

CONTRIBUTION TO CANADIAN
MINERALOGY 1925

FROM THE

DEPARTMENT OF MINERALOGY AND PETROGRAPHY,
UNIVERSITY OF TORONTO

TABLE OF CONTENTS

	PAGE
EVANESCENT PINK SODALITE AND ASSOCIATED MINERALS FROM DUNGANNON TOWNSHIP, ONTARIO, by T. L. WALKER and A. L. PARSONS...	5
THE CHARACTERISTICS OF PRIMARY CALCITE, by T. L. WALKER and A. L. PARSONS.....	14
ZONAL PLEOCHROIC TWINNED PHLOGOPITE, by T. L. WALKER and A. L. PARSONS.....	18
AXINITE FROM THE MONETA MINE, TIMMINS, ONTARIO, by T. L. WALKER and A. L. PARSONS....	20
ANTOZONITE FROM MONTEAGLE TOWNSHIP, HASTINGS COUNTY, ONTARIO, by F. L. SINE.....	22
FETID FELDSPAR FROM LOUGHBORO TOWNSHIP, FRONTENAC COUNTY, ONTARIO, by F. L. SINE.	25
THE MINERAL ASSOCIATION OF THE WOLFRAMITE DEPOSITS AT BURNT HILL BROOK, YORK COUNTY, NEW BRUNSWICK, by W. L. SWANSON.....	28
ALBERTITE IN GYPSUM FROM HILLSBORO, NEW BRUNSWICK, by A. L. PARSONS.....	33
A RE-EXAMINATION OF KEWEENAWITE, by ELLIS THOMSON.....	35
PETZITE FROM THE HOLLINGER GOLD MINE, by T. L. WALKER and A. L. PARSONS.....	39
THE RATE OF OXIDATION OF ARSENIDES OF IRON, COBALT, AND NICKEL, by T. L. WALKER and A. L. PARSONS.....	41
ARSENIDES FROM THE SILVER VEINS OF SOUTH LORRAIN, ONTARIO, by T. L. WALKER.....	49

	PAGE
MINERALOGRAPHIC NOTES ON CERTAIN ARSENIDES AND SULPHARSENIDES OF COBALT, NICKEL, AND IRON, by ELLIS THOMSON.....	54
A COMPARISON OF THE PORT ARTHUR, COBALT, SOUTH LORRAIN, AND GOWGANDA SILVER - VEIN MINERALS, by T. L. WALKER and A. L. PARSONS.....	59
THE CRYSTALLOGRAPHY OF POTASSIUM FLUOZIRCONATE, by D. E. KERR-LAWSON.....	63
NEW LOCALITIES FOR CANADIAN MINERALS, by T. L. WALKER and A. L. PARSONS.....	68
EXPLANATION OF PLATES.....	72

EVANESCENT PINK SODALITE AND ASSOCIATED MINERALS FROM DUNGANNON TOWNSHIP, ONTARIO

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

Sodalite was described by Thomson in 1810, on material collected by Giesecke in Greenland during the Napoleonic wars and brought into Leith on a sailing ship which had been seized by the British Navy. The casks containing the collection were bought by Thomas Allan, a mineralogist of note at the time. His son Robert Allan, in his *Manual of Mineralogy*, issued in 1834, states that his father had noticed that "its colour is green unless freshly fractured, when it presents a brilliant pink tinge, but this on exposure to light goes off in a few hours." This property is not recorded in the original description of Thomson, neither does it seem to be emphasized in any of the text-books issued in later years. It seems as if mineralogists had regarded this record as not well founded.

In 1904, Vredenburg¹, in describing certain rocks containing sodalite and nepheline from Kishengarh State in Rajputana, refers to a peculiar sodalite as follows:—

While some of the specimens are of a bright blue colour, similar to that of the mineral from many other localities, others appear under ordinary conditions transparent and colourless. But some of these colourless fragments, when kept in the dark for a fortnight or three weeks, assume a pink colour which disappears rapidly on exposure to bright daylight, and almost instantaneously in direct sunshine.

The phenomenon is particularly brilliant when the rock is first broken in the field, and the large blocks of elaeolite (some of which are over a yard wide) appear, on fracture, as if suffused with blood. The colour seems to re-appear more completely in some specimens than in others, for while the

¹Vredenburg, E., *Rec. Geol. Survey of India*, Vol. 31, 1904, p. 43.

disappearance of the colour is very rapid, its re-appearance, which constitutes the most remarkable feature of the change, is very slow. The precise nature and cause of this peculiar phenomenon are at present unknown.

In 1901, Borgström¹ described a new mineral belonging to the sodalite group which he called hackmanite. It differed from sodalite in containing .39 per cent. of sulphur which replaced part of the chlorine in sodalite. The new mineral was found in nepheline rocks from Kola Peninsula. It was reported to be bright red-violet in colour and to bleach rapidly in daylight.

In the summer of 1924, the writers discovered in Duggan township near Bancroft, Ontario, a sodalite which possesses the same property. On freshly-broken surfaces of the rock containing nepheline, cancrinite, calcite, and a very little plagioclase, one frequently observes spots of a fine pink colour, which for the most part disappears completely in direct sunshine in from ten to thirty seconds. When placed in the dark the colour gradually returns, but according to our observation it never becomes as bright as at first, even after being protected from light for one week.

In thin sections it is found that the pink areas coincide with the distribution of areas of an isotropic mineral of very low refraction.

Examination of fragments of pink mineral in index liquids shows that the isotropic mineral has an index of refraction in accord with that of sodalite.

This sodalite-bearing nepheline rock occurs in tongues which are in immediate contact with impure crystalline limestone, sometimes showing a great development of very fine essonite crystals, green crystals of diopside, and green-brown well-formed crystals of vesuvianite.

The sample for analysis was purified by bromoform and carbon tetrachloride. The analysis by H. C. Rickaby follows:

¹Borgström, L. H., *Geol. För. Förh.*, Vol. 23, 1901, p. 563.

		Cancrinite	
SiO ₂	37.08	.618	.032
Al ₂ O ₃	32.58	.319	.016
CaO.....	.50	.009	.009
MgO.....	.03	.001	
MnO.....	Trace		
Na ₂ O.....	22.26	.359	.024
K ₂ O.....	.53	.005	
H ₂ O.....	.67	.038	
CO ₂.....	.32	.007	.007
Cl.....	6.82	.192	
			.192 ÷ 2 = .096
		100.79	
Less Ox.			
Equiv....	1.53		
Total.....	99.26		

The specific gravity of the pure mineral is 2.30; and the prepared sample when weighed in the pycnometer gave a value of 2.33.

An examination with the microscope showed that the separation was not complete, and that the impurity was cancrinite. For this reason, in recalculating the analysis, sufficient cancrinite is deducted to use up the carbon dioxide and lime. The residue gives the formula $3\text{Na}_2\text{O} \cdot 3\text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \cdot 2\text{NaCl}$, which is in agreement with the accepted formula for sodalite, but unlike the hackmanite of Borgström, as it contains no sulphur. In specific gravity it agrees with sodalite and is exactly one less than the value given for hackmanite. Nothing of a fundamental nature has as yet been determined in regard to the colour change, except that it is due to some part of the visible spectrum. Exposure to X-rays fails to bring about the change in colour.

It seems probable that the pink sodalite from Greenland, Kishengarh, Kola, and Bancroft are all closely related, and that they should be regarded as sodalite unless it be agreed that the mineral of Borgström should be regarded as a

different species on account of the difference in specific gravity and sulphur content.

Nephelite

Associated with the pink sodalite is a glassy white nephelite, which on a fresh break resembles white feldspar, but on the weathered surface is slightly grey and is more deeply corroded than any feldspar that may accompany it. The mineral is uniaxial, negative, with $\omega = 1.540$ and $\epsilon = 1.538$.

A sample was prepared for analysis by separation in bromoform and carbon tetrachloride, afterwards drying at 20° C. An analysis by H. C. Rickaby follows:

			Cancrinite	Nepheline
SiO ₂ ...	41.80		.696	.024
Al ₂ O ₃ ...	35.48		.348	.012
CaO...	.63	.011		
MgO...	.13	.003		
H ₂ O...	.42	.023	.339	.024
K ₂ O...	6.28	.067		
Na ₂ O...	14.59	.235		
CO ₂...	.28	.006	.006	
<hr/>				
Total..	99.61			
S.G....	2.664			

A striking feature of the analysis is the perfect 1:2 ratio between the alumina and silica, which has never been shown in any analysis of nephelite. There is a slight deficiency in the alkalis, which is emphasized by deducting cancrinite to correspond to the carbon dioxide and thus throwing the maximum error into the nephelite residue. The perfect ratio between the alumina and silica removes a difficulty that has heretofore confronted those who have analysed nephelite, so that we can now assign definitely a formula that corresponds with that of the artificially prepared nephelite which may be written (K,Na)AlSiO₄.

In our material we were fortunate that the impurity was another orthosilicate-carbonate instead of albite, which has been recognized in some of the earlier work. The high ratio of silica to alumina in all analyses hitherto published would seem to indicate that in no case was there pure material for analysis. Foote and Bradley¹ show an average ratio of R₂O:Al₂O₃:SiO₂=1:1:2.21 and suggest a solid solution of nepheline with albite or silica. In the sample analysed by them a small quantity of albite was recognized under the microscope. In our material a minute quantity of cancrinite was recognized under the microscope, and the analysis shows about 4.5 per cent. of this mineral. The calculation of the percentage of albite in the material analysed by Foote and Bradley shows 10.1 per cent. It would appear that our material is the purest nephelite that has been analysed up to the present time.

Vesuvianite

Immediately below the layer of pink sodalite is from four to six inches of a pyroxenic band, with which is associated vesuvianite.

The vesuvianite is in tabular crystals with a maximum thickness of eight millimeters and a width of about twenty millimeters. The forms present are *c*(001), *u*(201), *e*(101), *a*(100), *m*(110), *f*(210), and *h*(310) (Dana letters). The dominant form is the base with about an equal development of the prisms of the first and second order. The pyramids and ditetragonal prisms are of only small size. It was observed that some of the broken crystals showed a zonal development, the inner portion being grey and the outer part a deep brown. A section cut parallel to the vertical axis showed parallel extinction throughout.

By the immersion method the general refractive index was determined as 1.730.

¹*Am. J. Sc.*, Ser. 4, Vol. 31, pp. 25-32.

In preparing the sample for analysis no separation was feasible for the inner and outer portions. The analysis by H. C. Rickaby follows:

SiO ₂ ...	35.76	.596	}	.646	.646
TiO ₂ ...	4.11	.050			
Al ₂ O ₃ ...	17.56	.172	}	.564	.188 × 3
Fe ₂ O ₃ ...	2.64	.016			
FeO....	2.05	.029	}	.012	1.284
CaO....	34.34	.613			
MgO...	1.50	.037	}	.732	
MnO...	.13	.002			
Na ₂ O...	.89	.014	}		
K ₂ O....	.45	.005			
H ₂ O....	.58	.032	}	.024	.024
F.....	.47	.024			
	100.48				
Oxygen					
Equi. of					
F.....	.20				
Total...	100.28				
S.G....	3.337				

The unusual feature of the analysis is the high percentage of titanium dioxide, which is all the more remarkable when it is noted that no appreciable amount of titanium is present in any of the associated minerals. This yields an almost perfect orthosilicate formula.

Essonite

A few feet north of the sodalite outcrop a horizontal band of rock was found which contained numerous crystals of garnet. Few of the crystals were perfect, but for colour and size they are quite remarkable, being of a deep cinnamon red and in the largest crystal measuring nine centimeters

between opposite dodecahedral faces. The only crystal form observed was the rhombic dodecahedron. The crystals were embedded in slightly bluish crystalline calcite and white cancrinite. By the immersion method the index of refraction was found to be greater than 1.74.

The analysis by H. C. Rickaby follows:

			Limonite	Essonite
SiO ₂ ...	38.78	.646	}	.649
TiO ₂...	.31	.003		
Al ₂ O ₃ ...	20.98	.206	}	.216
Fe ₂ O ₃ ...	2.94	.018		
FeO....	1.33	.018	}	.649
CaO....	33.84	.604		
MgO...	.62	.015	}	.649
MnO...	.62	.005		
Na ₂ O...	.40	.005	}	
K ₂ O...	.34	.002		
H ₂ O...	.20	.011		.011
Total...	99.94			
S.G....	3.596			

This is a normal essonite.

Cancrinite

While investigating the essonite and sodalite, a white massive mineral which effervesced in hydrochloric acid was observed. This, when examined in the index liquids, was found to correspond with cancrinite. The mineral is uniaxial, negative, with $\omega = 1.524$ and $\epsilon = 1.496$. It was found in thin section to be intimately associated with nepheline, sodalite, garnet, calcite, and plagioclase, and was particularly well-developed as an outer zone sometimes half an inch thick surrounding the masses containing the pink sodalite.

An analysis by H. C. Rickaby follows:

SiO ₂	35.68	.595	
Al ₂ O ₃	30.44	.298	
CaO.....	8.24	.147	} .149
MgO.....	.08	.002	
Na ₂ O.....	15.69	.255	} .444
K ₂ O.....	.78	.008	
H ₂ O.....	3.27	.181	
CO ₂	6.07	.138	
Total.....	100.25		
S.G.....	2.482		

From this the formula $\text{CaO} \cdot 3\text{R}_2\text{O} \cdot 2\text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot \text{CO}_2$ is derived, which corresponds to an orthosilicate in which part of the silicon is replaced by carbon.

Inasmuch as the proportions of the various bases differ materially from the standard compositions as given in Dana and Hintze, the molecular ratios of all the analyses in Hintze that were of a suitable character were calculated, those being neglected in which the alkalis were entirely out of the ordinary range. If we combine the CO₂ with the SiO₂, and H₂O with the alkalis, these appear to be uniformly orthosilicates in which the molecular ratio of carbon dioxide is about one-fourth of that of the silica as is the case with our material. There is considerable variation in the alumina-silica ratio, but in the better analyses it is 1:2, so that the formula can be written $4(\text{RO}, \text{R}_2\text{O}) \cdot 2\text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot \text{CO}_2$ or $2(\text{RO}, \text{R}_2\text{O}) \cdot 2\text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot 2(\text{RO}, \text{R}_2\text{O}) \cdot \text{CO}_2$, which embraces Clarke's¹ suggestion that the carbon is present as ortho-carbonic acid and provides for the higher percentage of lime in the cancrinite from Dungannon.

Diopside

Intimately associated with the vesuvianite and constituting the major part of a band which is about four inches thick is a pale green diopside. No measurable crystals were

¹*Am. J. Ser. 4, Vol. 31, p. 269.*

observed, and nothing unusual was observed in the optical character.

An analysis by H. C. Rickaby of material dried at 20° C. follows:

			Augite	Diopside
SiO ₂	54.15	.902	.008	.894
Al ₂ O ₃....	.50	.005		
Fe ₂ O ₃....	.57	.003	.008	
FeO.....	4.01	.056		
MnO.....	.11	.002		
CaO.....	24.56	.438		
MgO....	15.95	.399	.906	.008
Na ₂ O....	.46	.008		.898
K ₂ O....	.28	.003		
Total....	100.59			
S.G.....	3.278			

This is a normal diopside.

THE CHARACTERISTICS OF PRIMARY CALCITE

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

At frequent intervals mention has been made by various observers of calcite which in their opinion was an original constituent of igneous rocks, but no satisfactory criterion for the recognition of igneous calcite has been established. During the past summer the writers collected from three localities calcite which in their opinion is of the high temperature type. The first was a crystalline limestone immediately in contact with a pegmatite near Perth, Ontario; the second a coarse-grained crystalline calcite in a calcite-apatite vein-dyke on Turner's Island, Lake Clear, Renfrew county, Ontario; while the third was a crystalline calcite in a feldspar quarry near Hybla, Hastings county, Ontario. In all three cases the calcite was characterized by a cleavage or parting parallel to $e(01\bar{1}2)$ which is emphasized by weathering and frequently results in well-defined rhombohedra (Pl. I, Figs. 1-4). The material from Lake Clear offered the best opportunity for study on account of the size of these rhombohedra. The separation was parallel to $e(01\bar{1}2)$ although the cleavage fragments occasionally showed traces of the cleavage parallel to $r(10\bar{1}1)$. With care a few specimens were trimmed so as to show the ordinary cleavage (Pl. I, Fig. 4).

In the vein as a whole the observed minerals are calcite, apatite, augite, scapolite, and titanite, the last four of which are common constituents of high temperature rocks, while calcite has been formed artificially from fusions. The material for study came from a large lenticular mass of calcite which contained numerous phenocrysts of apatite and occasionally of augite completely enclosed in calcite. A remarkable feature of the vein is the complete absence of quartz and feldspars.

The mineral exhibits a striking pearly lustre on the cleavage $e(01\bar{1}2)$ in contrast to the vitreous lustre commonly shown. Thin sections cut parallel to $e(01\bar{1}2)$ the common

cleavage face in our material and parallel to the base were examined with the microscope. In both these sections the mineral appears to be biaxial with $2E$ about 15° , and the trace of the optic plane parallel to a trace of the cleavage $r(10\bar{1}1)$. The calcite is also unusual in that it does not exhibit complete extinction, possibly due to some molecular disturbance. The trace of the cleavage $e(01\bar{1}2)$ is marked by narrow bands which do not appear to be twin lamellae, but rather to represent a confused aggregation of carbonate. This molecular irregularity, the apparent biaxial character, and the perfect development of an unusual cleavage parallel to $e(01\bar{1}2)$ may all be ascribed to the molecular re-arrangement which marks the inversion from a calcite at 970° .

An analysis by H. C. Rickaby follows:

CO ₂	43.68		.993
FeO.....	.72	.010	.999
MnO.....	.28	.004	
MgO.....	.22	.005	
CaO.....	54.88	.980	
H ₂ O.....	.25	.014	
Total.....	100.03		
S.G.....	2.70		

This appears to be a normal calcite with no component that would be expected to affect the optical properties.

In some of the feldspar pegmatites near Hybla, Ontario, the main part of the feldspar crystallized before the calcite which forms subordinate masses as shown in the quarry walls. The calcite exhibits the same type of cleavage as has just been described from the apatite-calcite vein-dykes on Turner's Island.

We have in this type of calcite a ready means of indicating that certain igneous and metamorphic rocks have crystallized above 970° , and thus have another point on the geologic thermometer.

Boeke¹ determined that calcite melts at 1289° C. under a pressure of not less than 110 atmospheres. He also showed that at 1218° C. there was a eutectic of CaCO₃ and CaO. At a temperature of 970° ± 5° C. he found a reversible transition from calcite to *a* calcite which is the stable form from 970° up to the point of fusion. In the cooled melts of CaCO₃ which contained 7.83 per cent. CaO, he also showed the development of a trigonal skeleton.

Smyth and Adams² found that the melting point of calcium carbonate containing 0.38 per cent. CaO is 1389° C. at a pressure of 779,000 mm. They also found a eutectic of CaCO₃ and CaO at 1240° ± 1° and 30,000 mm ± 300 mm, the composition of which was judged to be about 50 per cent. CaCO₃ and 50 per cent. CaO. They were, however, unable to find any evidence, from the thermo-dynamic behaviour, of the inversion from calcite to *a* calcite at 970°, calling attention to the fact that Iceland spar that had been repeatedly heated above this point failed to show any signs of twinning or shattering such as might be expected from the analogous case of *a* quartz and *β* quartz.

Fersmann³, who apparently was unaware of the work of Smyth and Adams, found casts of trigonal skeletons in contact rocks in the Kola Peninsula and has given the name *elatolite* to the high temperature carbonate of lime.

Our material exhibits an optical disturbance and shattering, a distinct tendency to cleave and dissolve along the planes of the rhombohedron *e*(011̄2), a separation which has not been observed by us in ordinary calcite, but only in calcite associated with high temperature rocks. We believe that we have in this separation and in the optical anomalies a ready means of distinguishing igneous calcite.

We conclude that the carbonate here described has originated from the inversion of *a* calcite which was formed from igneous fusion at temperatures above 970°. The

¹Boeke, H. E., *N.J. Min.*, 1912, 1, pp. 91-121.

²Smyth, F. H. and Adams, L. H., *Jour. Am. Chem. Soc.*, Vol. XLV, pp. 1167-1184.

³Fersmann, A. E., *Bull. Acad. Sci. Russ.*, 1923, pp. 251-273.

peculiar cleavage and anomalous optical behaviour are due to the shrinkage and molecular re-arrangement on cooling below the inversion temperature. The apatite-calcite vein-dykes thus appear to be definitely of igneous origin. It is a matter of great interest to have criteria, which can be readily applied, to enable us to indicate whether or not certain igneous rocks formed above or below the inversion temperature 970°. If our conclusions are correct, these observations provide a new point on the geological thermometer.

ZONAL PLEOCHROIC TWINNED PHLOGOPITE

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

During the summer of 1924 the Royal Ontario Museum of Mineralogy secured samples of phlogopite which are of such unusual character as to merit a description of at least the more outstanding features. These micas were from three mines: one on lot 10, concession XI, Bedford township, Ontario; one on lot 27, concession XI, Bedford township; and the third on lot 13, concession XII, Loughboro township, Ontario.

On holding moderately thick cleavage plates to the light, it was observed that there was a marked zonal arrangement in all cases. The phlogopite from Bedford exhibited a rounded central nucleus (Pl. II, Fig. 1), while that from Loughboro usually showed the zones arranged parallel to the crystal faces of the prism zone (Pl. II, Figs. 2 and 3).

When these cleavage plates were inclined to the source of light it was found that the phlogopite from Loughboro township and from lot 10, concession XI, Bedford, was twinned according to the mica law and was markedly pleochroic, showing as reddish amber and yellowish amber. When viewed along a line at right angles to the cleavage no sign of twinning was observed. When examined under the microscope it was found to be biaxial with $2E$ from 18° - 20° .

In order to show the twinning and zonal growth photographs were taken using transmitted polarized light by introducing a large nicol between the mica and the camera lens so that the vibration direction of the nicol was parallel to the extinction direction of one of the twinned individuals, and would thus show the greatest contrast in colour in the different parts of the crystal. Both the zonal structure and the twinning are in this manner well shown.

A peculiar feature is exhibited in the dark area in Plate II, Figure 3, for while the rest of the crystal shows a pleochroism varying from red amber to yellow amber, this portion shows

pleochroism from deep red amber to red amber and has the same optical orientation as the material which makes up the greater part of the crystal. This crystal is also remarkable in the curved boundary between the twinned individuals.

For several years a plate of similar mica from the Lacey mine near Sydenham, Ontario, has been mounted in the Royal Ontario Museum of Mineralogy so as to illustrate twinning and pleochroism, the proper directions for observing the phenomena being indicated by pointers.

The material from lot 27, concession XI, Bedford township, shows no twinning, but exhibits the zonal development in an even more striking manner than the material described above. This is shown in the accompanying illustration (Pl. II, Fig. 4), which is taken from a contact print made directly from the mica.

Heretofore it has been rather difficult to secure good material for exhibiting zonal development except by sawing and polishing sections of crystals showing a zonal growth. The twinned crystals yield material that is superior to all other minerals for demonstrating pleochroism, as the two colours are shown side by side without the use of a dichroscope.

AXINITE FROM THE MONETA MINE, TIMMINS,
ONTARIO

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

Recently a small lot of axinite was obtained from the Moneta gold mine, Timmins, Ontario, by the Royal Ontario Museum of Mineralogy. The mineral is light drab in colour, and is distributed in vein quartz and sometimes in calcite. No crystals suitable for measurement were observed. An analysis by E. W. Todd gave the following result:

SiO ₂	42.34	.705				
Al ₂ O ₃	19.68	.193	} .205 × 3		÷ 1 = .705	
Fe ₂ O ₃	1.90	.012				
FeO.....	5.28	.074				
MnO.....	3.38	.048	} .583 × 1	} 1420 ÷ 2 = 710		
CaO.....	20.27	.362				
MgO.....	1.24	.031				
H ₂ O.....	1.23	.068				
B ₂ O ₃	5.16	.074			.074 × 3	
	100.48					
S.G.....	3.274					

In a previous article¹ the valence of alumina and ferric oxide was wrongly calculated by the writers as equivalent to one and one-half times the valence of RO and an erroneous formula was thereby deduced. For the present analysis and the average of the analyses in Hintze by multiplying the R₂O₃ by three and combining with the RO and R₂O we get a perfect orthosilicate ratio. The analysis of the material from Marmora township is, however, high in bases and does not yield a simple formula.

The particular interest in this occurrence is connected with the genesis of the auriferous veins, for axinite and other

borosilicates are looked upon as minerals of the pneumatolytic stage in the cooling of large masses of igneous rock. Another feature of interest is the large amount of calcite present. In addition, there is a low iron epidote which has recently been described¹ by Bruce and Greenland.

¹Univ. of Tor. Studies, Geol. Ser. 16, p. 32.

¹Am. Min., Vol. IX, p. 199.

ANTOZONITE FROM MONTEAGLE TOWNSHIP,
HASTINGS COUNTY, ONTARIO

By F. L. SINE

In the summer of 1924 the writer collected at the McDonald feldspar quarry, lot 18, concession VII, Monteagle township, samples of a dark blue fluorite which occurs somewhat sparingly in the pegmatite dike. This fluorite is characterized by a strong odour suggestive of ozone when crushed, a loss of the blue colour on heating, and a lack of the power to phosphoresce. During the crushing of the mineral a gas is evolved, and oxidation of any readily oxidizable substance which may be present takes place. The liberation of the gas may be readily seen by immersing a fragment of the mineral in a liquid and crushing it in the field of a low-power objective. Ordinary fluorite does not free a gas during crushing.

A fluorite, evidently similar to this, was described in 1861 by Schönbein¹, who obtained it from Wölsendorf in Bavaria, where it had the reputation of causing headache and vomiting among the miners. Schönbein believed that the strong odour observed on breaking the mineral was due to "antozone", and he therefore named this variety of fluorite "antozonite". In 1891, Becquerel and Moisson studied a similar mineral from Quincie² and concluded, after a number of delicate chemical tests, that the mineral contained an occluded gas which was liberated during the crushing, and that the occluded gas contained fluorine, which produced ozone on coming in contact with water.

The dark blue fluorite of Monteagle is associated with ellsworthite, quartz, zircon, and calcite. The zircon crystallized before the fluorite and ellsworthite, occurring in both of the latter as well-developed crystals and also contains

fluorite in corrosion cavities. The quartz also is of an earlier crystallization than the fluorite, and sends jagged intrusions into it in places. The ellsworthite has invaded both the quartz and the fluorite, in both of which it fills fractures radiating from itself. It also encloses numerous small fragments of the fluorite. An interesting feature is the penetration of the microscopic fractures of the fluorite by the ellsworthite. The boundary between the fluorite and the calcite is, in most cases, so sharp and unbroken that the order of crystallization is difficult to determine, but the calcite fills some cracks in the margin of the fluorite and also surrounds some tongues of it, showing, in certain cases, different orientation on opposite sides of the tongues. It is noticeable that the ellsworthite does not invade the calcite. The order of crystallization appears to be zircon, quartz, fluorite, ellsworthite, and calcite (Pl. I, Fig. 5). The thin section, in addition to giving information as to the order of crystallization, shows that the fluorite, which is for the most part nearly opaque, appears to have recrystallized about fractures, becoming transparent and showing the cubic type of crystallization.

When this fluorite was ground in an aqueous solution of potassium iodide, iodine was liberated and detected both by the starch test and by carbon bisulphide. To make certain that the gas was evolved from the dark fluorite and not from admixed ellsworthite, a blank test was run on pure ellsworthite with negative results. In like manner the transparent fluorites of the district were tested with negative results.

In order to determine the percentage of gas that was evolved by grinding the fluorite, a weighed quantity of the mineral was finely ground in a known volume of oxalic acid solution, which was then titrated against standard potassium permanganate and compared with a blank test on a like volume of oxalic acid solution. It was found that one gram of fluorite gave off 0.000186 grams of oxygen or 0.000442 grams of fluorine in the grinding. Similarly one gram of mineral when ground in a solution of ferrous ammonium sulphate yielded 0.000197 grams of oxygen or 0.000469 grams of fluorine.

¹*Jahrbuch pr. Ch.*, Vol. 83, p. 95, 1861.

²*Bull. de la Soc. Chim.*, Vol. 5, p. 154, 1891.

The mean of these results is equivalent to 4.55 parts of free fluorine by weight in 10,000 parts of the mineral. This appears small, but if expressed in volumes, the amount of fluorine appears large. Thus ten volumes of the mineral contain about eight volumes of fluorine. This can only be brought to a reasonable ratio by assuming that the fluorine is in a condensed state, such as a liquid. Perhaps this may give an explanation of the fact that some pieces of the fluorite decrepitate readily when heated. This appears an interesting case of the imprisonment of one or more of the mineralizers which are so often referred to in connection with the coarse crystallization of pegmatite dikes.

FETID FELDSPAR FROM LOUGHBORO TOWNSHIP, FRONTENAC COUNTY, ONTARIO

By F. L. SINE

On lot 3, concession XI, of the township of Loughboro in the county of Frontenac, occurs a feldspar which is rather unusual in that it emits a peculiar odour when broken. It is a handsome white spar, occasionally somewhat bluish in tint. A small amount of the spar was quarried for the production of stucco dash, the crushing having been carried out at a mill situated one half mile to the westward of the quarry.

Its nauseating odour when broken can best be compared to that of rotting cabbage, or to that produced when selenium is burned in blowpipe practice. To establish the nature of the odour many tests were tried, but only two gave positive results. The water in which the mineral is ground, when acidified with hydrochloric acid, gives a dark stain to bright copper, while the gases rising from the crushed mineral darken a filter paper which has been moistened by lead acetate solution. These two results would be obtained by the action of either hydrogen selenide or hydrogen sulphide. Since the odour of the crushed mineral suggests the former it seems reasonable to conclude that the reactions are due to the former gas and that the mineral contains selenium.

Fetid feldspar has been mentioned before. De Schmid¹ reported a strong odour in the bluish-white feldspar of North Burgess V-13, and attributed it to the presence of hydrogen sulphide. The writer examined this deposit and confirmed the observation.

The quartzite at the roadside in Loughboro X-1 was found to emit, when broken, an odour similar to that of the Loughboro spar, though of a milder type. It is rather remark-

¹De Schmid, H. S., *Canada, Mines Branch*, No. 401.

able that, while the country rock of the Loughboro white feldspar is also a Grenville quartzite, situated some two miles from that characterized by the fetid odour, it does not possess the odour.

The minerals associated with the feldspar are quartz, diopside, titanite, and pyrite. The individual crystals of feldspar are not large and usually do not exceed two inches in diameter. The diopside, where fresh, or where surrounded by quartz or feldspar, is of pale green colour. The crystals are of the square prismatic type, formed by the pinacoids (100) and (010) with the unit prism (110). Basal cleavage is prominent and results in easy rupture of the crystals, which usually do not exceed one half inch in diameter. Scattered quite thickly through the diopside aggregates, and less abundantly through the quartz and feldspar, are seal-brown titanite crystals reaching one and a half inches in their greatest dimension. They have the usual habit of sphene as found in Eastern Ontario. The cleavage on $m(110)$ is perfect. The faces are lustrous, but pitted. Pyrite, which appears as small crystals not exceeding one-eighth of an inch in diameter, occurs chiefly in the quartz and diopside, which it stains on weathering.

In a thin section the feldspar is seen to be microcline showing, in part, a micropertthitic intergrowth of an exceptional structure (Plate III, Fig. 3). The plagioclase, while maintaining roughly the alignment parallel to the macro-pinacoid, lacks the regular vein-like arrangement observed in the majority of the hypoperthites. The plagioclase bodies are more or less equidimensional. The exact parallelism of orientation is maintained, however, and the albite twinning of the two members coincides as in other micropertthites. The thin section shows that the feldspar, chiefly the microcline near its junction with the plagioclase, appears rough and cloudy due to alteration or inclusions or both.

An analysis by W. K. McNeill, Provincial Assayer, gave the following results:

	Per cent.
Silica	65.72
Alumina	18.98
Ferric Oxide.....	.63
Lime.....	.62
Soda.....	3.68
Potash.....	9.61
Water.....	.14
Carbon Dioxide.....	.53
	<hr/>
Total.....	99.91

From the above it is evident that the plagioclase is albite. Many feldspars containing no more iron than is shown in this analysis are reddish in colour owing to the presence of hematite. In the present case, the colourless character of the mineral suggests that here the iron is probably combined as part of one of the feldspars.

THE MINERAL ASSOCIATION OF THE
WOLFRAMITE DEPOSITS AT BURNT HILL
BROOK, YORK COUNTY, NEW BRUNSWICK

By W. L. SWANSON

While engaged, in September, 1910, in an examination of the molybdenite deposits at the confluence of the S. W. Miramichi and Burnt Hill brook, in York county, New Brunswick (Long. 66° 48' W., Lat. 46° 34' N.), Dr. T. L. Walker incidentally discovered the presence of wolframite, which was later found to be in economic quantity, and collected the material for the present study. It had been known for many years that small quantities of molybdenite occurred there, and, later, when topaz was found associated with molybdenite and wolframite, these deposits assumed a peculiar interest because of their similarity to some of the well-known tin deposits.

The geology of the area which contains the wolframite deposits is simple, as shown by the investigations of Walker,¹ Brock,² and Camsell.³ The country rock, which is slate of Cambro-Silurian age, according to Bailey and Ells,⁴ has been intruded by large granite batholiths which have caused it to become greatly fissured and metamorphosed. The zone of the sedimentaries showing the most extreme metamorphism forms a border roughly about a half-mile in width along the contact with the granite intrusive. The slate, in this highly metamorphosed area, is rather massive in character and does not exhibit, so well, the slaty cleavage and black colour shown in the slate further removed from the granite contact. The slate, in the metamorphosed zone, has been considerably fissured, and these fissures have been filled by quartz derived

¹Walker, T. L., *Economic Geology*, 1911, Vol. 6, pp. 396-398.

²Brock, R. W., *Summary Report, Geological Survey of Canada*, 1911, pp. 13-15.

³Camsell, Charles, *Summary Report, Geological Survey of Canada*, 1915, pp. 247-249.

⁴Brock, R. W., *Summary Report, Geological Survey of Canada*, 1911, p. 14.

evidently from the granite. These quartz veins are quite numerous and vary in width from a few inches to two feet or more. Some of these quartz veins are said by Brock to be bordered by greisen. The quartz which bears the wolframite is milky and vitreous in appearance, and occurs both massive and crystallized. When crystallized the quartz occurs commonly in vugs and druses. The wolframite occurs in the quartz veins along with topaz, as a rule, and is in the form of large crystals scattered irregularly through the veins. It is usually more or less segregated into bunches of crystals, which are commonly near the centre or along the borders of the vein.

From hand specimens of the granite, of the slate which formed the country rock, and of the vein material which bore the wolframite, the writer undertook to determine the mineral association of the ore by means of petrographic, mineralogical, and chemical investigations.

PETROGRAPHY

Granite

The microscopic examination of the intrusive granite showed that the essential minerals are quartz, orthoclase, muscovite, and biotite, while the accessory minerals are magnetite, apatite, and plagioclase. Chlorite is secondary after biotite, and kaolin after both orthoclase and plagioclase. Macroscopically it approaches a granite porphyry in appearance. Large phenocrysts of orthoclase and quartz were plainly evident, which inclines one to the belief that the granite magma had been at a quite high temperature when it intruded the slate, and subsequent to the intrusion it had cooled slowly.

Unaltered Slate

Under the microscope the main mass of the rock appeared to be formed of kaolin of a dirty brown colour, due probably to discolouration from iron oxide and carbonaceous material. Long thread-like structures were all arranged parallel to each

other showing that the slate had been subjected to considerable pressure. They were probably formed from a mixture of clayey and carbonaceous material. A considerable amount of quartz, in the form of small grains, was seen to be scattered about in the section. A few shreds of muscovite were observed, as also were a few grains of pyrite.

Partially Altered or Spotted Slate

Microscopic examination showed that near the unaltered slate the spotted slate consists of quartz, much muscovite, a few grains of magnetite with dark spots which represent the original shale or slate containing carbonaceous material. Sections at a greater distance from the unaltered slate show cordierite, orthoclase, biotite, and muscovite.

Highly Altered Slate

Under the microscope the minerals in the highly altered slate were found to be quartz, biotite, muscovite, magnetite, and a ground mass of uncertain identity. Granitic, granular, and pavement structure characterized different slides. Quartz was in every case the most abundant mineral.

Vein Material

Five sections were examined and showed topaz, quartz, muscovite, magnetite, and secondary limonite. In two of these sections topaz was the predominant mineral; in the other three quartz was the most prominent, though topaz was found in all. In the hand specimens topaz, quartz, muscovite, molybdenite, and wolframite were identified.

The hand specimen from which the sections rich in topaz were made was found to be largely massive with a small crystalline portion. All the material was stained a rusty brown by a heavy coating of iron oxide. Part of this specimen was crushed in a steel mortar and separated by Thoulet's solution of specific gravity 3.2, when it was found that 97.5 per cent. sank, showing that the specimen was nearly pure topaz. Similar treatment of the specimen in which quartz

was found to be the prominent mineral showed the presence of one per cent. by weight of topaz.

From the results of the above examination it would appear that topaz occurs both massive and crystallized in the quartz veins, and is present in quite appreciable amount. The topaz appears to occur more abundantly as crystals than in the massive form. It is also distinguished from the quartz in that it, as a rule, is thickly coated with iron oxide of a rusty-brown colour.

Mineralographic Investigation

Three polished fragments of wolframite were examined by means of a mineralographic microscope, and it was found that no foreign minerals, with the exception of quartz, were present in sufficient amount to be seen even when magnified 150 diameters. The quartz occurs in the form of a few minute particles scattered through the wolframite.

From the result of this examination it was decided that, if any cassiterite were present in the wolframite, it was present in a very finely divided condition. The examination also showed, and this was later verified by chemical examination, that the wolframite was homogeneous.

Chemical Investigation

A mean of three very concordant analyses of the wolframite is as follows:

WO ₃	75.45
SiO ₂.....	.23
FeO.....	15.75
MnO.....	8.31

	99.74
S.G.....	7.10

Traces of the rare metals were present. These metals were thought to be niobium and perhaps tantalum, but they were present in such small amount that they could not be identified with certainty. Tests made for tin were negative.

The mean of two concordant analyses of the granite from Burnt Hill brook is as follows:

SiO ₂	73.09
Al ₂ O ₃	13.75
Fe ₂ O ₃.....	.67
FeO.....	1.25
CaO.....	.68
K ₂ O.....	6.69
Na ₂ O.....	3.53
TiO ₂.....	.17
MgO.....	.05

	99.88

From the information obtained from the above investigations, certain conclusions regarding the mineral association of the tungsten deposits at Burnt Hill brook are derived. The petrographic examination of the altered slates shows that there has taken place a great deal of chemical action and recrystallization, following the intrusion of the granite. The examination of the vein material indicates that pneumatolytic agents have been present in considerable amount as shown by the formation of topaz and molybdenite.

The presence of cassiterite was not revealed by the petrographic or mineralogical investigations, nor was any trace of tin found in the chemical analysis of the wolframite. This might lead one to believe that tin does not occur in the Burnt Hill brook area, although it has been reported by Brock,¹ Camsell,² and Robinson.³

¹Brock, R. W., *Summary Report, Geological Survey of Canada*, 1911, pp. 13-15.

²Camsell, Charles, *Summary Report, Geological Survey of Canada*, 1916, pp. 247-249.

³Robinson, C. W., *Summary Report, Geological Survey of Canada*, 1914, p. 110.

ALBERTITE IN GYPSUM FROM HILLSBORO, NEW BRUNSWICK

By A. L. PARSONS

Through the courtesy of F. M. Thomson, Esq., the Royal Ontario Museum of Mineralogy received during the past winter a sample of albertite in gypsum from the quarries of the Albert Manufacturing Company at Hillsboro, New Brunswick, which are located about five miles north-east of Albert Mines, where the albertite or Albert coal was formerly mined. The specimen under consideration is a mass of gypsum about eighteen by twelve by eight inches with an approximately cylindrical or cigar-shaped mass of albertite extending the entire length. The maximum diameter of the albertite mass is about one inch. A small portion of the gypsum was broken off to make the specimen more shapely for display, when another smaller mass of albertite was revealed which had been completely enclosed in the gypsum.

The gypsum is nearly white, but shows seasonal bands that are somewhat grey. Near the albertite these bands are curved, but otherwise are approximately straight, so that it does not seem likely that heavy oil or asphalt has been forced in laterally. A more probable source would seem to be that asphalt issued from a submarine fissure in the carboniferous sea while gypsum was being deposited. Such conditions are known to exist in the Dead Sea where asphalt is occasionally found floating on the surface. In the case under consideration the asphaltic matter seems to have been too heavy to rise to the surface of the water and was consequently covered over by gypsum. It is evident from a comparison of the deposits in the Dead Sea and at Hillsboro that the water from which the gypsum was deposited had a lower specific gravity than that of the Dead Sea, so that a substance which would readily float in the concentrated brine of the Dead Sea would just as readily sink in the Carboniferous sea, and the specific gravity of the albertite

probably represents a maximum density which was not reached. From an examination of the seasonal bands it appears to have required about five years to cover completely the mass of albertite.

An analysis of the albertite by L. J. Rogers (I) together with the original analysis by Wetherill¹ (II) follows:

	I	II
C.....	78.80	86.04
H.....	6.16	8.96
N.....	1.50	2.93
S.....	2.03	trace
Ash.....	1.40	.10
O.....	(10.11)	1.97
Total.....	100.00	100.00

Neither of these analyses yields a simple formula and both appear to be mixtures. The striking difference is in the percentage of oxygen.

¹*Trans. Phil. Soc. Philad.*, 353, 1852.

A RE-EXAMINATION OF KEWEENAWITE

By ELLIS THOMSON

Through the kindness of Professor A. E. Seaman of the Michigan College of Mines, a portion of the original sample of keweenawite described by König¹ was supplied to the Royal Ontario Museum of Mineralogy for investigation. Since this investigation shows conclusively that the keweenawite is a mixture of several minerals and has brought a few additional facts to light concerning the homogeneity of the basic copper arsenides, it was thought that a short article giving this additional information might be of some value.

In addition to a qualitative microscopic determination of the minerals present, estimates were made microscopically of the approximate proportions of the different minerals. This work was supplemented by chemical analyses by H. C. Rickaby of the Department of Mineralogy. In some cases part of the analysed sample was subjected to a quantitative microscopic determination; in others the actual specimen examined microscopically was afterwards analysed.

Seven specimens were examined mineralogically, of which three were examined quantitatively and analysed. The keweenawite was found to consist of a mixture of niccolite and a greyish creamy copper arsenide with minor amounts of tennantite, sometimes with rammelsbergite and safflorite and sometimes with smaltite and chloanthite. In order that some idea may be formed of the variation in relative proportions of these minerals, a detailed description will be given of the mineralogical constituents of specimens 1 and 2 and their quantitative relations.

Sample No. 1

This specimen is a portion of the original keweenawite described by König. An examination of a polished section

¹*Am. J. Sc.*, Ser. IV, Vol. 14, p. 410, 1902.

showed the presence of copper arsenide and niccolite as well as smaller amounts of smaltite-chloanthite and tetrahedrite. The proportions as determined microscopically on this section are shown below (I).

Several grams of this material were then prepared for analysis, and one gram of this prepared material was set aside for another quantitative microscopic determination, the results of which are shown below (II).

	I	II
Tetrahedrite.....	1	1
Cobalt Nickel Arsenides.....	17	21
Copper Arsenide.....	83	78

The chemical analysis with the calculated mineral composition follows:

	$Cu_3As_2S_7$	$CoAs_2$	$NiAs_2$	$NiAs$	Cu_3As
Cu..	56.60	.890	.005	.....	.885
Ni..	5.07	.086	.....	.....	.....
Co..	2.39	.041	.....	.012	.074
As..	35.87	.478	.002	.041	.....
S....	.16	.005	.005	.082	.024
	100.09	.....	.63%	.024	.074
			8.51%	9.92%	78.41%

It is clear both from the microscopic and chemical evidence that the nickel is present in the form of niccolite, and to a lesser extent as chloanthite, while the very small percentages of cobalt and sulphur are to be ascribed to smaltite and tennantite, respectively. It was found impossible to make a quantitative differentiation of smaltite-chloanthite from niccolite microscopically, and on that account they are grouped together.

No attempt was made to work out the percentage of tennantite in the powdered sample, but it was present in such very small quantity that it would have no appreciable effect on the calculations in any case. The copper arsenide in these two sections is quite homogeneous and from the chemical evidence was determined to be domeykite (Cu_3As).

The above three quantitative mineralogical statements are in substantial agreement.

Sample No. 2

This specimen was labelled keweenawite, but differs considerably in mineralogical composition from No. 1. In polished section it was found to consist of a mixture of niccolite, rammelsbergite, safflorite, a greyish creamy white copper arsenide, and tennantite (Pl. III, Fig. 2). The section when examined quantitatively showed the following composition: niccolite 42 per cent., copper arsenide 39 per cent., rammelsbergite-safflorite nearly 19 per cent., and tennantite probably less than .25 per cent. The rammelsbergite and safflorite in this sample were present in considerable amounts, so that the etching reactions and the crystal habit could be studied carefully. The rhombic crystallization was quite clearly shown, the crystals appearing in the form of long laths or needles. It was comparatively simple in this section also to study the etching reactions in parts where there was comparatively little of the copper arsenide to complicate matters. The extreme susceptibility of the copper arsenide to etching and the comparative inertness of the small proportions of smaltite and chloanthite present in No. 1, made this determination a much more difficult matter.

The polished specimen was then broken up and analysed with the following results:

	$Cu_3As_2S_7$	$CoAs_2$	$NiAs_2$	$NiAs$	Cu_3As
Cu	30.58	.481	.002	.....	.479
Ni	15.87	.270	.....	.....	.092
Co	3.71	.063	.....	.063	.....
As	48.73	.650	.001	.126	.184
S	.05	.002	.002	.....	.....
	98.94	.20%	13.17%	19.23%	23.85%
					42.53%

As in the previous case, the sulphur is taken up by the tennantite, and it is to be noted that the proportions of this

mineral as given by the chemical and microscopic methods are in very close agreement. The biggest discrepancy between the chemical and the microscopic results is in the proportion of niccolite to rammelsbergite-safflorite, probably due to the variation in the proportions of these minerals even in a specimen carrying twenty grams of metallic minerals. In regard to the arsenide of copper the results are fairly concordant. As in sample No. 1, the copper arsenide is domeykite.

Four additional samples of similar material when examined microscopically showed the same minerals in varying proportions, so that no further analyses or quantitative determinations were carried out on them. In all of these, with one exception, the copper arsenide is quite homogeneous. In this section, it appeared to be a eutectic of three different constituents, one greyish creamy white (domeykite), one creamy white, and the other pinkish white. Of the three constituents the first is by far the most abundant. With so many additional minerals present, however, the writer did not consider it possible to find out with any degree of certainty the chemical composition of the other two members of the eutectic.

In conclusion, it is evident that kweenawite is not a distinct mineral species, but a mixture of arsenides of copper, nickel, and cobalt.

PETZITE FROM THE HOLLINGER MINE, TIMMINS, ONTARIO

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

Through the courtesy of A. F. Brigham, Esq., General Manager of the Hollinger Consolidated Gold Mines, the Royal Ontario Museum of Mineralogy received some remarkably large and rich samples of petzite, which was discovered in 1924 in considerable quantity on the 800-foot level of the Hollinger mine. The mineral is associated with quartz, ankerite, and native gold. Sometimes it is intimately associated with ankerite, in which it occurs as films in cleavage cracks so that the ankerite appears almost black; more rarely, it forms masses up to one half-inch in diameter.

The mineral is iron-black in colour, devoid of cleavage, and brilliant metallic in lustre. The specific gravity determined on 1.5 grams in the pycnometer was found to be 7.53, which is unusually low for a gold-silver telluride. A mineralogical examination, by Professor Ellis Thomson, having shown that the material was homogeneous and corresponded to the tests for petzite, it was decided to make a chemical analysis.

The sample for analysis was obtained by treating selected pieces of cleavable ankerite with hydrochloric acid. In this way the telluride was set free without suffering any alteration during the process. The sample so obtained when examined with the binocular microscope was found to contain a few small grains of quartz and an occasional speck of native gold, otherwise it appeared to be remarkably homogeneous. All visible gold was removed. The analysis by H. C. Rickaby follows:

Ag.....	49.57	459	}	569
Au.....	11.10	056		
Fe.....	.76	014×2	}	280
Co.....	.76	013×2		
Te.....	33.62	264	}	
As.....	1.20	016		
Insol.....	2.38			
S.....	Trace			
Sb.....	Trace			
Ni.....	Trace			
	<hr/>			
	99.39			

The mineral dissolved in nitric acid leaving a residue of 13.48 per cent. consisting of 11.10 per cent. of reddish-brown gold, which dissolved in aqua regia, and 2.38 per cent. which was insoluble in acid. This corresponds closely to the formula $(Ag_2, Au_2, Fe, Co).(Te, As)$.

It is interesting to note that the treatment with nitric acid gives a complete separation of silver and gold. All the gold was found in the residue and all the silver in the solution. Carnot,¹ in his analyses of tellurides from Western Australia, frequently found that nitric acid gave an insoluble residue containing all the gold, but in his calculation of formulae included the gold with the silver as part of the same mineral. Notwithstanding the simplicity of the formula derived from our analysis, it seems not improbable that the gold occurs along with a telluride of silver very finely divided in a eutectic. In that case the silver telluride would appear to be hessite, with small amounts of iron, cobalt, and arsenic unaccounted for.

¹Carnot, A., *Bull. Soc. Min. France*, Vol. 24, p. 357, 1901.

THE RATE OF OXIDATION OF ARSENIDES OF IRON, COBALT, AND NICKEL

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

The writers have called attention in another paper¹ to the readiness with which some arsenides of iron, cobalt, and nickel oxidize in moist air and become covered with a bloom of arsenate, while others are very much more stable under identical conditions.

To determine quantitatively the rate at which the oxidation proceeds under definite conditions, a sample of arsenides largely made up of rammelsbergite, safflorite, cobaltite, and a small amount of loellingite was prepared. It was crushed so that it passed the twenty-mesh screen and rested on the sixty-mesh. This material was analysed by H. C. Rickaby and found to have the following composition:

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

A portion of the prepared sample was examined mineralogically by Professor Thomson, who indicates the following mineralogical composition: rammelsbergite and safflorite 70 per cent., cobaltite 12 per cent., skutterudite 8 per cent., loellingite 6 per cent., gangue 4 per cent. The high specific gravity suggests that the diarsenides of cobalt and nickel are rhombic rather than cubic.

¹See page 52.

A portion of the sample was put into each of three well-stoppered 2500 cc. bottles with 500 cc. of water and agitated for several hours daily for ten days. In the first bottle the gas was air, in the second oxygen, and in the third 200 cc. of carbon dioxide was added to the oxygen. During the agitation a considerable diminution of the pressure resulted from the combination of part of the oxygen with the arsenic and bases to form new compounds, while the water, originally clear, became clouded by the formation of arsenates.

After ten days the contents of each bottle were filtered. The residue was divided into unaltered mineral and soluble arsenate by brief treatment with dilute hydrochloric acid. The unaltered arsenide was dried and weighed, while each of the two liquid portions was analysed separately. The general result was that (a) about one-sixth of the original arsenide was broken up, (b) the clear filtrate contained arsenious oxide, acid arsenate of cobalt and nickel, and a trace of soluble sulphate, and (c) the arsenate formed was normal arsenate of cobalt and nickel.¹ The details of the analysis are as follows:

	1	2	3
Residue.....	86.28	81.72	81.80
S	.12	.06	.08
As in As ₂ O ₃	4.70	5.43	5.26
Filtrate.....	1.90	4.85	4.57
Ni	1.31	1.31	1.31
Co	.38	.33	.44
As in As ₂ O ₃	2.45	1.99	2.57
Arsenate....	2.26	2.38	2.28
Ni	.62	.69	.68
Co	.04	.07	.07
	<hr/> 100.06	<hr/> 98.83	<hr/> 99.12

Examined in detail the above analytical data indicate that under the conditions of the experiment:

¹The nature of the products of oxidation was first determined by Plattner and afterwards confirmed by Kersten, *Pogg. Annalen*, Vol. 60, p. 271, 1843.

1. Cobaltite is comparatively inert.
2. Loellingite, though more active than cobaltite, is less readily oxidized than the cobalt-nickel diarsenides.
3. About one-half of the oxide of arsenic resulting from the decomposition of the mineral occurs in the filtrate as arsenic trioxide.
4. The safflorite and rammelsbergite are decomposed in the proportions in which they are found in the sample.
5. The soluble arsenate of nickel and cobalt present in the filtrate is acid in all three—in the first where the oxygen was limited it conforms to the formula $H_2Ni_2As_2O_8$, which is identical with the formula assigned to the rare arsenate forbesite, while in the second and third it agrees with $H_4NiAs_2O_8$.
6. About one-third of the nickel and cobalt is found in the clear filtrate and along with the arsenic trioxide and part of the pentoxide, and would in the ordinary process of weathering be carried away in solution, to be deposited along cracks and fissures often far remote from the place of origin.
7. There is no appreciable difference between the second and third tests due to the presence of carbon dioxide along with the oxygen.

A second series of tests was made on different arsenides of cobalt, nickel, and iron, using in all cases the same mixture of oxygen and carbon dioxide—1800 cc. of the former and 200 cc. of the latter, in bottles containing 500 cc. of water and eight grams of mineral which had been crushed to pass through twenty-mesh screen and rest on sixty-mesh. The bottles were agitated daily for several hours. As the internal gas pressure was measured every twenty-four hours, the progress of oxidation from day to day was revealed by the gradual diminution of the pressure. At the end of ten days the resulting products were examined as before.

Samples 4, 5, 6, and 7 were analysed by H. C. Rickaby with the following result:

	4	5	6	7
Ni.....	trace	15.91	40.52	trace
Co.....	14.40	11.29	2.78	8.20
Fe.....	11.85	.78	.28	17.58
As.....	70.55	64.10	55.35	65.85
S.....	.48	4.00	.78	.63
Sb.....			trace	
Insol.....	2.40	3.44	.22	7.54
	<hr/> 99.68	<hr/> 99.52	<hr/> 99.93	<hr/> 99.80
S.G.....	6.771	6.527	7.55	6.536

Professor Ellis Thomson examined the prepared samples mineralographically and reported the following percentage of the ore minerals:

	4	5	6	7
Arsenopyrite.....	..	..	..	1
Cobaltite.....	..	12	..	..
Loellingite.....	70	10	..	85
Niccolite.....	..	..	92	..
Rammelsbergite and Safflorite ..	70	..	..	..
Safflorite.....	10	..	..	6
Skutterudite.....	20	8	3	8
Smaltite and Chloanthite.....	..	..	5	..

These samples behave very differently. No. 5 was the most active, with an oxidation of 35.98 per cent. followed by No. 6, with 7.69 per cent., No. 4 with 4.50 per cent., and No. 7 with .50 per cent.

No record was kept of the number of hours of agitation. At the beginning it was about two or three hours daily, while for the last five days the agitation was about eight hours daily. For the first six days no addition of oxygen was made, but for the last four days the pressure was relieved by the addition of sufficient oxygen to restore equilibrium with the atmosphere. These two departures from the practice in the earlier experiments are important, for they are doubt-

less responsible for the much greater amount of mineral oxidized in the later experiments.

By the daily pressure determinations it was possible to know the relative rates of oxidation of the different minerals, and also the differences in rate for the same mineral for different periods of the experiment. This information indicates that No. 5 used up in all 849 cc. of oxygen corresponding in weight to 1.227 grams. The oxygen necessary to combine with the amounts of nickel, cobalt, iron, sulphur, and arsenic shown in the analysis of No. 5 is 1.151 grams. If to this be added the oxygen dissolved in 525 cc. of water, .027 grams the total weight of oxygen combined and dissolved becomes 1.178 grams. The close correspondence between the two values obtained constitutes at once a check on the chemical data, the pressure determination, and the value of pressure records as an index of the rate of oxidation.

The chemical examination of the contents of the bottles 4, 5, and 6 by H. C. Rickaby is detailed below.

	4	5	6
Residue.....	95.50	64.02	92.41
Filtrate.....	S	.09	.34
	As as As ₂ O ₃	.37	9.06
	As as As ₂ O ₅	1.80	10.93
	Ni	trace	4.19
	Co.....	.63	.54
Arsenate.....	As as As ₂ O ₅	.70	4.55
	Ni	trace	3.98
	Co	.06	1.35
	Fe	.60	.04
	<hr/> 99.75	<hr/> 99.00	<hr/> 99.96

In the case of bottle 7, containing a fairly pure loellingite, only one-half of one per cent. of the sample was oxidized. In the filtrate, the arsenic as As₂O₃ amounted to .09 per cent.

From the above data the following conclusions may be derived:

1. Number 5 has given results comparable with number 3, already described, except that the rate of decomposition is double that in number 3. This is apparently due to greater agitation of the former and to the admission of oxygen during the latter part of the experiment so as to relieve pressure.
2. In numbers 4 and 6 the filtrate appears to contain sulphate of cobalt and nickel, arsenious oxide and acid arsenate of cobalt and nickel corresponding to the formula $H_4NiAs_2O_8$.
3. The arsenic and metals present in the arsenates of 4, 5, and 6, correspond to the normal arsenates of the metals.
4. The chemical data show that under identical conditions rammelsbergite is decomposed four times as rapidly as niccolite, eight times as rapidly as the mixture used in 4 and seventy-five times as rapidly as 7, which was very largely composed of loellingite. Meteoric waters might, therefore, be expected to remove rammelsbergite before attacking most of the other arsenides.

As it was thought that the solution or filtrate might have a definite solvent action on the silver of the veins, a part of the filtrate from number 2 was agitated for four days with one-half gram of finely divided silver. At the end of that time it was found that the liquid was quite free from dissolved silver. It is proposed later to test the solubility of some of the more important silver minerals in this type of liquid, as it seems that a solution containing so much arsenious oxide in solution, in addition to acid arsenate of nickel and cobalt, should have great power of decomposition, solution, and transportation when acting on other minerals in or near the oxidizing arsenides.

The Keeley mine from which the rammelsbergite (numbers 3 and 5) came is well known for the extensive and deep weathering of the vein matter and of the country rock. It is also distinguished for the prominence of rammelsbergite in the fresh vein material, so that the writers suggest that the

degree of weathering may *in part* be due to the prominence of rammelsbergite in the veins.

If a few drops of the clear liquid be evaporated on an object glass and examined with the microscope it is observed that there is an abundant separation of octahedral crystals of arsenic trioxide. Such a solution of arsenious oxide and acid nickel and cobalt arsenates would probably in its migration give rise to a precipitate of normal arsenate or bloom free from the more soluble arsenic trioxide. This is what appears to occur along all cracks and fractures in the vicinity of oxidizing arsenides. In some cases the bloom may, by the evaporation of the water, be precipitated along with the trioxide of arsenic, as illustrated by the "earthy cobalt bloom" described by Kersten¹ from Schneeberg and Anna-berg. The writers have tested many samples of cobalt and nickel bloom from northern Ontario, but in all cases they were normal arsenate washed free from both trioxide and pentoxide of arsenic and soluble arsenates.

The rare acid cobalt arsenate known as forbesite has been found as a surface incrustation in the Atacama desert, overlying masses of weathering cobalt-nickel arsenides. Under desert conditions the water circulation by capillarity would be upward, so that forbesite would appear to be due to the evaporation of ascending waters charged with acid arsenate of cobalt, similar to that obtained in the filtrate in our experiments. There is no information available to indicate the association of arsenolite with forbesite although such would be expected from our experiments.

Similarly, the magnesium-nickel arsenate cabrerite, which is found in Spain where arsenides have oxidized in a country rock of dolomite, pharmacolite, a calcium arsenate which occurs along with arsenides of cobalt and nickel in Baden, and roselite, the lime-magnesium-cobalt arsenate found under similar conditions at Schneeberg, may owe their origin to the reaction of the soluble products of the oxidation of arsenides of cobalt and nickel on carbonates of lime and magnesium.

¹Pogg., Vol. 60, p. 262, 1843.

It seems very probable that such an acid solution must play a part in the solution transportation and precipitation of some of the metals of economic value, and that investigations along this line would give important information in regard to leaching concentration and enrichment of economic deposits.

ARSENIDES FROM THE SILVER VEINS OF SOUTH LORRAIN, ONTARIO

By T. L. WALKER

While in a general way the association of minerals found in the silver-cobalt veins in South Lorrain resembles that of the well-known deposits at Cobalt, there appears to be sufficient variation to warrant a brief description of some of the more important minerals found at the former locality. The minerals discussed in the present memorandum have all been found in the deposits at Cobalt, but not in the same abundance as in South Lorrain, where niccolite and the smaltite-chloanthite intergrowth are relatively unimportant.

Skutterudite

As has been previously shown,¹ this mineral commonly forms the outer zone on cubic crystals, the central portion of which is made up of alternating zones of smaltite and chloanthite. It is a peculiar case of isomorphism in which diarsenides take part with the triarsenide in the regular growth of crystals of the pentagonal class.

Specimens of skutterudite from the Keeley mine exhibit brilliant cubic crystals from two to five millimeters in diameter. They are usually ruptured, as the result of the alteration and expansion of the minerals forming the central part. Cross sections were found to show that the smaltite and chloanthite were quite soft and crumbled, while the more resistant skutterudite mantle was perfectly fresh. An analysis of the fresh part by E. W. Todd² showed that very little of the diarsenides of cobalt and nickel remained.

¹Walker, T. L., *Am. Min.*, Vol. VI, p. 54.

²*University of Toronto Studies*, Geol. Ser., 17, p. 33.

		[Co,Ni]AsS	FeAs ₂	CoAs ₂	CoAs ₃	
Fe.....	3.56	.064	.064	.....	.....
Co.....	17.66	.299	.010	.005	.284	
Ni.....	.66	.011	.011	.....	.....
Bi.....	.06	.....	.....	.....	.....
As.....	75.70	1.011	.021	.128	.852	
S.....	.66	.021	.021	.....	.....
Insol...	1.64	.....	.....	.....	.....
	99.94	3.44%	13.09%	1.05%	80.57%

Skutterudite in Northern Ontario very often occurs in small brilliant cubic crystals scattered through chloritic altered rock either in the wall or in inclusions in the vein. It here seems to represent a late phase of the mineralization and to contain a relatively small diarsenide core. Specimens of this type were described some years ago from the Temiskaming mine. Unusually fine crystallized material was recently obtained from the Frontier mine. The crystals are about one millimeter in diameter and very brilliant. From an analysis by H. C. Rickaby it appears that the skutterudite makes up nearly ninety per cent. of the whole:

		[Co,Ni]AsS	FeAs ₂	CoAs ₂	CoAs ₃
Fe.....	.95	.017	.017	.....	.....
Co.....	20.50	.347	.034	.....	.313
Ni.....	.20	.003	.003	.....	.....
Cu.....	.10	.001	.....	.....	.....
As.....	75.15	1.002	.037	.034	.931
S.....	1.18	.037	.037	.....	.....
CO ₂.....	.16	.....	.....	.....	.....
Insol.....	1.22	.....	.....	.....	.....
	99.46	.....	6.14%	3.50%	88.32%
S.G.....	6.519	.....	.....	.....	.....

Loellingite

Though loellingite is not common in the veins at Cobalt, it plays a prominent part in certain deposits in South Lorrain.

In some of the massive ore from the Frontier mine the principal arsenides are loellingite and skutterudite and smaltite. Bell and Thomson³ have described loellingite from the Keeley mine associated with safflorite, skutterudite, and cobaltite. The mineral has not been found in crystals suitable for measurement, so that their conclusions are based on microscopic examination taken in conjunction with quantitative analyses.

Recently loellingite has been found at the Keeley mine in masses one foot in diameter. It occurs in nodular radiating masses or in concentric growths, in which some constituent has been replaced by reddish cherty silica (Pl. III, Fig. 1). Professor Ellis Thomson has kindly examined sections of these growths with the microscope and reports that the minerals present in order of importance are loellingite, safflorite, cobaltite, and skutterudite. This agrees well with the following analysis by H. C. Rickaby.

		CoAsS	FeAs ₂	CoAs ₂	CoAs ₃	
Fe...	14.60	.261	.261	.....	.....
Co...	12.56	.213	.....	.170	.020
Ni...	.36	.006	.....	.....	.....
As...	71.30	.951	.522	.340	.060	
S.....	.92	.029	.....	.....	.....
	99.74	4.81%	53.77%	35.53%	5.68%

In veins where weathering has been prominent, as is the case in some of the workings of the Keeley mine, the arsenides which are less readily acted upon by meteoric waters tend to become relatively more prominent by the removal of those more easily attacked. In the cobalt-silver veins the nickel minerals rammelsbergite, niccolite, and gersdorffite are far more readily destroyed than are the arsenides of iron and cobalt. Cobaltite, skutterudite, and loellingite are by far the most resistant.

³University of Toronto Studies, Geol. Ser., 17, pp. 27-32.

Rammelsbergite

In 1916 Ellsworth¹, in his study of the minerals found in the veins which carry the silver ores at Cobalt, called attention to the presence of chalcocite, symplectite, loellingite, and rammelsbergite, none of which had been previously recognized at Cobalt. The last two of these minerals have since been found to be relatively abundant in ores of the Keeley and Frontier mines.

Recently the Royal Ontario Museum of Mineralogy obtained from the Keeley mine some masses of fairly pure rammelsbergite nearly a foot in diameter. This mineral can be readily recognized by the rapidity with which it weathers, for if it be left in the open, or in a damp place under shelter it becomes covered in a few weeks with a creamy white earthy deposit of annabergite. In the process of weathering its structure is made manifest. The rammelsbergite is composed of radiating aggregates, each of which is surrounded in part by a narrow zone of some more resistant mineral which does not weather so readily. Since the radiating units are commonly from one quarter to one inch in diameter the weathering gives rise to a dappled or spotted appearance (Pl. IV, Figs. 1 and 2).

Some of the purest pieces were placed under a bell-jar in a dish which contained a little water in the bottom, with the result that in one week the masses were so completely covered with annabergite that it was not possible to recognize the original mineral. Specimens of niccolite when similarly treated give rise to a green deposit of annabergite, while smaltite, loellingite, and breithauptite at the end of the experiment were still apparently quite fresh. Up to the present rammelsbergite has not been found in the Cobalt district in crystals suitable for crystallographic measurement.

An analysis of carefully selected material analysed by H. C. Rickaby gave the following result:

¹Ellsworth, H. V., *Report of the Bureau of Mines, Ont.*, Vol. 25, p. 200.

	CoAsS	FeAs ₂	CoAs ₂	NiAs ₂
Fe . . . . .	.73	.013	.....	.....
Co	11.24	.190	.103	.087
Ni	17.46	.287	.....	.287
As	66.61	.888	.103	.026
S	3.30	.103	.....	.174
Insol. . . . .	.84	.....	.....	.....
100.18	.....	17.10%	2.68%	18.18%
				61.33%

The specific gravity of the sample as prepared for analysis was determined by means of the pycnometer and found to be 6.734. The high specific gravity indicates that the diarsenides are rhombic rather than cubic. The mineral assemblage calculated from this analysis agrees with that found by Professor Ellis Thomson, who examined microscopically the sample prepared for analysis.

Safflorite

This mineral appears to be closely associated with rammelsbergite and in South Lorraine has never been found alone. It has been recognized mineralographically in many ore samples from the Keeley and Frontier mines, while the chemical analyses show that in some samples largely made up of rammelsbergite the associated safflorite constitutes about one-fifth of the whole mass.

MINERALOGRAPHIC NOTES ON CERTAIN ARSENIDES AND SULPHARSENIDES OF COBALT, NICKEL, AND IRON

By ELLIS THOMSON

In the course of a microscopic investigation of the silver ores of the Keeley mine, South Lorrain, Ontario, the writer was able to develop extra microchemical data for the identification of the metallic minerals associated with the native metal at this mine. As one of these minerals, skutterudite, is not listed in the current text-books, while others, such as rammelsbergite and safflorite, have received only scant attention, it was felt that the results obtained were worthy of a separate record, although included incidentally in a previous paper on the Keeley ores.¹

No reference will be made to those compounds, such as niccolite or temiskamite, which, by virtue of their characteristic colour, may be identified with ease. Attention will be concentrated rather on those arsenides and sulpharsenides, which are almost identical macroscopically, having much the same colour, hardness, and relief.

COBALT MINERALS

Cobaltite ($CoAsS$)

Cobaltite is pinkish-white in colour, has a high hardness, a very high relief, and appears commonly in crystal form, the habit being cubic or pyritohedral. It is the most inert chemically of all these white hard metallics. It gives negative results with the four standard reagents of Davy-Farnham, and is only occasionally and but slightly etched by mercuric chloride and concentrated nitric acid. These two reagents sometimes etch the mineral a light yellow or brown, which is

¹Bell, J. M. and Thomson, Ellis, *Univ. of Toronto Studies*, Geol. series, No. 17, 1924, pp. 18-37.

easily removed by rubbing. It may be distinguished from the other minerals described below by its pinkish-white colour, its cubic crystallization, its inertness to all chemical reagents, and its very high relief.

Skutterudite ($CoAs_3$)

Skutterudite is white in colour, has a high hardness, a high relief, and appears in much the same crystal forms as cobaltite with a marked preponderance of cubic sections. It is also very inert chemically, being etched only by mercuric chloride, and not always by that reagent, to a light yellow or brown colour, which is readily removed by rubbing. It is etched quite deeply, however, by concentrated nitric acid to a dark grey pitted surface, which remains after rubbing. In this respect it differs quite radically from cobaltite. This mineral is readily distinguished from other minerals mentioned in this paper, by its inertness to most reagents, and from cobaltite as indicated above.

Smaltite ($CoAs_2$)

Smaltite resembles skutterudite in physical properties, being white in colour and high in relief. It does not crystallize with the same readiness as skutterudite, however, being commonly in massive form. Where crystals occur they have the same general habit as the skutterudite with a predominance of cubic sections. With dilute nitric acid the mineral darkens, sometimes with effervescence, more often without, and rubs to a dark brown or grey colour. It is generally intergrown zonally with chloanthite, when the crystals present a composite appearance. The chloanthite is always more deeply etched with the acid than the smaltite. Ferric chloride tarnishes it sometimes a light brown, at other times leaves it practically unaffected. With mercuric chloride it tarnishes slowly to a brown colour which rubs clean. The cubic crystallization and the microchemical reactions serve to differentiate smaltite from other arsenides and the sulpharsenides.

Safflorite ($CoAs_2$)

Safflorite is white in colour, has a high hardness, and a high relief. It crystallizes readily in long prismatic crystals of the rhombic system. Under the action of dilute nitric acid it tarnishes readily to a dark grey rough surface which remains after rubbing. Ferric chloride tarnishes it slightly to a light brown and brings out its crystal structure. It is unaffected by the other four reagents. It may be distinguished from other arsenides and from the sulpharsenides by its crystal form and its characteristic microchemical reactions. It differs from smaltite in crystal habit and in its susceptibility to etching with dilute nitric acid, and from rammelsbergite by the absence of effervescence when treated with the same acid.

NICKEL MINERALS

Gersdorffite ($NiAsS$)

Gersdorffite is almost identical with cobaltite in appearance, having much the same colour, hardness, and relief. It crystallizes in the cubic system, its habit being similar to that of cobaltite, with which it frequently forms composite crystals. Under the action of dilute nitric acid it turns first brown and then black, rubbing to a rough grey surface. Ferric chloride sometimes tarnishes it a faint brown, while mercuric chloride tarnishes it a brown colour which rubs clean. This mineral resembles cobaltite most closely, but differs from it in its marked susceptibility to the action of dilute nitric acid and mercuric chloride.

Chloanthite ($NiAs_2$)

Chloanthite resembles smaltite, but differs largely in the more intense etching with dilute nitric acid. It appears commonly as a component part of composite crystals along with smaltite. It may be distinguished from the rhombic nickel diarsenide largely by its cubic crystallization and the fact that it is somewhat less susceptible to the action of dilute nitric acid than rammelsbergite.

Rammelsbergite ($NiAs_2$)

Rammelsbergite is white in colour, has a high hardness, and a fairly high relief, but shows a very smooth polished surface. It occurs in long slender rhombic crystals, frequently arranged in radiating fashion. It is etched very rapidly by dilute nitric acid, becoming quite black in the course of a few seconds, the reaction being accompanied by vigorous effervescence. Ferric chloride and mercuric chloride etch it to a brown colour which rubs to a paler shade, with a mottled appearance in the case of the latter reagent. The rhombic crystallization and the extreme susceptibility to the action of dilute nitric acid are the characteristic features for this mineral.

IRON MINERALS

Arsenopyrite ($FeAsS$)

This common iron mineral is white in colour, has a high hardness, and a high relief. It crystallizes readily in rather stout rhombic crystals sometimes showing the characteristic diamond-shaped cross-section. Dilute nitric acid is the only one of the six reagents which affects it. When treated in this way it tarnishes quickly to iridescent or dark brown tints, occasionally with effervescence, and rubs to a roughened surface. The microchemical reaction for iron, the deep tarnish with dilute nitric acid, and the rhombic crystallization are the characteristic features for this mineral.

Loellingite ($FeAs_2$)

Loellingite is very similar to arsenopyrite in physical properties, being white in colour with a high relief. It also crystallizes in rhombic crystals of stout prismatic habit, and in this respect it agrees with arsenopyrite. It tarnishes very slowly a faint brown with dilute nitric acid, the other reagents giving as a rule a negative reaction. Mercuric chloride sometimes etches it differentially as in the variety leucopyrite. Its short prismatic rhombic habit and its

comparative inertness to microchemical reaction serve to distinguish it from other similar minerals.

It should be noted that in general the nickel minerals are more readily attacked by the reagents than are the corresponding cobalt minerals. At one time the hard white metalics found in association with the silver-cobalt ores of Northern Ontario were referred to as smaltite, chloanthite, and cobaltite. The chemical and microscopic studies of these ores by the Staff of the Department of Mineralogy have shown the presence of gersdorffite, rammelsbergite, skutterudite, safflorite, and loellingite. In some deposits it has been found that smaltite and chloanthite are quite rare and that loellingite, skutterudite, and rammelsbergite assume the dominant role.

In conclusion, the writer wishes to acknowledge a debt of gratitude to Dr. J. Mackintosh Bell, the Managing Director of the Huronian Belt Company, for his kindness in placing at the disposal of the writer ample material for compiling this memorandum.

A COMPARISON OF THE PORT ARTHUR, COBALT, SOUTH LORRAIN, AND GOWGANDA SILVER VEIN MINERALS

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

Since the discovery of the rich silver ores at Cobalt and later at Gowganda and South Lorrain there has been an intensive study of the mineral associations in these regions, and the results of many of these studies have been recorded in various publications. In the case of the Port Arthur deposits a comparatively small amount was recorded, but we know the principal minerals that were found. The number of minerals that are common to all four districts makes it desirable to put in tabular form the minerals that are known to occur in these silver veins, so as to emphasize the similarities and differences of the deposits, and thus stimulate further study which may possibly remove some of the differences.

The following tabulation has been compiled from lists prepared by Ingall, Miller, Johnston, Bowen, Ellsworth, Burrows, and Knight, supplemented by the work of the writers. In each group of associations the minerals are given in their alphabetical order.

	Port Arthur	Cobalt	South Lorrain	Gowganda & Elk Lake
Annabergite.....	X	X	X	X
Argentite.....	X	X	X	X
Bismuth.....	X	X	X	X
Calcite.....	X	X	X	X
Chalcopyrite.....	X	X	X	X
Chloanthite.....	X	X	X	X
Erythrite.....	X	X	X	X
Galena.....	X	X	X	X
Nickelite.....	X	X	X	X
Pyrite.....	X	X	X	X
Quartz.....	X	X	X	X
Silver.....	X	X	X	X
Smaltite.....	X	X	X	X

	Port Arthur	Cobalt	South Lorrain	Gowganda & Elk Lake
Amalgam.....	×	×	?	
Arsenopyrite.....	×	×	×	
Dolomite.....	×	×	×	
Sphalerite.....	×	×	×	
Stephanite.....	×	×	×	
Tetrahedrite.....	×	×	×	
Aragonite.....	?	×		
Arsenic.....	×	?		
Chalcocite.....	×	×		
Fluorite.....	×	?		
Graphite.....	×	×		
Pyrrhotite.....	×	×		
Barite.....	×	×		×
Bornite.....	×	×		×
Animikite (mixture).....	×			
Apophyllite.....	×			
Azurite.....	×			
Cerargyrite.....	×			
Chlorite.....	×			
Copper.....	×			
Domeykite.....	×			
Harmotome.....	×			
Hunttilite (mixture?).....	×			
Macfarlanite (mixture).....	×			
Mountain Leather.....	×			
Rhodochrosite.....	×			
Saponite.....	×			
Siderite.....	×			
Witherite.....	×			
Malachite.....	×		×	
Marcasite.....	×		×	
Apatite.....		×	×	×
Cobaltite.....		×	×	×
Proustite.....		×	×	×
Xanthoconite.....		×	×	×
Breithauptite.....		×	×	
Gersdorffite.....		×	×	
Loellingite.....		×	×	

	Port Arthur	Cobalt	South Lorrain	Gowganda & Elk Lake
Matthäite.....		×	×	
Pyrrargyrite.....		×	×	
Rammelsbergite.....		×	×	
Skutterudite.....		×	×	
Stromeyerite.....		×	?	
Millerite.....		×		×
Stibite.....		×		×
Teniskamite.....		×		×
Argropyrite.....		?		
Arsenolite.....		×		
Aibolite.....		×		
Chalazite.....		×		
Conite.....		×		
Dyscrasite.....		×		
Emplectite.....		×		
Epsomite.....		×		
Ferrisymplesite.....		×		
Freibergite.....		×		
Glaucodot.....		?		
Heterogenite.....		×		
Heulandite.....		×		
Brundageite.....		×		
Laumontite.....		×		
Polybasite.....		×		
Roselite.....		×		
Serrodite.....		×		
Sphaerocobaltite.....		×		
Symphesite.....		×		
Ullmanite.....		×		
Bismuthinite.....			×	×
Chert.....			×	×
Hematite.....			×	×
Aegonite.....			×	
Enstatite.....			×	
Chapmanite.....			×	
Diabantite.....			×	
Jeffersite.....			×	
Limonite.....			×	
Melanterite.....			×	
Magnetite.....			×	

	Port Arthur	Cobalt	South Lorrain	Gowganda & Elk Lake
Orpiment.....			X	
Realgar.....			X	
Safflorite.....			X	
Chrysotile.....			X	
Cobalt Oxide.....				X
Epidote.....				X

THE CRYSTALLOGRAPHY OF POTASSIUM FLUOZIRCONATE

By D. E. KERR-LAWSON

Introduction

In the course of an examination of some zirconium compounds, the writer secured the above salt in a form which seemed well adapted to crystallographic investigation. In 1860 Marignac¹ described the preparation and geometrical properties of some twenty fluozirconates, including that of potassium, and came to the conclusion that the crystals of this salt belonged to the rhombic system. The crystals described in this article agree very closely with Marignac's description, as to forms present, crystal habit, and interfacial angles. The fact that the base and flatter clinodomes consistently gave double signals symmetrical to a plane parallel to the orthopinacoid, when the crystals were examined on the goniometer, suggested the possibility that they might be monoclinic with β nearly 90° , and that the rhombic appearance was due to twinning on the orthopinacoid. This was confirmed by finding untwinned crystals of obvious monoclinic habit, by the examination of the two ends of a doubly terminated pin, and finally by determining the optical properties. Owing to the importance of this compound of zirconium, it was felt that an amplification of Marignac's description was desirable.

Preparation of Crystals

Marignac states that this salt is formed when the solutions of potassium fluoride and zirconium fluoride are mixed, provided neither is in too great excess. The crystals described in this article were grown from a solution prepared as follows: A known quantity of zirconia (Eimer and Amend, C.P.) was

¹Marignac, M. C., *Ann. Ch. Phys.*, 3rd Ser., Vol. LX, 1860.

dissolved in hydrofluoric acid, and to this was added potassium carbonate solution containing the amount of potash necessary to form the required salt. On account of the great increase in solubility of the substance with rise in temperature, crystals are readily formed by cooling a solution which has been evaporated on the water bath till the substance begins to separate out. To obtain them in a form suitable for goniometric measurement it is necessary to control the fall in temperature, secure the free growth of the crystals in all directions, and provide an efficient means of removing the adherent mother liquor from them the instant they are withdrawn from the solution.

The crystals were grown from a saturated solution prepared as above, in a J. Lawrence Smith platinum crucible provided with a rubber stopper, through which a platinum wire projected almost to the bottom. Round the wire was wound a piece of fine hairy string to the fibres of which the crystals might attach themselves. The wire served to hold them away from the sides of the crucible both during their growth and subsequent removal. The elongated form of this type of vessel is well suited for the growth of crystals when only a limited amount of solution is available. Sufficient liquid was used to cover the greater part of the platinum wire and string. The crucible, as arranged, and containing the saturated solution near boiling point, was submerged in hot water in a wide-mouthed thermos bottle. After standing for about twenty-four hours, when the water was only a few degrees above room temperature, the capsule was removed, the stopper withdrawn, and the crystals adhering to the string promptly washed by being plunged successively in several small beakers of ethyl alcohol.

Geometrical Properties

Among the crystals thus obtained three habits were prominent. Occasionally one observes the simple monoclinic type, showing the base (001), the prism (110), the clinopinacoid (010), the negative hemi-orthodome (101), the clinodome (021), and the hemi-pyramids ($\bar{1}11$), (221), and (131) (Fig. 1).

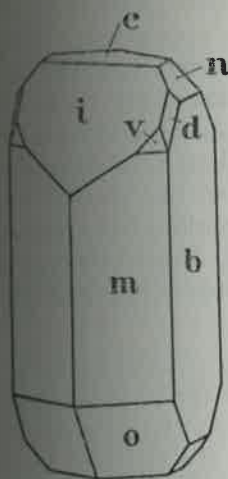


Fig. 1

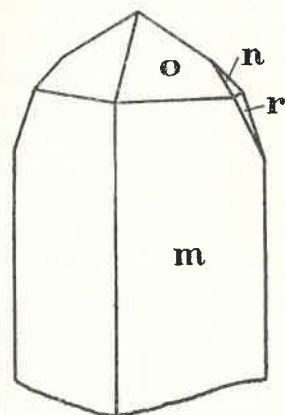


Fig. 2

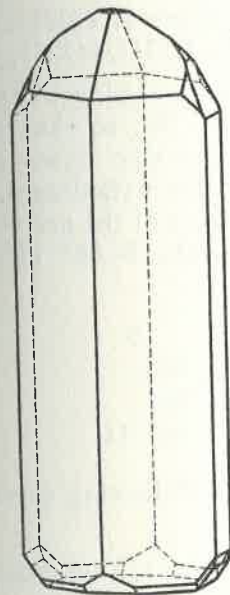


Fig. 3

By far the commonest habit was a form twinned on the orthopinacoid, giving a pseudo-rhombic appearance. When the crystals were small and attached by one end, this type showed the prism (110), the hemi-pyramid ($\bar{1}11$), and the clinodomes (021) and (041) (Fig. 2). A third type, exceptionally favoured by hanging free on a long projecting fibre, was twinned according to the same law, but showed both ends of the crystal. Here the twin simulated the rhombic hemimorphic type. In addition to the forms observed on the two previous types the hemi-pyramids (111) and ($\bar{1}31$) occurred (Fig. 3).

It will be seen that the positive hemi-pyramid ($\bar{1}11$) is a much more prominent form than the corresponding negative form (111), and consequently that when the two positive hemi-pyramids are brought together by the twinning at the upper end of the crystal, this end has a pyramidal appearance, while at the lower end where the two small negative hemi-pyramids occur, the bases are the conspicuous feature.

The forms observed were: $c(001)$, $m(110)$, $b(010)$, $i(101)$, $n(021)$, $r(041)$, $o(\bar{1}11)$, $d(131)$, $v(221)$, $t(111)$, and $s(\bar{1}31)$.

The normal to the basal pinacoid makes with the vertical (c) axis an angle of $0^\circ 20'$, so that the angle β is $89^\circ 40'$. The angle between the two bases as shown on twins is $0^\circ 40'$, that between the orthodomes of the two crystals is $92^\circ 40'$, and the average ϕ of the prism faces (110), as derived from three good crystals, is $60^\circ 11'$. These data may be tabulated as follows:

	ϕ	ρ
(001)....	90°	$0^\circ 20'$
(101)....	90°	$46^\circ 20'$
(110)....	$60^\circ 11'$	90°

From the above the following crystallographic constants are derived:

$$p_0 : q_0 : r_0 : : 1.0418 : 0.5971 : 1, e = 0.0058, \mu = 89^\circ 40'.$$

$$a : b : c : : 0.5731 : 1 : 0.5971, \beta = 89^\circ 40'.$$

Optical Properties

On cleavage plates parallel to the base, the substance as a rule shows polysynthetic twinning. The index for vibrations parallel to the twinning plane (axis b) was determined to be 1.454 ± 0.003 . Since the minimum index α is the obtuse bisectrix, the crystals are optically positive. The index for fragments showing the emergence of one optic axis is 1.465 (β). Sections parallel to the clinopinacoid indicate that the extinction on the vertical axis c is about 45° . In such plates the polysynthetic twinning on (100) is well shown, and in addition another series of twinning bands parallel to the base. This seems to suggest a second less common twinning law with (001) as twinning plane and composition face. In sections normal to the acute bisectrix, $2V$ was determined by the microscope to be about 60° .

NEW LOCALITIES FOR CANADIAN MINERALS

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

Chabazite

During the past year Professor R. P. D. Graham presented to the Royal Ontario Museum of Mineralogy a specimen of this mineral associated with stilbite and heulandite, which he found in a vein on the west side of Cross lake at Cobalt, Ontario. The crystals are of the common rhombohedral habit and in a few instances exhibit penetration twins. The maximum diameter of the crystals is about three millimeters. The particular interest in this occurrence is its association with the veins that have been so important as a source of silver.

Heulandite

This mineral occurs as a colourless drusy crust in the specimen noted above from Cobalt, Ontario.

Stilbite

Four nearly colourless sheaf-like aggregates of stilbite about three millimeters in length are associated with chabazite and heulandite from the west side of Cross lake at Cobalt. This mineral was also observed in a specimen from the Bonsall mine at Gowganda.

Laumontite

A single specimen of partially dehydrated chalky laumontite occurs with native silver, crystallized erythrite, and lilac-coloured aragonite in a mass of oxide of cobalt from the Kirkegaard collection. The exact locality from which the material was obtained is unknown, but it is thought to have been Cobalt.

Stephanite

A few brilliant crystals of this rare mineral have been found associated with proustite and xanthoconite in the Keeley mine at South Lorrain, Ontario. In habit these crystals are similar to those obtained at the Penn-Canadian mine at Cobalt.¹

Proustite

Crystallized proustite occurs associated with xanthoconite and stephanite in the Keeley mine at South Lorrain, Ontario. This mineral also is found associated with xanthoconite at the Castle-Trethewey mine at Gowganda.

Xanthoconite

This extremely rare mineral has been found in the Keeley mine at South Lorrain, and in the Castle-Trethewey mine at Gowganda. In the first instance it was associated with proustite and stephanite, in the second with proustite.

Ottrelite

This occurs as a rock-forming mineral in a schist on the 800 foot level of the Hollinger mine, Timmins, Ontario.

Chondrodite

In a rock cut on the railway near the station at Chaffey's Locks, Ontario, remarkably bright chondrodite is found in crystalline limestone.

Mimetite

A specimen of mimetite was found in the Frontier mine at South Lorrain, Ontario.

Dolomite

Associated with the celestite on lot 7, concession X, Bagot township, near Calabogie, is crystalline dolomite,

¹*Univ. of Toronto Studies*, 1921, Geol. Ser. No. 12, p. 69.

which at first glance resembles a scoria. $\omega = 1.684$, $\epsilon = 1.507 \pm .003$. The material was separated and analysed by H. C. Rickaby with the following results:

CO ₂	45.55	1.055	
FeO.....	.66	.010	
CaO.....	30.68	.548	
MgO.....	22.07	.552	1.112
SrO.....	trace		
MnO.....	.12	.002	
H ₂ O.....	.45	.025	
Insol.....	.23		
	99.76		
S.G.....	2.829		

The excess of base over acid requires explanation, and there is a remarkable paucity of analyses that can be used for comparison. The vein is in diorite gneiss and is presumably a high temperature deposit.

Epidote

Recently the Royal Ontario Museum of Mineralogy received from T. L. Gledhill, Esq., an unusual sample of epidote from claim 13138, Harker township. The specimen weighs about fifty pounds and consists of radiating and sheaf-like aggregates of epidote in quartz and garnet. Some of the radiating masses are as much as four inches long. In colour the mineral is a fine pistachio green.

Marcasite

Some specimens collected on the dump of the Trout Lake mine, South Lorrain, show mammillary radiating incrustations of marcasite on glassy white quartz. The crust is seldom more than one-quarter of an inch thick. While the upper surface is rusty with a film of limonite, it is often possible to recognize the characteristic pointed terminations of marcasite. Some small closed cavities, when broken

open, are seen to be lined with brilliant brassy crystals. The ore being mined at the Trout Lake mine when these specimens were collected was all very much weathered, so that the marcasite is probably not a part of the original vein filling.

EXPLANATION OF PLATES

PLATE I

- Fig. 1.—Cleavage fragment of calcite showing cleavage parallel to $e(01\bar{1}2)$.
 Figs. 2, 3, and 4.—Cleavage fragments of calcite showing cleavages parallel to $r(10\bar{1}1)$ and $e(01\bar{1}2)$.
 Fig. 5.—Antozonite (F), Ellsworthite (E), and Zircon (Z) ($\times 7$).

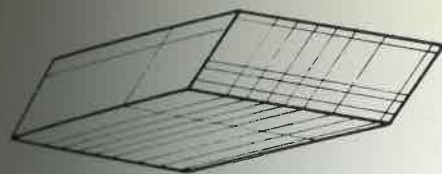


Fig. 1

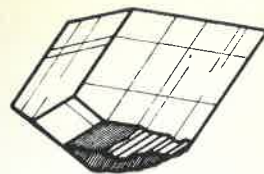


Fig. 2

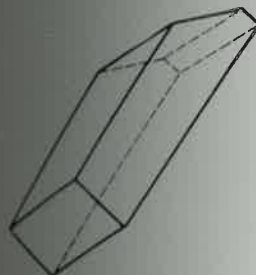


Fig. 3

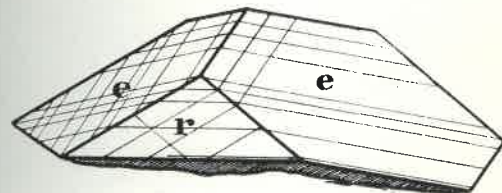


Fig. 4

PLATE II

- Fig. 1.—Phlogopite showing twinning and zonal structure, lot 10, concession XI, Bedford township, Ontario ($\times \frac{1}{2}$).
 Figs. 2 and 3.—Phlogopite showing twinning and zonal structure, lot 13, concession XII, Loughboro township, Ontario ($\times \frac{1}{2}$).
 Fig. 4.—Phlogopite showing zonal structure from lot 27, concession XI, Bedford township, Ontario, printed directly from the mica and reduced ($\times \frac{1}{2}$).

PLATE III

- Fig. 1.—Loellingite, Keeley mine, South Lorrain, Ontario ($\times \frac{1}{2}$).
 Fig. 2.—Keweenawite showing niccolite (N), rammelsbergite-safflorite (RS), and domeykite (D) ($\times 156$).
 Fig. 3.—Microcline micropertite, lot 3, concession XI, Loughboro township, Ontario ($\times 23$).

PLATE IV

- Fig. 1.—Unaltered rammelsbergite, Keeley mine, South Lorrain, Ontario (nat. size).
 Fig. 2.—Rammelsbergite after exposure to moist air for one week (nat. size).



Fig. 5

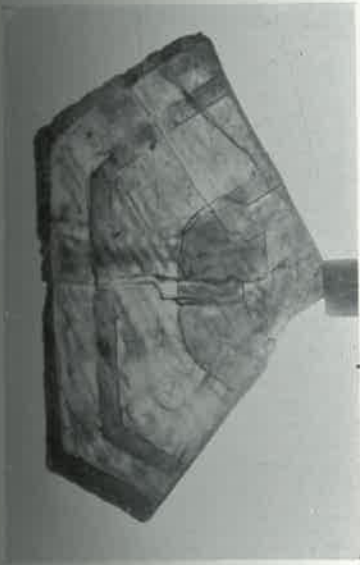


Fig. 1

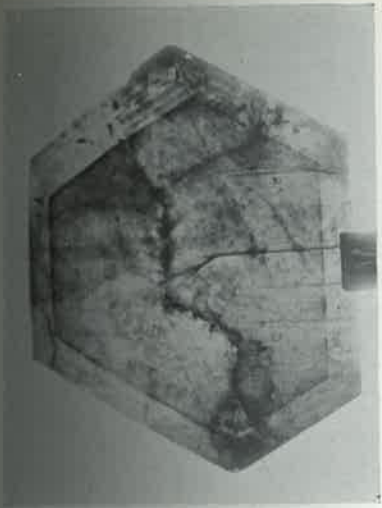


Fig. 2

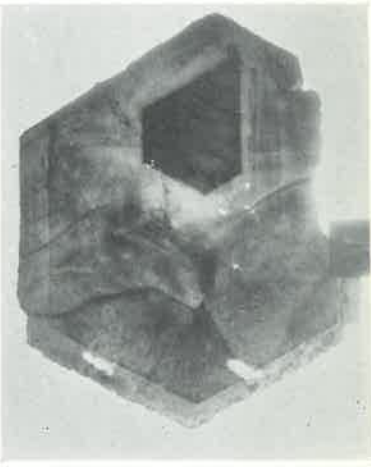


Fig. 3

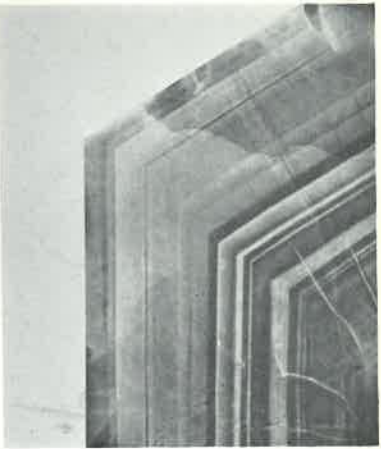


Fig. 4

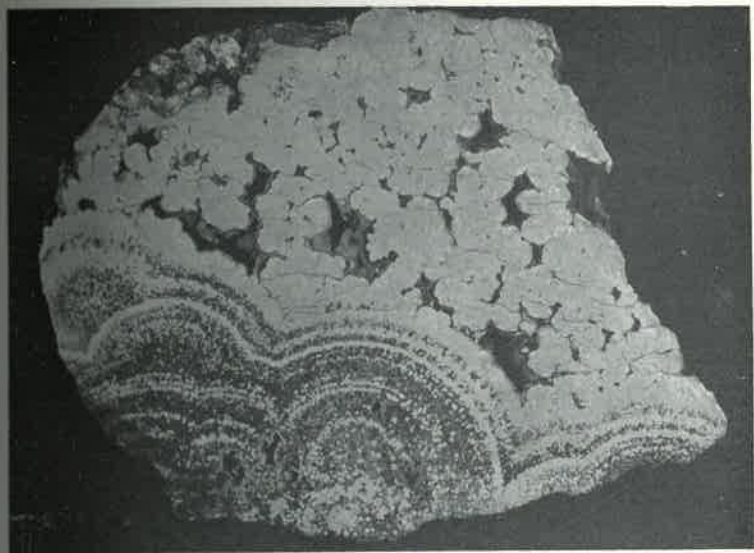


Fig. 1

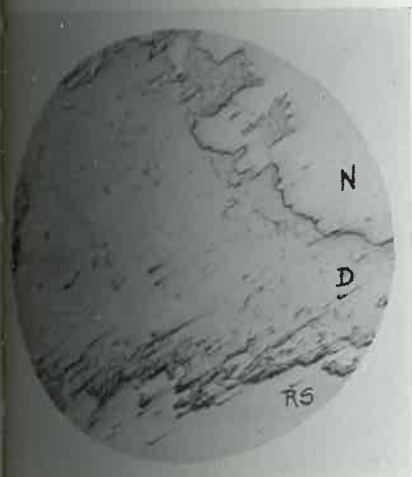


Fig. 2



Fig. 3

Fig. 1

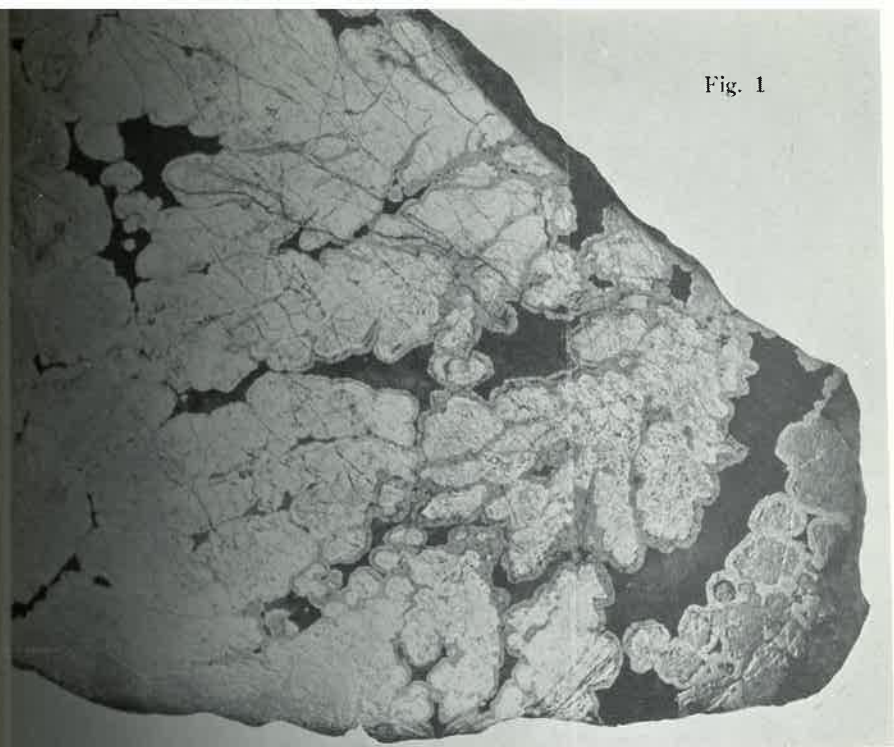


Fig. 2

