and were much interested in the nature of the contact between the older rocks and the nepheline syenite, especially where exposed on the east shore of Coldwell peninsula two miles south of Port Coldwell and on the south shore of the peninsula three and a half miles south west of the village.

At the latter point a coarse syenite with an abundance of brick red spreustein forms a breccia with the old greenstone and at times seems to invade it in a most irregular manner.

¹H. L. Kerr, Bureau of Mines of Ontario, Vol. XIX, Pt. 1, p. 194.

²*Op. cit.*, p. 211.

Pl. I, Fig. 3, shows what appears to be a dyke of greenstone occurring in greenstone, the walls being marked on each side by a half-inch zone of nepheline rock containing spreustein. The dyke is two and a half inches wide with very sharp boundaries between the syenite band and the outer dark rock and irregular borders between the central dark part of the dyke and the light-coloured syenite. On the weathered surface the central dark part is readily distinguished from the outer country rock by a very characteristic pitting of the former.

Thin sections of the three rock types show that the two dark rocks are quite distinct.

1. The nepheline syenite is composed largely of fairly fresh tabular crystals of anorthoclase, a little green hornblende primary in character, non-pleochroic aegirine, and red areas representing decomposition products of sodalite or nepheline.

2. The country rock contains subhedral crystals of orthoclase and plagioclase showing small extinction angles, ragged perforated individuals of green-brown hornblende, with smaller amounts of diopside, strongly pleochroic titanite, fluorite, and magnetite. Pl. I, Fig. 2, shows the contact of 1 and 2.

3. The central dark part of the dyke shows an abundance of hornblende and plagioclase with elliptical spots with an aggregate of a colourless mineral in the centre and scaly brown biotite as a broad outer zone. To the weathering of these spots the pitting on the weathered surface is apparently due. The colourless mineral referred to is biaxial, is moderate in birefringence, extinguishes obliquely on one good cleavage, and as shown by the Becke test possesses indices of refraction higher than biotite. These spots appear to have been produced by the alteration of phenocrysts in the basic rock of the dyke. Scattered through this altered dyke are numerous fairly fresh crystals of untwinned orthoclase (Pl. I, Fig. 1). Many of the aggregates of these secondary minerals have outlines suggesting that the original mineral was olivine, which, in view of the basic character of the rock as shown by analyses, would be the most probable porphyritic mineral.

Sederholm¹ states that pseudomorphs of scaly biotite after olivine are frequent in the uralite-porphyrites in the Tam-mela region of Finland.

These observations suggest that number 3 represents the alteration of a basic dyke by magmatic juices circulating along the joint of the dyke walls. The sharpness of the boundaries between the nepheline rock with the country rock and of certain nepheline syenite veinlets which invade the country rock shows that the wandering solutions were inactive on the country rock. The irregular border of the nepheline rock on the central part of the dyke and the development of fresh crystals of orthoclase scattered porphyritically within the dyke indicate that solution, deposition and replacement have played a prominent part. The occurrence of the nepheline rock on the dyke border may be due to the presence on the dyke of a fine-grained or even glassy zone which was more readily acted upon by the invading solutions. In a rock so basic orthoclase phenocrysts could hardly form part of the original primary minerals of the dyke.

Analyses of these three rock types made by H. C. Rickaby are as follows:

	I	II	III
SiO ₂	53.12	47.02	45.62
TiO ₂	.40	1.80	.65
Al ₂ O ₃	18.40	17.68	14.90
Fe ₂ O ₃	7.46	3.86	4.40
FeO	5.10	8.91	4.81
CaO	2.93	8.64	10.43
MgO	.80	4.02	10.99
MnO	.12	.23	.20
K ₂ O	2.87	1.22	3.52
Na ₂ O	6.49	5.29	3.05
H ₂ O	1.61	.92	1.02
CO ₂	.25	.26	.50
P ₂ O ₅	Trace	Trace	Trace
	99.55	99.85	100.09
S. G.	2.76	2.98	3.02

¹J. J. Sederholm, Bull. Comm. Geol. Finlande, No. 58, p. 25.

- I. Nepheline syenite,
- II. Country rock,
- III. Dark central part of the dyke.

In Pl. I, Fig. 4, is shown a polished surface of another specimen from the same locality. The dull portion of the dark area represents the original greenstone, while the part taking a better polish represents irregular areas of relatively coarse nepheline rock formed by the action of invading magmatic solutions. In one of these areas is seen a cross section of a large fresh orthoclase crystal. In other specimens these crystals at times attain a length of two inches.

The chemical, microscopic, and macroscopic examination of these specimens in the laboratory and a study of the contact relationship of the syenite in the field suggest that some late differentiate from the intrusive which gave rise to a great variety of syenites, has been introduced into the greenstone during the pegmatitic phase of consolidation and has given rise to nepheline rocks by reaction on the older basic eruptives. As indicated by the tiny veinlets in Pl. I, Fig. 3, this material filled cracks in the country rock less than a millimeter wide, and invaded the basic dyke causing the formation of comparatively fresh orthoclase crystals,—pseudophenocrysts. If this interpretation be correct, the active material must have been an aqueous melt.

Sederholm¹ describes composite dykes with acid margins and darker more basic centres from Finland, as follows:

"On the northern shore of Timmerholm, which lies 1 km. to the east, a narrow vein of aplite is visible, whose middle part is very rich in biotite, while the rock nearer to the contact is a pale aplitic granite (Fig. 51). The continuation of the same vein is found on the neighbouring island of Högsjär. Here the darker portions resemble fragments of a schistose rock. Possibly the darker portions of the dyke in Fig. 51 are more completely assimilated fragments of a basic schistose rock."

The formation of nepheline rocks has been regarded by some as due simply to the differentiation of an igneous magma and by others to the consolidation of a liquid magma resulting from the assimilation of limestones by an igneous magma

¹*Op. cit.*, p. 109.

followed by further differentiation. In the present observations there seems to be evidence to indicate that such rocks may arise from a circulation which removes part of the iron, lime, magnesia, and possibly potash from the older basic rock.

Along the shore of Lake Superior in the vicinity of Port Coldwell, and on the shores of the thousand islands of the Georgian Bay there is a splendid opportunity for a detailed study of the relationship of the different crystalline rocks to one another. It is desirable that studies in the field should be undertaken similar to those of Sederholm in his study of the migmatites of Finland. Such investigations would throw much-needed light on the early history of these old crystalline rocks.

INFLUENCE OF HOT NATURAL BRINES ON DOLOMITIZATION

By T. L. WALKER and WILLIAM GERRIE

It is now generally agreed that organic remains consisting largely of calcium carbonate may become richer in magnesia as a result of the magnesia of the sea water replacing part of the lime. In this way it is thought that some at least of the dolomites may have been formed. With a view to determining the readiness with which this reaction takes place, a number of calcareous animal materials were ground and placed in vessels with sea water. The duration of the experiments, the fineness of the material, the concentration of the sea water and temperature are indicated in the following account.

The sea water which was obtained from St. Andrews, New Brunswick, contained .0377 per cent. of calcium and .121 per cent. of magnesium, and at 20°C had a density of 1.025. Most of the experiments were made by placing in a bottle 10 grammes of finely ground material along with half a litre of sea water and agitating this continuously for a definite period in a room the temperature of which was constant at 18±1°C. The material used was in all cases analysed for calcium and magnesium.

EXPERIMENT I

Time 14 days; normal sea water; temperature 18±1°C.

Material Used	Mesh of Powder	Magnesium		
		Powder Before	Powder After	Sea Water After
Unio-local.....	100	.100	.115	.120
Sea Clam, St. Andrews, N.B.	100	.065	.135	.121
Heliophyllum halli.....	100	.120	.295	.121
Common Oyster.....	60-100	.385	.360	.120
Trachyphyllum amarantha...	60-100	.275	.270	.121
Oculina.....	60-100	.215	.185	.120

In this experiment, as in the two following, the changes in magnesium content are relatively small and may in some measure be ascribed to the methods employed in the analyses.

EXPERIMENT II

The conditions were the same as those of the previous experiment except that the sea water was concentrated to half the volume and the small amount of dissolved material which separated during the concentration was removed by filtration. The duration of the agitation was 14 days except for the *Unio*, which was 16 days. Magnesium content of the concentrated sea water was .236 per cent.

Material Used	Mesh of Powder	Magnesium		
		Powder Before	Powder After	Sea Water After
<i>Unio-local</i>	100	.100	.085	.233
Sea Clam, St. Andrews, N.B.	100	.065	.065	.232
<i>Heliophyllum halli</i>	100	.120	.265	.234
Common Oyster	60-100	.385	.220	.232
<i>Trachyphyllum amarantia</i>	60-100	.275	.180	.234
<i>Oculina</i>	60-100	.215	.180	.234

EXPERIMENT III

Conditions as in I and II, except that the sea water was concentrated to one seventh of its volume, the precipitate removed by filtration and then diluted to one sixth of the original volume to prevent further precipitation. Specific gravity of concentrated sea water 1.128; magnesium content .618 per cent.; time of agitation 30 days, except 32 days for the first and 36 days for the second.

Material Used	Mesh of Powder	Magnesium	
		Powder Before	Powder After
<i>Heliophyllum halli</i>	100	.120	.260
Common Oyster	100	.170	.240
<i>Trachyphyllum amarantia</i>	100	.275	.200
<i>Oculina</i>	100	.215	.220

EXPERIMENT IV

In the previous three experiments the material was kept at constant room temperature and agitated during the period of the reaction. In experiment IV, 5 grammes was placed with 500 cc. of normal sea water and heated at 97°C in sealed bottles for 19 days. In this case there was no mechanical agitation.

Material Used	Mesh of Powder	Magnesium	
		Powder Before	Powder After
<i>Unio-local</i>	100	.100	1.265
Sea Clam, St. Andrews, N.B.	100	.065	.215
<i>Heliophyllum halli</i>	100	.120	.330
Common Oyster	100	.170	.840
<i>Trachyphyllum amarantia</i>	100	.275	1.290

From these data it appears that under the conditions of the first three experiments the one fossil type employed, *Heliophyllum*, gained in magnesium more rapidly than any of the others while in experiment IV it was one of the slowest to react. In the first three experiments the changes of the other five types was slight compared with the marked changes indicated by the last experiment.

Does the acceleration of the magnesia-lime replacement under the conditions of the last experiment have any serious bearing on the problem of magnesia enrichment as indicated in dolomitization? The temperature of the reaction, 97°C, is too high to correspond to any ordinary sea water. It is of interest to note, however, that van't Hoff in his studies as to the physical conditions under which salt deposits are formed, has indicated that some of them are only formed at high temperatures. The following minimum temperatures are here of interest: vanthoffite 46°, loewite with glaserite 57°, loewite with vanthoffite 60°, and kieserite with sylvite 72°. If highly concentrated ocean brines attain in nature such high temperatures as those under which the substitution of

magnesia for lime is hastened, it may be concluded that dolomitization may in some cases be partly due to these conditions.

MOLYBDENITE IN LACORNE AND MALARTIC TOWNSHIPS, QUEBEC.*

By WILLIAM GERRIE

The molybdenite veins which are the subject of the present study form two groups in the extreme south-west corner of LaCorne township and another in the north-east corner of Malartic township in the Temiskaming district of Quebec. Stripping on three outcrops on the property has disclosed three groups of veins carrying molybdenite which from the south have been named A, B, and C. These vein groups lie roughly on a line three quarters of a mile long which cuts the township corners at a strike of N 30° E. The property was first visited in 1919 by Professor Mailhiot¹ of the Ecole Polytechnique, Montreal, who briefly described some of the veins in LaCorne township.

The molybdenite deposits lie on the western margin of the LaCorne intrusive body, which varies from a hornblende syenite in the interior of the township to a biotite granite at its western border. The molybdenite veins occur in a contact zone of fine-grained granite and biotite schist of sedimentary origin. Four rock types are represented on the outcrops. The first of these is the biotite schist. The next in order of age occurs in the form of dark green bands of a pyroxene lamprophyre occurring in the biotite schist. The third type is a fine-grained somewhat gneissic biotite granite which occurs in the form of small sills in the central part of the molybdenite area and in larger masses elsewhere. This granite, as will be seen from the following analyses, is identical with the granite at the western edge of the LaCorne intrusive. The youngest rocks are pegmatites connected with the granite-syenite intrusion found all along the western border of the intrusive mass. To the east in the intrusive proper the

¹A. Mailhiot, The Gold Deposits of Lake de Montigny, Abitibi. Bur. of Mines, Quebec.

*Published with the kind permission of the Director of the Geological Survey of Canada. Field work carried on under the guidance of Dr. W. F. James and Dr. J. B. Mawdsley.

pegmatites are felspathic and carry traces of molybdenite, but on the molybdenite claims they are sharply defined quartz pegmatites, carrying in places good values in molybdenite.

	(a)	(b)	(c)	(d)	(e)
SiO ₂	69.10	69.00	69.15	67.30	58.30
Al ₂ O ₃	17.90	17.35	16.10	15.95	17.65
Fe ₂ O ₃	.72	1.28	1.30	1.75	2.00
FeO	1.38	1.22	1.50	1.30	3.98
CaO	3.44	3.40	2.95	3.68	6.24
MgO	1.14	.75	1.18	.70	3.60
Na ₂ O	1.16	1.33	1.88	2.88	3.22
K ₂ O	5.00	5.48	5.10	4.08	4.54
	99.84	99.81	99.16	97.64	99.53

- (a) Representative of small sills on group B.
- (b) " " large mass on group C.
- (c) " " " " " " A.
- (d) Granite two miles north-east of property.
- (e) Hornblende syenite lot 44, range III, LaCorne Township.

Over the three vein groups there is one set of pegmatites disposed in parallel arrangement with a strike of N. 55° to 80° E. and a dip of 50° to 90° toward the south. They give the echelon effect in B and C. Another set of pegmatites, important only in A, has a strike of N. 35° W, and a dip toward the west. In width these veins vary from a few inches up to seven and one half feet. Some of them have been uncovered for over 200 feet without fully indicating their length. In all, twenty-four veins have already been disclosed, ten of which are on group B. The close of the pegmatitic activity in its turn was marked by some slight pneumatolytic action, which is indicated in a few places adjacent to the pegmatites by small veins and vugs of fluorite and quartz.

Minerals found in the Pegmatite

Quartz is usually white, rarely smoky. It is always badly fractured in the smaller veins, though well-formed crystals five millimetres long occur in the fluorite veinlets. The feldspar, commonly white or pink, is mostly orthoclase or

microcline with subordinate plagioclase. Muscovite is pale sea-green in colour, and occurs in streaks due to shearing. The molybdenite is mostly disseminated in the muscovite less frequently as bright scaly crystals in the quartz and feldspar where it has been preserved against shearing effects. An analysis of material concentrated from a sample of ore from a vein on group B showed:

Mo	58.00
S	39.10
Insol.	3.88
	<hr/> 100.98

The insoluble material consists of fine scales of muscovite which probably occurred along the cleavage planes of the molybdenite. The molecular ratios of Mo: S: : .622: 1.256 is agreeable to the accepted formula for molybdenite. Apatite is present as rude hexagonal prisms resembling beryl in form and colour. Black tourmaline forms small masses of capillary crystals or rosettes of large crystals usually much fractured, though on one of the veins on group C it is olive-green in colour. Pyrite is seen in well-formed cubes near schist walls. Other minerals of less frequency are violet fluorite, bismuthinite, and columbite. Molybdenite was observed as a weathering product on the ore piles. The order of crystallization in the veins appears to be: apatite and pyrite, tourmaline and feldspar, muscovite, molybdenite columbite and bismuthinite, quartz, and fluorite quartz and chalcopyrite. Apatite, pyrite, and feldspar invariably line the walls, as does tourmaline, though it also impregnates the wall rock and occurs with feldspar within the vein.

The Pegmatite Veins

The veins are essentially quartz pegmatites, in which quartz constitutes about 90 per cent. of the vein matter. This suggests that these veins are the distal parts of felspathic pegmatites such as those which occur across the valley. However, it is a peculiar fact that nearly all the small

veins are felspathic, and all the large veins tend to become so where they pinch out. Moreover, in the small veins, where the silica-alkali ratio is low, the alkalis are present as feldspar, but in the large veins, where the ratio is very high, the alkalis are present as muscovite. Most of the molybdenite is found either in the muscovite or in the feldspar. Thus, there are two types of veins—a quartz-feldspar type and a quartz-muscovite type. The latter type is more important, though the smaller veins of the other type are usually much richer. An unusual feature of these two types of veins is their occurrence in vein-group C. Here the quartz-feldspar type occurs exclusively in the schist and the quartz-muscovite type in the large granite mass. In a vein which crosses the contact, the change in type takes place exactly at the contact, and the molybdenite is restricted to the feldspar type in this outcrop.

Economic Aspects

Molybdenite is usually found in the alkali mineral of the vein. In vein-group A the intersection of veins seems a favourable place for its occurrence. In vein-group B, the large veins are enriched in muscovite and molybdenite wherever they cross a granite sill or a group of granite sills. The small felspathic veins of this vein-group are rich ore-bearers. In group C the quartz veins in the granite are barren, but the quartz-feldspar veins in the schist are often heavily charged with molybdenite. In these smaller veins the molybdenite is found towards the walls of the vein, since it is at home in feldspar (Pl. III, Fig. 3). The outcrops in group B are the most important economically, since the veins are not only larger, but more numerous. A shaft has been sunk to 43 feet in the main vein and most of the prospect pits are on this outcrop. The discovery of many large veins by stripping south from B seems very probable. The ore is practically free from sulphides other than molybdenite and is an attractive milling ore, carrying from 2 to 3 per cent. molybdenite on the average. Though no ore has been shipped except a test lot of ten tons to the Mines Branch at Ottawa, these veins give promise of producing a reliable tonnage of molybdenite.

A MINERALOGRAPHIC EXAMINATION OF COHENITE FROM OVIFAK, GREENLAND

By ELLIS THOMSON

This mineral was first described by Forchhammer¹, and later in greater detail by Shepard², Törnebohm³, Cohen⁴, and finally by Böggild⁵. Up to the present it has been found in meteorites and particularly with native iron in Greenland, the two best-known localities being Ovifak in the Godhaven district and Niakornak in the Jakobshaven district. Through the kindness of Professor Böggild, some of the material from the Ovifak locality was presented to the Royal Ontario Museum of Mineralogy. Some observations on the chemical and mineralographic characteristics of this material form the basis of the following statement.

Cohenite, as is well known, is found only in association with native iron, from which it can be separated by digestion with very dilute hydrochloric acid. A residue obtained in this way was analysed by H. C. Rickaby with the following result:

Fe.....	78.12
S.....	16.40
Insoluble.....	3.86
	98.38

This corresponds roughly to Fe_3S , instead of Fe_3C .

When enclosed in wax, polished and examined with the microscope the analysed material appeared to be homogeneous until treated with different chemical reagents, when the

¹Forchhammer, Overs, over Vid. Selsk. Forh., No. 1, 1854.
²Shepard, Am. Jour. Sc., 43, 1867, p. 28.
³Törnebohm, Bih. Vet. Akad. Handl., Stockholm, Bd. 5, No. 10.
⁴Cohen, Ann. d. k. k. Hofmuseums, Wien, 12, Hefte 1, p. 58.
⁵O. B. Böggild, Mineralogia Groenlandica, pp. 26-27.

heterogeneity was brought out. It was noted, for example, that some of the fragments or portions of them were etched quite strongly by dilute nitric or hydrochloride acids, but that the remaining fragments or portions of fragments were unaffected, while a 20 per cent. solution of ferric chloride etched all the fragments equally or with such slight differential effects as might be attributed to varying crystal orientations. This analysed material was also compared, as to its microchemical reactions, with a specimen of troilite from Del Norte county, California. As the microchemical reactions of the troilite were similar, if not identical, with those of part of the analysed material, it was concluded that one of the minerals in the mixture was the monosulphide troilite.

The original specimen containing the cohenite was found to be even more complex. In addition to several transparent minerals, which were not determined, it showed three metallic constituents in intimate intergrowth. Of these three, two were galena white to creamy white in colour, and made up the major portion of the metallics in the section, while the third, subordinate in amount, was yellowish cream in colour. The yellowish cream mineral reacted to the four standard reagents of Davy-Farnham in about the same degree as the troilite, and, lacking confirmation by chemical analysis, was assumed to be troilite.

The two major metallic constituents failed to reveal their identity by etching with these standard reagents. As this material was similar to that found in certain steels, a polished specimen was submitted to Professor J. A. Newcombe of the Department of Metallurgy, who etched it with the reagents used to test the pearlite mixture in steel, and found that the structures produced were practically identical with those of pearlite (Pl. III, Fig. 2). Pearlite is a mixture of cementite (Fe_3C) and ferrite (Fe). On etching this mixture with picric acid, the ferrite is attacked, and the cementite remains unaffected, while sodium picrate tarnishes the cementite and leaves the ferrite fresh. As the specimen submitted behaves in the same way when etched, it was concluded that the material of the cohenite specimen is composed of cementite

and ferrite, which are known to mineralogists as cohenite and native iron. The structure produced followed closely the outer rejection rim and grating patterns of the pearlite in steel, with the cohenite forming a border on grains of iron and following the cleavage planes in to the central portion of the iron. Cohenite is harder than the native iron and stands out in relief as does cementite in pearlite.

The specimen therefore appears to be composed of three minerals, metallic in lustre, namely, cohenite, native iron, and troilite, in addition to several non-metallic constituents which were not determined.

CANADIAN LOCALITIES FOR CHALMERSITE

By ELLIS THOMSON

Through the kindness of Mr. E. L. Brown of Toronto and Mr. G. S. Scott of Timmins, Ontario, the writer was supplied with specimens of chalmersite from two new Canadian localities. The first came from the Sherritt claims on the shores of Cold lake, northern Manitoba, situated about thirty miles north west of the Flin Flon mine near the Manitoba-Saskatchewan boundary. The second, from Mr. Scott, was found in Raglan township, Renfrew county, Ontario. As localities for this rare mineral have been multiplying in other parts of the continent, it was thought a brief description of these two occurrences might be of interest. Chalmersite has already been described by Schwartz¹ from Parry Sound, Ontario, and from Oiseau river district, Manitoba.

Cold Lake, Northern Manitoba

The chalmersite from this locality occurs in the form of slender needles sparsely distributed in chalcopyrite (Pl. II, Fig. 3), which is associated with considerable pyrrhotite and sphalerite. Groups of needles parallel to one another follow a parting plane in the chalcopyrite, though occasionally they indicate two or even three distinct crystal directions. The ore is found in the form of a magmatic segregation in a country rock resembling the eruptive series at Sudbury, Ontario. The order of deposition is as follows: pyrrhotite, chalcopyrite, chalmersite, and finally sphalerite. Chalcopyrite and sphalerite were in part contemporaneous in deposition, while the chalmersite was evidently thrown out of solid solution with the chalcopyrite, following the lines of weakness in the usual way.

¹G. M. Schwartz, *Econ. Geol.*, Vol. 22, No. 1, 1927, pp. 44-61.

Raglan Township, Renfrew County, Ontario

This occurrence of chalmersite differs from that just described as the chalmersite is here the predominating metallic mineral. It is associated with considerable chalcopyrite (Pl. II, Fig. 1) and a little magnetite, arsenopyrite, and sphalerite. All five of these metallic minerals appear in granular form. In places, however, the chalmersite occurs in the usual acicular form, scattered sparsely through the chalcopyrite areas, or these relations may be reversed when the chalcopyrite appears in stout needles or shreds in areas of chalmersite (Pl. II, Fig. 2). These features are of minor importance, as compared with the common granular structure, and it seems likely that the crystal directions of the chalcopyrite did not play any considerable rôle in determining the arrangement of the chalmersite grains. Both the chalcopyrite and the chalmersite have altered along fracture cracks in a few places to chalcocite, but in the case of the chalmersite, the alteration has generally progressed to a later stage with covellite replacing the chalcocite. It would appear that the chalmersite was more susceptible to alteration than the chalcopyrite, as not only has the alteration progressed further in the former, but it is especially noteworthy in this connection that, in those parts of the section where chalcopyrite predominates and chalmersite appears in the form of needles following the parting planes of the chalcopyrite, these needles are largely altered to covellite, while the chalcopyrite surrounding them remains quite fresh. The metallics occur as stringers of nearly solid sulphides, with a little quartz gangue, in a light gray gneiss. These stringers follow the foliation of the country rock which is heavily mineralized with sulphides a few feet on either side of the stringers. The order of deposition of the metallic minerals appears to be as follows: magnetite, sphalerite, chalcopyrite and chalmersite, chalcocite, and finally covellite.

The chalcopyrite and chalmersite are practically contemporaneous in time of deposition. This occurrence is extraordinary in the dominance of chalmersite over chalcopyrite,

the granular structure of the former and the absence of pyrrhotite, which is a usual associate. If, as stated by Schwartz¹, the chalmersite was originally in the form of a solid solution with chalcopryrite, this occurrence must represent a product from a solution high in the chalmersite molecule, where the crystal directions of the chalcopryrite had little effect in determining the structure of the chalmersite. In the hand-specimen the mineral from Raglan resembles pyrrhotite in colour and general physical characteristics. It is nonmagnetic and in polished section has a much lower relief than pyrrhotite. Possibly many so-called non-magnetic pyrrhotites are in reality chalmersite.

¹*Op. cit.*, p. 61.

CATALYTIC ACTION IN THE OXIDATION OF SULPHIDES AND ARSENIDES

By FERGA CARMICHAEL

In 1926 experiments were made on the oxidation of some of the common sulphides in the presence of distilled water and an atmosphere of oxygen¹. Ten grammes of mineral, crushed to go through a twenty-mesh screen and rest on a sixty-mesh screen, was placed in a bottle containing 500 cc. of distilled water and 2100 cc. of oxygen at atmospheric pressure. The bottle was stoppered securely to prevent any escape of oxygen and furnished with a glass tube and stop-cock so that a fresh supply of oxygen could be introduced daily, thus making it possible to bring the gas in the container to atmospheric pressure every twenty-four hours. By a daily measurement of the atmospheric pressure, the pressure in the bottle and the temperature, it was possible to calculate the amount of oxygen used up from day to day. The bottles were placed in a rectangular box to which a horizontal reciprocating motion of six inches per second was imparted by means of a suitable power mechanism. At the end of the period of agitation the bottles were removed from the shaking apparatus, and the clear liquid, which contained the soluble oxidation products, was filtered off. This left, in the case of some of the sulphides, a slimy insoluble oxidation product adhering to the unaltered residue, which was separated by washing the whole with dilute hydrochloric acid (1: 10), which dissolves the slime and leaves the residue unaffected. Analyses were made of the soluble oxidation product, the insoluble oxidation product and of the original mineral. The unaltered residue was weighed, the weight giving a check on the amount of mineral consumed as determined by the oxygen used up and by the chemical analysis.

¹F. Carmichael, Univ. of Toronto Studies, Geol. Ser. No. 22, pp. 29-36.

During the past winter this work was continued, particular attention being paid to the effect produced by the addition to the charge of certain catalyts. Three of the most active catalyts employed in industrial chemistry—platinum, iron, and manganese—were used. Since the polydymite from the Vermilion mine, Sudbury, Ontario, and the covellite from the Rambler mine, Holmes, Wyoming, contain a small amount of platinum arsenide as sperrylite, and are remarkable for their rapid oxidation in the form of mineral specimens, it was thought that the addition of a small quantity of finely ground sperrylite might hasten the oxidation of other minerals. This was tried, but without success. No increase in the amount of mineral used up was observed. Platinum black, however, proved an effective catalyts. That the metal itself should be found to be a more active catalytic agent than the compound was to be anticipated. Rideal and Taylor¹ had found that platinum monoxide, even when freshly prepared, is not so active as platinum black. The iron was used in the form of finely powdered pyrite, and manganese as manganese dioxide.

The method of procedure was essentially the same as that of the earlier experiments, except that the period of agitation was fifteen as opposed to thirteen days, while the temperature during the time of the experiments was kept constant at $18 \pm 1^\circ\text{C}$ by using a constant temperature room. The liquid was filtered through a fine glass crucible made by Schott and Genossen of Jena, thus making possible a more accurate weighing of the unaltered residue.

For each of the minerals experimented upon, a set of four bottles was made up as described above. The first of these contained no catalyts, but to the second, third, and fourth was added a tenth of a gramme of platinum black, pyrite, and manganese dioxide respectively. Experiments were made on chalcocite, pyrrhotite, nickeliferous pyrrhotite, polydymite, and rammelsbergite.

¹E. K. Rideal and H. S. Taylor, *Catalysis in Theory and Practice*, p. 40.

Chalcocite, Pyrrhotite, and Nickeliferous Pyrrhotite

In the case of the above minerals the rate of oxidation was very slow, and the results did not indicate any marked acceleration as a result of the introduction of the foreign substances into the charge.

Polydymite, Vermilion Mine, Sudbury, Ontario

This mineral was known from earlier experiments¹ to oxidize more rapidly than any other sulphide examined. In those experiments it was found that in the oxidation a large part of the sulphur separates as elementary sulphur which remains behind with the unaltered mineral when the decomposition product is treated with dilute hydrochloric acid. It was then shown that finely ground polydymite after

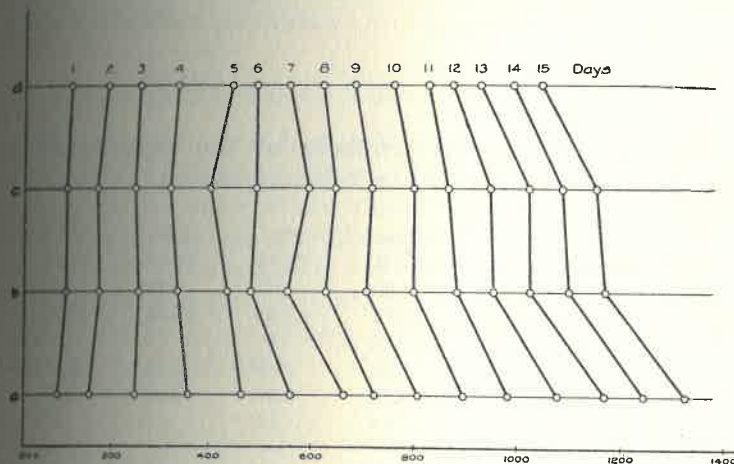


Fig. 3

a, platinum black; b, manganese dioxide; c, polydymite alone; d, pyrite

agitation for fifty days gave 11.4 per cent. of elementary sulphur which was separated from the residue by means of carbon bisulphide.

¹*Op. cit.*, p. 33.

In the present experiments the four bottles were charged, in the manner previously described, with 10 grammes of the polydymite, 0.1 grammes of the catalyst, 500 cc. of distilled water, and 2100 cc. of supposedly pure oxygen. The gas was found upon analysis, however, to contain only 93.2 per cent. of oxygen, the remaining 6.8 per cent. being made up of some inert gas, possibly nitrogen. The rate at which the impure gas was introduced into the bottles containing the four charges for each of the fifteen days is indicated in Fig. 3.

An analysis of the original polydymite is as follows:

Iron.....	11.88
Nickel and Cobalt..	47.42
Copper.....	.88
Sulphur.....	39.94
Insoluble.....	.44
	100.56

The analyses of the products of the experiments on polydymite are shown in the following table:

	Alone	Pt.	FeS ₂	MnO ₂
Unaltered Mineral.....	75.01	72.26	78.85	78.16
Filtrate	Fe.....	.26	.23	.29
	Ni and Co.....	11.77	13.80	10.43
	Cu.....	.62	.71	.75
	S.....	6.67	7.89	6.13
Insoluble	Fe.....	3.70	4.36	2.93
	Ni and Co.....	.19	.18	.12
	Cu.....	—	—	—
	S.....	.42	.47	.31
	98.64	99.90	99.91	100.59
Less per cent. of catalyst.....	0.00	1.00	1.00	1.00
	98.64	98.90	98.91	99.59

The analyses indicate that the insoluble decomposition product is chiefly hydroxide of iron, that the small amount

of chalcopyrite contained in the polydymite is almost completely oxidized, and that the reaction is accelerated by the presence of the platinum black and retarded by pyrite and manganese dioxide.

The volume of gas, expressed in cubic centimetres, which were used in these experiments, is given in the following table:

	Alone	Pt.	FeS ₂	MnO ₂
(a).....	1152	1324	1046	1170
(b).....	1072	1233	975	1095
(c).....	1101	1294	989	1075

- (a) Gas introduced into the bottles.
 (b) Pure oxygen contained in the gas given in (a).
 (c) Oxygen indicated by the analyses.

The amounts of oxygen indicated in (b) and (c) agree on the whole within five per cent.

Rammelsbergite, Keeley Mine, South Lorrain, Ontario

This mineral shows in a striking way the variation in rate of oxidation caused by addition of one-tenth of a gramme of a catalyst to the ten gramme charge. It was selected because it was already known to oxidize rapidly even without the use of catalysts. The material used was not analysed, but it is thought that it is probably not very different from the sample used in earlier experiments¹, which was found to have the following composition.

Ni.....	15.91
Co.....	11.29
Fe.....	.78
As.....	64.10
S.....	4.00
Insol....	3.44
	99.52
S. G.....	6.527

¹T. L. Walker, and A. L. Parsons, Univ. Toronto Studies, Geol. Ser., No. 20, pp. 41-48.

The rate at which the impure gas was introduced into the bottles, as based on the pressure data, is graphically shown, for fifteen days for each of the charges, in Fig. 4.

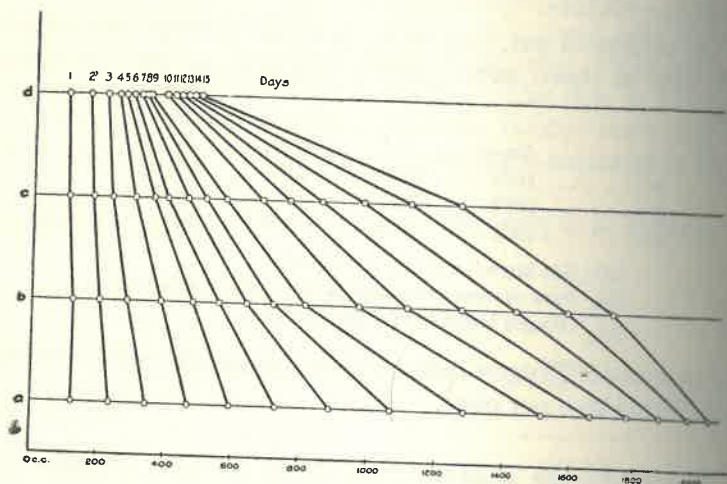


Fig 4.

a, platinum black; b, manganese dioxide; c, pyrite; d, rammelsbergite alone

The results of the chemical analyses of the different products is as follows:

	Alone	Pt.	FeS ₂	MnO ₂
Unaltered Mineral	83.88	37.69	59.50	44.12
Filtrate	S . . . . .	.13	.23	.36
	As as As ₂ O ₃	6.82	13.49	12.35
	As as As ₂ O ₅ . . . . .	.82	24.38	10.22
	Ni . . . . .	.31	8.61	3.73
Insoluble	Co . . . . .	.02	1.03	.22
	As as As ₂ O ₅	4.39	8.39	7.41
	Ni	3.61	7.23	6.51
	Co . . . . .	.57	1.44	1.06
	Fe . . . . .	.28	.33	.28
	100.83	102.82	101.75	101.43
Less per cent. of catalyst	0.00	1.00	1.00	1.00
	100.83	101.82	100.75	100.43

The comparison of the measured quantities of oxygen consumed as based on pressure data with quantities calculated from the chemical analyses is given in the following table:

	Alone	Pt.	FeS ₂	MnO ₂
(a)	492	2060	1258	1726
(b)	458	1920	1172	1610
(c)	455	1908	1208	1668

- (a) Gas introduced into the bottles.
- (b) Pure Oxygen contained in the gas shown in (a).
- (c) Oxygen indicated by the analyses.

In this case the quantities of oxygen given in (b) and (c) agree to within three per cent.

It seems evident from the above results that all three of the catalysts used increased the rate of the reaction, although platinum black was more active than either manganese dioxide or pyrite. According to Rideal and Taylor¹, arsenious acid acts as a poison to the catalytic effect produced by platinum. This, however, has not been found to be the case with the rammelsbergite, since, as will be seen from the analysis, 1.349 grammes of arsenic in the form of As₂O₃ was in solution in 500 cc. of water at the end of the fifteen days agitation. It is remarkable that in the case of the charge without catalyst practically all the nickel and arsenic pentoxide are found in the insoluble decomposition product in contrast to the distribution in the case of the other three charges.

These experiments suggest that the rate of oxidation as observed in rocks, and particularly in mineral veins, may be in part due to the accidental occurrence with the sulphides and arsenides of small amounts of minerals able to supply the necessary catalytic conditions. In the past the rate of oxidation has been almost entirely related to circulation, time, and topography. The experiments are being continued.

In closing the writer would like to express her gratitude for the many helpful suggestions given her by Dr. T. L. Walker.

¹Op. cit., p. 35.

PLEOCHROIC HALOES IN BIOTITE FROM NEAR MURRAY BAY, P.Q

by

D. E. KERR-LAWSON

Introduction

While examining some pleochroic haloes in thin sections of rocks, the writer was impressed with the fact that his study of these structures might be greatly facilitated if they could be found in mica of the pegmatitic variety, thereby eliminating the restriction of manipulation imposed by the smallness of the flakes found in ordinary rocks. Dr. T. L. Walker suggested that the dark biotite found at the Mine de Pied des Monts, near Murray Bay, P.Q., might contain haloes, and an examination of the material proved this to be the case. A detailed study of the haloes in this biotite brought some rather unique features to light, as will appear later. Before proceeding with their description, however, a brief résumé will be given of the whole subject, as it is thought that some readers of this publication may be familiar only in a general way with pleochroic haloes, while others may be unacquainted with the reasons for the present interest in them.

History and Interpretation of Haloes

According to Zirkel¹, Rosenbusch² was the first (1877) to note the occurrence of these coloured zones around small inclusions in certain minerals. The latter in his book on microscopic physiography³ devotes considerable space to the phenomenon, giving references up to 1890, and an account of the views then held regarding their origin. Opinion was then divided as to whether they were due to a local concen-

¹F. Zirkel, *Lehr. der Pet.*, Zweiter Auflage, Bd I, s. 91-92.

²H. Rosenbusch, *Steiger Schiefer*, 1877, p. 221.

³H. Rosenbusch, *Mikroskopische Physiographie*. I, 1892.

tration of organic pigment or to a locally increased content of iron-rich molecules. Joly¹ suggested the view now accepted, namely, that the coloured areas are due to the alpha-ray activity of the small central inclusion or nucleus. As is well known, a radioactive element spontaneously disintegrates, forming another element of lower atomic weight and emitting one or more kinds of the so-called rays or radiations. Certain series are known, of which the first element is radioactive, but not known to be the result of previous disintegration, and of which the last members are stable, but of which each intervening element is formed by the breaking down of its predecessor, and which itself disintegrates, forming the following member of the series and emitting radiations. The rates of decay of the various members of one of these series in general differ widely, but in each case takes place in such a way that the amount of any element which decays in a short time is proportional to the amount of that element which is present. A state of equilibrium accordingly tends to be set up between the quantities of the members of such a series present in a sample, provided the sample is undisturbed chemically for a long period. The type of radiation responsible for pleochroic haloes is the alpha radiation, which consists of charged helium atoms ejected with high velocity. When a radioactive element is in equilibrium with its disintegration products, each alpha-radiating member of the series is shooting off the same number of alpha particles per second. As each element imparts a characteristic velocity to its alpha particles, the ranges or distances which the alpha particles from each will travel before coming to rest are different, those elements with the fastest rates of decay having the longest ranges, and *vice versa*. A minute crystal of uraninite in air, therefore, is to be regarded as projecting alpha particles radially, the loci of whose points of rest are the surfaces of a series of concentric spheres, their common centre being also the centre of the crystal, and their radii being the maximum ranges of the alpha particles from the eight alpha radiating members of the uranium series. In a solid medium, such as

¹J. Joly, *Phil. Mag.*, March, 1907.

mica, there is every reason to believe that a similar condition exists, except that the ranges, and consequently the radii of the spheres, are only about one two-thousandth of those in air.

It has been found that in their passage through a gas, the alpha particles ionize it—*e.g.*, render it conducting. The ionizing power is greatly increased just before the particle comes to rest. A curve representing the relation between amount of ionization and distance from the source of the alpha particles (say for uranium in equilibrium with its disintegration products) shows, therefore, certain prominences closely linked up with the ranges of the particles from these products.

Joly¹ has shown that the pleochroic haloes in biotite are complex structures, being essentially a series of concentric shells of differing colour density, whose relative distribution is more or less closely related to the ionization curve in air. The halo constitutes a graphical record of the integral ionization which has been produced by the radioactive series decomposing in equilibrium in the nucleus since its crystallization. As Joly² has pointed out, comparison of haloes of different ages with each other, and with the ionization curve, is the only means at present available, to give direct evidence regarding the constancy of the rate of accumulation of lead in radioactive minerals. Working along these lines, he has found evidence (1) that thorium haloes agree exceedingly well with the ionization curve, (2) that uranium haloes show a discrepancy indicating that uranium formerly decomposed faster than at present and (3) that the discrepancy is greater in haloes from ancient rocks than from younger ones.

Haloes in Biotite from Murray Bay

The haloes to be described in this paper were found in a sample of biotite from the Mine de Pied des Monts, Charle-

¹J. Joly, *Phil. Mag.*, March, 1907, Feb. 1910.

J. Joly, and A. L. Fletcher, *Phil. Mag.*, April, 1910.

J. Joly, *Roy. Soc. Lond., Phil. Trans., A.*, 217, 1916—18, p. 51, et seq.

²J. Joly, *Roy. Soc. Lond. Proc. A.*, 102, 1922—23, p. 682 et seq.

J. Joly, *Roy. Soc. Lond. Phil. Trans., loc. cit.*

voix county, province of Quebec. This pegmatite deposit, according to Dr. J. B. Mawdsley¹, of the Geological Survey, Ottawa, cuts a Precambrian complex chiefly granite. It was worked some thirty years ago for muscovite, and is mentioned in this connection, very briefly, by Ells², Cirkel³, and De Schmid⁴. Some attention was also drawn to it in 1904, by Obalski's⁵ publication of the description of a large crystal of cleveite, weighing 375 grammes, from this dike. There is apparently no detailed description in the literature, either of the deposit or of the geology of the region. The dimensions of the pegmatite mass are stated by De Schmid⁶ to be 300 feet in length with an average width of 20 feet.

The specimen of biotite in the possession of the Royal Ontario Museum of Mineralogy is part of a large irregular crystal, and its dimensions are 13 inches by 11 inches by 1 inch, its weight being 12½ pounds. The material is greenish black in colour with a brilliant lustre. Sheets of about 1/3 mm. in thickness, are almost opaque, but sheets of the order of a hundredth of a millimetre are perfectly clear and transparent, with a pale greenish yellow colour. With convergent light, this mica appears practically uniaxial, so that the direction of the plane of symmetry cannot be determined from the interference figure. The specific gravity is 3.116. The material is remarkable for the facility with which it can be split into very thin sheets. With practice, one can readily obtain leaves several millimetres in diameter, which are thin enough to show interference colours by reflection from the opposite surfaces. The writer made a number of measurements of the thickness of leaves such as were found by experience to show the haloes to best advantage, by examining the cut and upturned edges in the micrometer microscope, confirmed them by weighing a leaf of measured area, and

¹J. B. Mawdsley, *Pr. Comm.*

²R. W. Ells, *Geol. Surv. Can., Min. Res. Bull. on Mica* (1904), p. 7.

³F. Cirkel, *Mines Branch, Dept. of Mines, Can., Bull. on Mica* (1905), p. 18.

⁴H. S. De Schmid, *Mines Branch, No. 118*, 1912, p. 201.

⁵J. Obalski, *Jour. Can. Min. Inst.*, Vol. VII, 1904, p. 245 et seq.

⁶H. S. De Schmid, *loc. cit.*

concluded that most of the best defined haloes examined by him had been viewed in plates of thickness considerably less than one-tenth of the halo diameter, *e.g.*, six or seven microns. That the thinness of the sections was largely responsible for the excellent definition and detail shown in some cases, is confirmed by the fact that this detail was never well shown, where the halo occurred in a thicker portion of the section. In viewing microscopically a halo consisting essentially of a series of concentric shells of darkened biotite, separated by similar shells of lighter material, the detail in section is much more likely to be clear in plates thin enough to avoid much overlap due to sphericity.

Distribution of Haloes in Biotite

When a plate of the biotite the thickness of a piece of writing paper is viewed with a low power of the microscope, a large number, probably more than half, of the haloes in the field are seen to be disposed along straight cleavage cracks, (Pl. IV, Fig. 2). The remainder are distributed without regularity or visible connection with cleavages, although a single isolated halo will often be observed to have a short cleavage crack starting from its centre and running for a distance of perhaps twice its radius. Fig. 5 is a plan, approximately to scale, of the cleavage cracks in a piece of the biotite 44 mm. by 26 mm. The inset shows the directions of the plane of symmetry and of the pressure and percussion figures, as determined by making etch pits and artificial percussion figures. Each of the six rays of the star is proportional in length to the number of cleavages coinciding with the direction indicated. The arrangement of the pleochroic haloes along lines in the biotite from Murray Bay is shown in Pl. II, Fig. 4.

During his preliminary search for haloes in this mica, the writer found them to be very erratic in their distribution. In splitting successive leaves off a thick book of it, a number of such leaves would fail, one after another, to show any, while the next would show a cloud of them. This seems to

suggest that the nuclei were secondary, that their material was brought in solution along the basal cleavage, being deposited partly in the subordinate cleavages (corresponding to pressure and percussion planes), and partly between the leaves. This would seem to account for the distribution described in the preceding paragraph. On the other hand, micas sometimes contain inclusions in oriented arrangement, as is well seen in the case of rutile in phlogopite. In the biotite from Murray Bay it is possible, but improbable, that

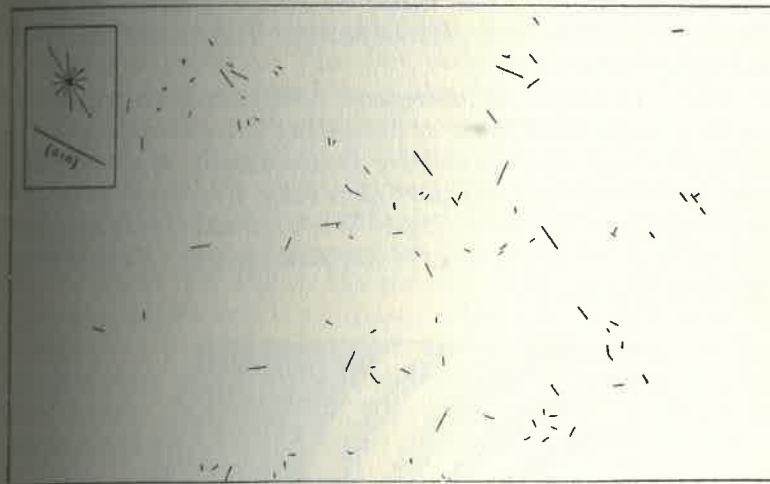


Fig. 5

the nuclei were primarily included in the mica, partly along lines in the six directions indicated and that the cracks may have been developed by forces resulting from differential thermal expansion¹, or even by some force connected with their radioactivity.² The writer has observed, in one or two cases, haloes arranged in a line parallel to one of the six directions, but without any visible fissure connecting them, even under high magnification.

¹T. L. Walker, and A. L. Parsons, Univ. of Tor. Studies, Geol. Ser. No. 16 1923, p. 25.

²H. V. Ellsworth, Geol. Surv. Can., Sum. Rep., Part D, p. 58, 1921.

Stages of Development of Haloes

Joly¹ has described the various stages of development of pleochroic haloes from biotite of Palaeozoic age. It will readily be appreciated that the nuclei may differ greatly, not only in size, but even more in their content of radioactive material. Hence, acting over the same period of time, they will eject differing numbers of alpha particles, and affect the adjacent biotite to a greater or less extent. Similar stages were observed among the haloes of the Murray Bay mica, and an effort was made to secure a series of photographs illustrating their development. The results are shown in Pl. IV, Figs. 1-6.

For convenience of references, both here in describing the various stages, and later in indicating the dimensions of the different rings as observed by measurement, a drawing has been made representing part of a fully developed halo, and letters assigned to these rings. With the aid of this diagram, the corresponding features in the photographs will be readily recognized (Fig. 6).

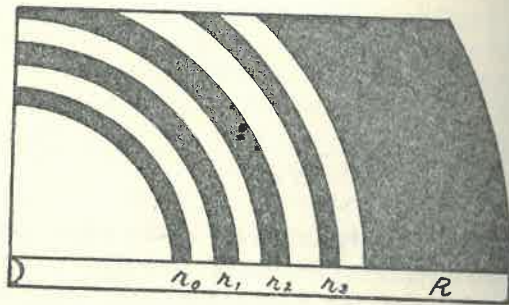


Fig. 6

The first visible manifestation of a halo in this mica is a faint annulus around a nucleus, the outside radius corresponding to the outside radius of r_1 , while the inside radius is indefinite (Pl. IV, Fig. 1, upper halo). In the next stage the interior of this has been darkened almost to conformity with

¹J. Joly, Roy. Soc. Lond., Phil. Trans., *loc. cit.*

the annulus itself, giving the halo a disk-like appearance, while by careful focussing and regulation of the light the margin of this disk is seen to be very sharply defined, and to be surrounded by a narrow, very bright band, which appears actually lighter in colour than the unaffected biotite. Outside of this appears the first suggestion of r_2 (Pl. IV, Fig. 1, lower halo). In the third stage, r_2 becomes distinct, while r_3 shows faintly. By more intense darkening of the extreme outer margin of the disk, r_1 now appears. The interior of the disk also differentiates, by the appearance of the ring r_0 . The region between r_1 and r_0 remains light, but considerable darkening goes on inside r_0 . The part between r_3 and the outside radius of R is represented by a bleached zone at this stage (Pl. IV, Fig. 2). Following this, r_3 becomes well defined, while the outer margin of R begins to darken. The inner portion of R , and the region immediately outside of r_3 , retain their bleached appearance. The depth of colour of the other features is of course proportionately intensified (Pl. IV, Fig. 3). In Pl. IV, Fig. 4, the process has gone still further. The region inside r_1 is very dense, while the darkening of R is proceeding from the outside inwards, encroaching on the bleached zone. Pl. IV, Fig. 5 shows R darkened right to its inner margin, while Pl. IV, Fig. 6 shows loss of all detail except the narrow zone between r_3 and R .

In the later stages of development, the nucleus is surrounded by an intensely blackened region, which completely masks it; this blackened zone, as its radial dimension is small, serves to distinguish centric sections, although the actual kernel is hidden. In some of the embryonic haloes, however, the nucleus was distinguished as a very minute, highly refringent particle (usually in the form of a short prism), by using an oil immersion objective giving a magnification of about 1000 diameters,

Interference of Haloes

That the regions between the dark rings are zones in which a strong bleaching tendency exists, finds confirmation not

only in the fact of their striking appearance, both as seen under the microscope and in the micro-photographs, but also in the phenomena which are observed where two haloes overlap. Joly¹ has invoked an effect akin to photographic reversal, to account for the fact that the inverse square law appears to play little or no part in influencing the distribution of colouring in haloes. He states in part:—

"It might appear that by studying the effect obtaining in the mica where two haloes overlap, we might get evidence as to the existence of reversal effects. Unfortunately, these effects seem very variable. Sometimes there is overlap with little or no increased depth of colour. This is favourable to the reversal theory. But again, and when we have reason to believe that there is true overlap in the same plane, there is increase of darkening."

The photographs of overlapping haloes from the Murray Bay material (Pl. IV, Figs. 7, 8, and 9) show that each halo develops very much as though the other were so many ordinary colour irregularities in the biotite. Where a dark ring of one halo crosses a dark region in another, there is increase of darkening; but where one of the light inter-annular spaces of a halo crosses a dark region of another halo, there is diminution of darkening, so that the two haloes mutually interpenetrate. On account of the thinness of the sections, and the fact that both are in focus at the same time there is no reasonable doubt of their being in the same plane. Pl. II, Fig. 5, is a photograph of the same overlapping haloes, as in Pl. IV, Fig. 9, but magnified to 800 diameters.

Measurements of Haloes

As might be inferred from the clearness of some of the photographs, these haloes can be measured with considerable accuracy. A series of measurements was carried out on some of the more perfect ones, the results of which are given in the table below. The measurements were made with a Swift micrometer ocular and Swift $\frac{1}{4}$ inch objective. The milled head on the micrometer was divided into hundredths and with the optical system described, one of these divisions

¹J. Joly, Roy. Soc. Lond., Phil. Trans. A., *loc. cit.*

represented .00000639 cm. in the field of the microscope. It was found that on superimposing the cross hairs, the reading of the micrometer was constant within two or three of these divisions, so that the limitation of accuracy rested entirely with the clearness of definition of the rings in the halo. The method of measurement was that described by Joly, the halo being placed a little excentrically on the revolving stage, and by a slight rotation of the latter brought tangential to the fixed cross hair, the moving hair being then brought tangential to the opposite side. The calibration was effected by means of a Swift standard scale divided into tenths and hundredths of a millimetre, and the apparent linear magnification was about 225.

RADII OF RINGS OF HALOES IN μ

	r_0		r_1		r_2		r_3		R	
	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer
		11.9	13.6	15.1	16.7	18.2	—	21.9		—
		12.5	14.1	15.2	17.3	18.7	—	22.3		33.06
		12.3	—	15.3	17.1	18.7	—	21.8		32.99
		12.2	—	15.2	17.1	18.8	—	22.0		—
		12.2	—	15.3	16.9	18.3	—	—		—
		12.4	13.7	15.4	16.8	18.5	—	—		—
		12.6	14.4	15.7	17.3	19.0	—	—		—
		12.4	—	15.4	17.4	18.8	—	—		—
		12.4	14.2	15.5	17.3	18.7	20.9	22.1		32.99
Mean		12.3	14.0	15.4	17.1	18.6	20.9	22.0		33.0

Some of the haloes in more advanced stages, in which R was well darkened, showed a rather sharp inner boundary of R at about 24μ . The inner boundary of r_0 was not measured. This ring appears first as a narrow dark border to the inner disk, probably narrower than r_1 , and seems to darken inwards as the halo develops. It may be added that the measurements quoted in the table have been confirmed by numerous others on less perfect haloes, and the writer does not expect that subsequent measurements will appreciably change them.

In order to compare the distribution of colouring in the halo with the distribution of ionization, after the method of Joly, the curve in Fig. 7 is reproduced from one of his papers.¹ This gives the relation of ionization and distance from the source in the case of alpha particles from the uranium series decomposing in equilibrium, in air, for a narrow cone of rays. It has been assumed that the outer radius of R corresponds

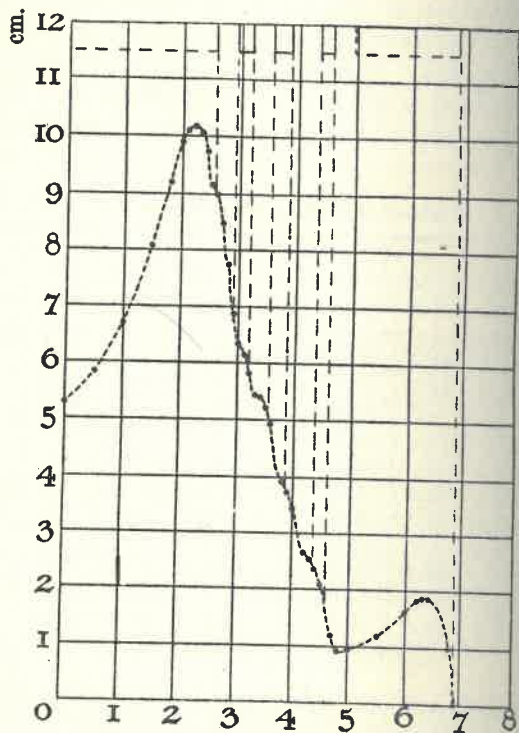


Fig. 7

to the outer limit of ionization from RaC , at 6.9 cm., and the other features of the halo have been plotted proportionately. It will be noted that the light region between r_3 and R , which is so persistent even in the later blackened stages, corresponds

¹J. Joly, Phil. Trans., *loc. cit.*

to the minimum of ionization at about 5 cm., and that the outer boundary of r_1 , which is the first sharp boundary to appear in the developing halo, corresponds to the minor sharp minimum at 3.3 cm. Evidently, then, the first appearance of the haloes in these sections is symmetrically disposed about the portion of the curve between 0 cm. and 3.3 cm., and while one might have expected some more sharply defined indication of this early stage of the maximum at 2.2 cm., yet there is nothing to indicate that the halo might have been formed under conditions of ionization requiring a difference in the

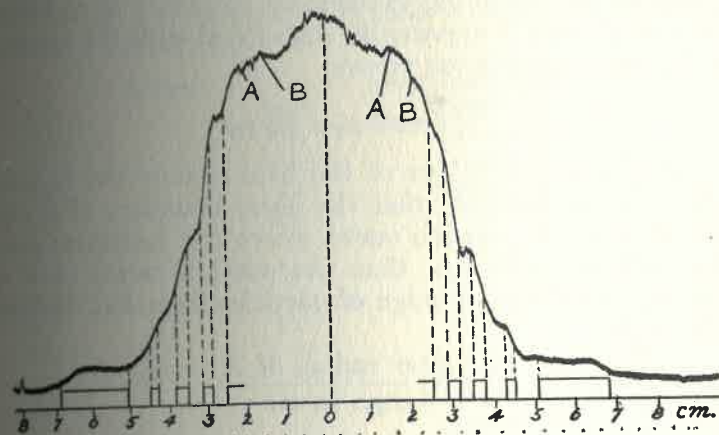


Fig. 8

horizontal arrangement of this portion of the curve. The outer boundary of r_0 is apparently to be attributed to the first perturbation on the downward slope of the curve, at about 2.6 cm.

An ingenious method of studying the colour density distribution in haloes is due to Professor J. C. McLennan, F.R.S., of the Department of Physics, University of Toronto, who suggested that the negatives of microphotographs of them could be examined in the microphotometer used for measuring the relative intensity of spectrum lines. Mr. H. J. C. Ireton, of the Department of Physics, kindly ran a

plate through the machine in Professor McLennan's laboratory and obtained the curve which is reproduced below (Fig. 8). This represents the light absorption along a diameter of the halo illustrated in Pl. IV, Fig. 5. The measured position of the rings, and a scale of the air dimensions, are plotted below the curve. From this trial, it looks as though interesting results might be obtained from the similar treatment of haloes in earlier stages of development.

The curve seems to suggest with respect to the inner disk in this late stage of development a small depression at the points A, corresponding to the inner boundary of r_0 , followed by a maximum B apparently associated with the maximum at 2.2 on the ionization curve.

Conversion Factor

In plotting the rings of the halo against the ionization curve, it was assumed that the outer boundary of R represented the point on the curve where the ionization due to RaC fell to zero—*e.g.*, that the outside radius of R was sensibly equal to the range of particles from RaC in biotite. The ratio

$$\frac{\text{Outer radius of } R}{\text{Range in air}}$$

then gives the distance in biotite corresponding to 1 cm. in air. Taking the outer radius of R as 33μ , and the range of RaC in air as 6.97cm^1 we find for this factor the value 0.000473. Now this may be calculated from the known constants for air or other media, if the chemical composition and density of the biotite are known, by the Bragg and Kleeman relation,² which may be expressed in a general way thus:

$$\frac{\text{Range in } A \times \text{density of } A}{\text{Range in } B \times \text{density of } B} = \frac{\sqrt{\text{At. wt. of } A}}{\sqrt{\text{At. wt. of } B}}$$

This may be extended to compounds and gaseous mixtures

¹G. Hevesy, and F. Paneth, Radioactivity, 1926, p. 22.
²W. H. Bragg, Studies in Radioactivity, 1912, Chap. 5.

containing atoms P, Q, R, \dots , and P', Q', R', \dots , if for the simple square root terms we substitute the following:²

$$\left(\frac{\text{Percent. of } P}{100} \times \sqrt{\text{at. wt. of } P} \right) + \left(\frac{\text{Percent. of } Q}{100} \times \sqrt{\text{at. wt. of } Q} \right) \dots \dots$$

$$\left(\frac{\text{Percent. of } P'}{100} \times \sqrt{\text{at. wt. of } P'} \right) + \left(\frac{\text{Percent. of } Q'}{100} \times \sqrt{\text{at. wt. of } Q'} \right) \dots \dots$$

In order to apply this relation to the biotite,¹ an analysis was made by H. C. Rickaby, and a density determination by the writer. The results of these are given here, together with the calculation of the conversion factor, first using the constants for air, and secondly, the constants for aluminium, as the basis of calculation.

Analysis	Mean Square Root	Produce
SiO ₂	34.12	4.4399
TiO ₂	1.35	4.9785
Al ₂ O ₃	20.02	4.4828
Fe ₂ O ₃	3.46	5.3879
FeO	20.51	5.7349
CaO	.29	5.1651
MgO	6.34	4.4657
MnO	.48	5.7057
K ₂ O	9.50	5.5020
Na ₂ O	.36	4.5305
Li ₂ O	.06	3.0899
H ₂ O	2.53	2.0013
F	1.15	4.3589
	100.17	480.92
Less oxygen equiv.	.48	4.0000
	99.69	479.00

The density was found to be 3.116.

Taking the density of air at 15°C, and 760 mm. as 0.00122, and the mean square root of its atomic weights as 3.762, the conversion factor is:

$$\frac{0.00122 \times 4.79}{3.116 \times 3.762} = 0.000498$$

¹J. Joly, and A. L. Fletcher, Phil. Mag., 1910, *loc. cit.*

Taking the density of aluminium as 2.7, its atomic weight as 27.1, and the range in it of α particles from RaC as 40.6μ ,¹ the conversion factor is therefore:

$$\frac{0.00406 \times 2.70 \times 4.79}{6.97 \times 3.116 \times 5.20} = 0.000465$$

Summarising, we have:

Range in Biotite corresponding to 1 cm. in air:

- (1) Calculated from Air constants = 0.000498
- (2) Observed from Air constants = 0.000473
- (3) Calculated from Al constants = 0.000465

As would be expected, the agreement between the observed result and that obtained from the aluminium constants, is much closer than that between the observed value and that from the air constants. From recently published figures for the range of RaC in metals,¹ it appears that the experimentally determined ranges in heavy atoms are somewhat lower than the corresponding results calculated from the air data and the density and atomic weight of the metal. If the stopping powers of the several atoms combined in the biotite molecule be not very different from the stopping power of the same atoms in the free state, and as the biotite molecule contains a considerable fraction of oxygen, fluorine, etc., it may not be altogether a coincidence that the conversion factor calculated from aluminium is a little lower, and that calculated from air considerably higher, than the observed conversion factor.

Influence of temperature on Haloes

It has long been known that heating tended to obliterate haloes, and such appears to be the case with those under discussion. The writer's experiments seem to indicate that a short exposure to a high temperature is as effective in destroying the halo as a much longer period at a lower tem-

¹G. Hevesy, and F. Paneth, *loc. cit.*

perature. Thus, five minutes at 700°C caused their disappearance, while about half an hour was required at 650°C. They are not destroyed by heating for twelve hours at 425°C, though at this temperature they disappear after twenty-four hours. The inference from this is that the rocks of the vicinity have not been raised to temperatures above 400°C within the time necessary to develop the haloes. This temperature corresponds, using the thermal gradient of 1°F. per 60 feet, to a depth of eight and one-half miles.

Summary

1. Pleochroic haloes occur in a biotite from near Murray Bay, P.Q., distributed along the major and minor cleavage planes in such a way as to suggest that the nuclei were formed after the crystallization and rupture of the mica.
2. This biotite can be cleaved into exceptionally thin sheets, so that the haloes have been viewed in much thinner sections than usual.
3. The haloes consist of shells of darkened mica, separated by lighter shells, in which there is an active lightening or bleaching action at work, which is capable of influencing a normally dark portion of an interfering halo.
4. The positions of the sharp boundaries in the halo do not materially change over a considerable range of development.
5. The first effect of the rays from RaC is to lighten the biotite.
6. The haloes do not seem to show, either in their early or later stages, any feature which might indicate that they were formed under different conditions of ionization from those which now prevail. With regard to their age, the pegmatite in which they occur cuts a Precambrian granite, and is probably of about the same age as the granite; but the indication of a later origin of the nuclei introduces a more uncertain factor.

7. The calculated conversion factors show fairly satisfactory agreement with the factor determined from observation, that based on air being higher, while that on aluminium is slightly lower.

8. Heating destroys the haloes, a short exposure to high temperatures being as effective as a longer exposure at a lower temperature.

In conclusion, the writer wishes to express his thanks to Dr. T. L. Walker, both for his aid on many occasions and for his continued interest in the progress of the work.

EXPLANATION OF PLATES

PLATE I

- Fig. 1—Microphotograph of central part of dyke shown in Fig. 3 ($\times 15$).
- Fig. 2—Microphotograph of contact between country rock and nepheline syenite as shown in Fig. 3. ($\times 15$).
- Fig. 3—Central dark portion, basic dyke, outer dark portion, country rock, light bands, nepheline syenite. ($\times \frac{3}{4}$).
- Fig. 4. Basic rock in which nepheline syenite and large orthoclase crystals have developed as a result of action of magmatic juices. ($\times 1/2$).

PLATE II

- Fig. 1.—Chalmersite from Raglan township, Ontario: cm, chalmersite; cp, chalcopyrite; dark grey, sphalerite; and black, gangue. ($\times 155$).
- Fig. 2.—Same as Fig. 1. ($\times 100$)
- Fig. 3.—Chalmersite from Sherritt claims. ($\times 100$).
- Fig. 4.—Arrangement of pleochroic haloes along lines in biotite from Murray Bay, P.Q. ($\times 11$).
- Fig. 5—Interference of haloes in biotite from Murray Bay, P.Q. ($\times 800$).

PLATE III

- Fig. 1.—Anorthite showing twinning in residual grains surrounded by granular aggregate. (crossed nicols).
- Fig. 2.—Cohenite from Ovifak etched with picric acid—white, cohenite; stippled grey, mixture of cohenite and iron; dark grey and black, gangue and cavities. ($\times 75$).
- Fig. 3.—Quartz-pegmatite vein showing molybdenite segregated along the border

PLATE IV

- Figs. 1-9—Pleochroic haloes, biotite, Murray Bay, P.Q.
Figs. 1-6 are arranged in order of development, 1 being the most primitive and 6 the most mature.
Figs. 7-9—Exhibit interference of haloes. ($\times 300$).

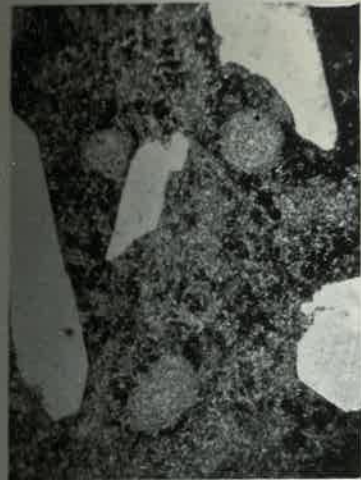


Fig. 1



Fig. 2

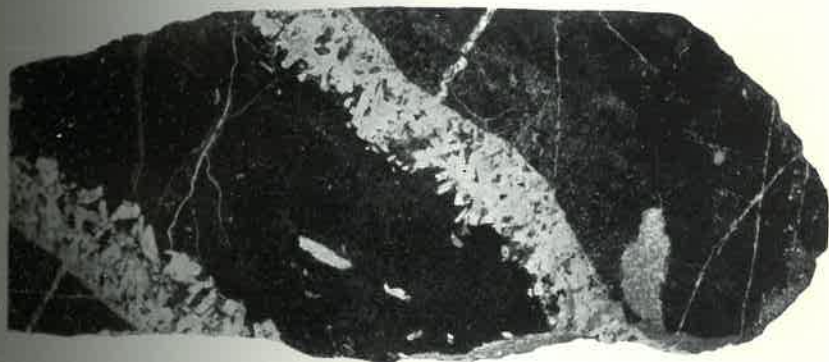


Fig. 3



Fig. 4

Fig. 1

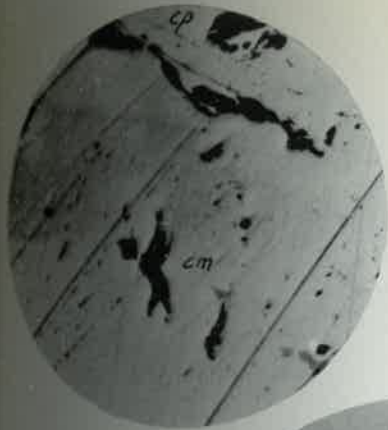


Fig. 2

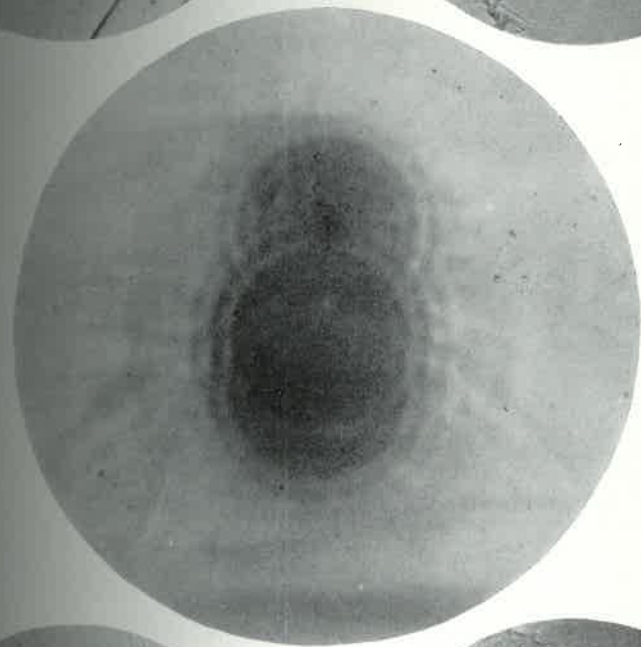
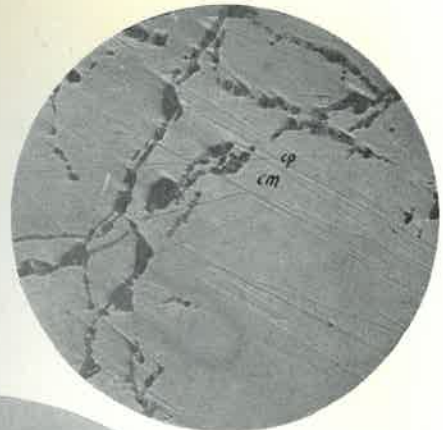


Fig. 3

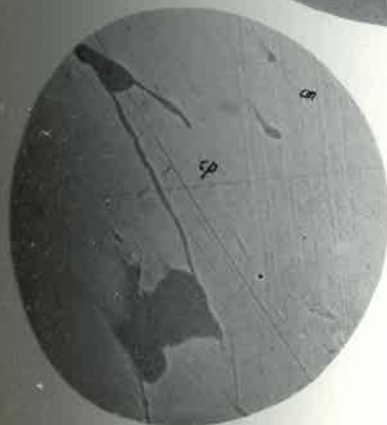


Fig. 5



Fig. 4

PLATE III



Fig. 1



Fig. 2

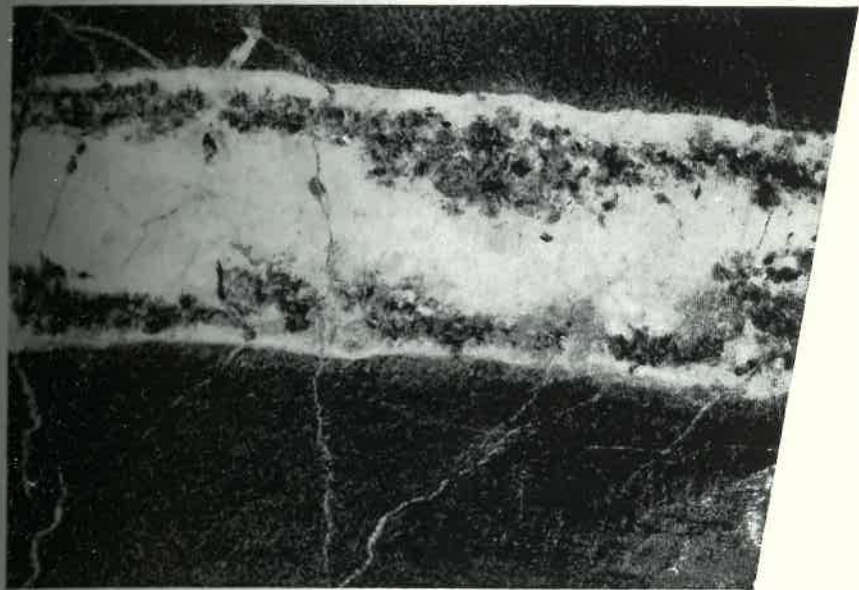


Fig. 3



Fig. 1



Fig. 2

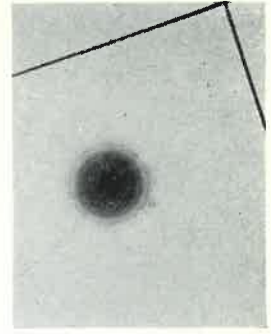


Fig. 3



Fig. 4



Fig. 5

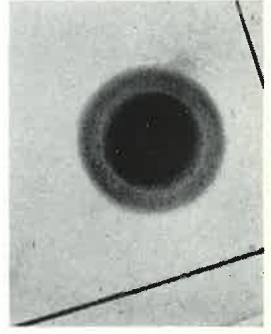


Fig. 6



Fig. 7



Fig. 8



Fig. 9