HORNBLENDE LAMPROPHYRE DYKES IN SOUTHWESTERN LESUEUR TOWNSHIP, QUEBEC

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ABSTRACT

A dense swarm of hornblende lamprophyre (spessartite) dykes intrudes Keewatin-type rocks near Bachelor Lake in the southwest part of Lesueur Township, Abitibi-East County, Quebec. These narrow vertical northwesterly-striking dykes lie near the southeast edge of a small pluton composed of eucrite, olivine gabbro, and gabbro. Most of the spessartite dykes have conspicuous euhedral phenocrysts of hornblende and augite in a groundmass rich in slender prisms of hornblende. The spessartite generally shows partial alteration of augite to uralite, extensive alteration of plagioclase to clinozoisite, white mica, and albite, and complete alteration of olivine to tremolite.

Part of the swarm of dykes cuts an orebody composed of sphalerite, pyrite, pyrrhotite, and small amounts of galena, chalcopyrite, native silver, pyrargyrite, polybasite, marcasite, arsenopyrite, and magnetite. Several spessartite dykes cut ore rich in sphalerite, pyrite, or pyrrhotite and contain, themselves, sparse native silver, chalcopyrite, and galena. One explanation of this relationship is that the dykes were emplaced after deposition of most of the ore but before the silver, copper, and lead minerals; other explanations require either highly selective replacement by the ore minerals or selective redistribution of ore minerals as a consequence of intrusion of the dykes.

The spessartite dykes are somewhat similar texturally and mineralogically to the gabbro and olivine gabbro forming part of the southeast margin of the pluton and very similar mineralogically and in type of alteration products to the gabbro pegmatites in the eucrite core. These similarities and the close spatial association suggest that the spessartite and the eucrite are related genetically.

Introduction

A dense swarm of hornblende lamprophyre (spessartite) dykes has been revealed by detailed surface mapping and extensive diamond drilling in an area situated a few miles southwest of Bachelor Lake, Quebec. The Lake is near the centre of Lesueur Township, Abitibi-East County and may be reached conveniently by means of the road and railway shown in Fig. 1 and by means of aircraft based at Senneterre.

The regional setting of the spessartite dykes may be seen on the maps made by Sproule (1940), Longley (1951), and Graham (1950), who worked on scales of 1:253,440, 1:63,360, and 1:24,000 respectively. The dyke swarm is approximately equidistant from the sides of a long irregular northeasterly-trending belt consisting predominantly of steeply-dipping Keewatin-type lavas and pyroclastic rocks which are concealed in many places by glacial deposits. This belt, which is about six miles wide in

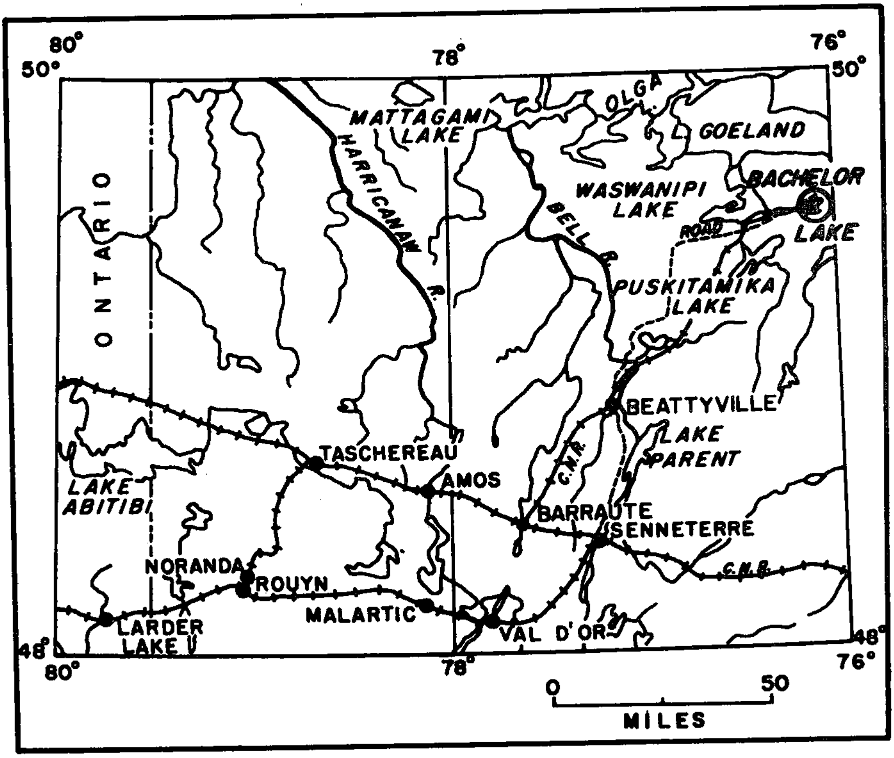
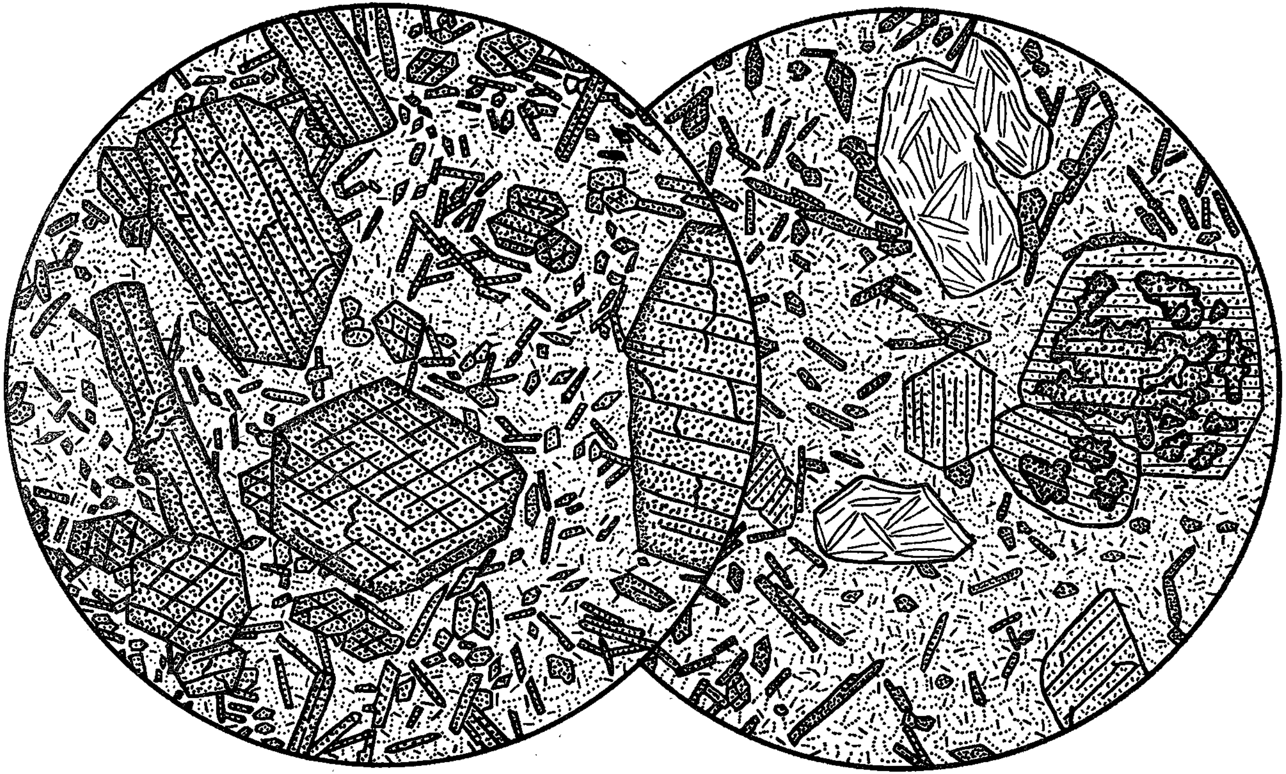


FIG. 1. Index map of northwestern Quebec showing location of Bachelor Lake, which is near the centre of Lesueur Township.

the vicinity of the dyke swarm, is intruded on both sides by granitic batholiths.

Typical parts of the swarm of spessartite dykes are shown in Figures 2 and 3. Most of the dykes are narrow vertical bodies that strike northwesterly. They crop out and have been intersected by drill holes mainly in a northeasterly-trending zone about three miles long and a few thousand feet wide. This zone lies along the southeast edge of a northeasterly-trending pluton, at least three miles long and one mile wide, composed principally of eucrite, olivine gabbro, and gabbro. A few of the dykes cut the margin of the pluton but most of them cut the andesitic lavas, andesitic pyroclastics, and rhyolitic pyroclastics adjacent to it. The dykes have sharp chilled contacts and, apparently, caused no metamorphism. Small amounts of kimberlite, described previously (Watson, 1955), and granite porphyry were intersected by drill holes among the spessartite dykes but the relationships of these three rock types are not yet known.



A B

FIG. 4. Spessartites. **A.** Phenocrysts of brown hornblende with green rims in groundmass composed mainly of hornblende prisms, sodic plagioclase, and clinozoisite and white mica after plagioclase. Diameter 5 mm. **B.** Phenocrysts of partly uralitized augite (right), uralite (centre and lower right), and tremolite after olivine (top and centre) in groundmass composed mainly of hornblende prisms, sodic plagioclase, and clinozoisite and white mica after plagioclase. Diameter 5 mm.

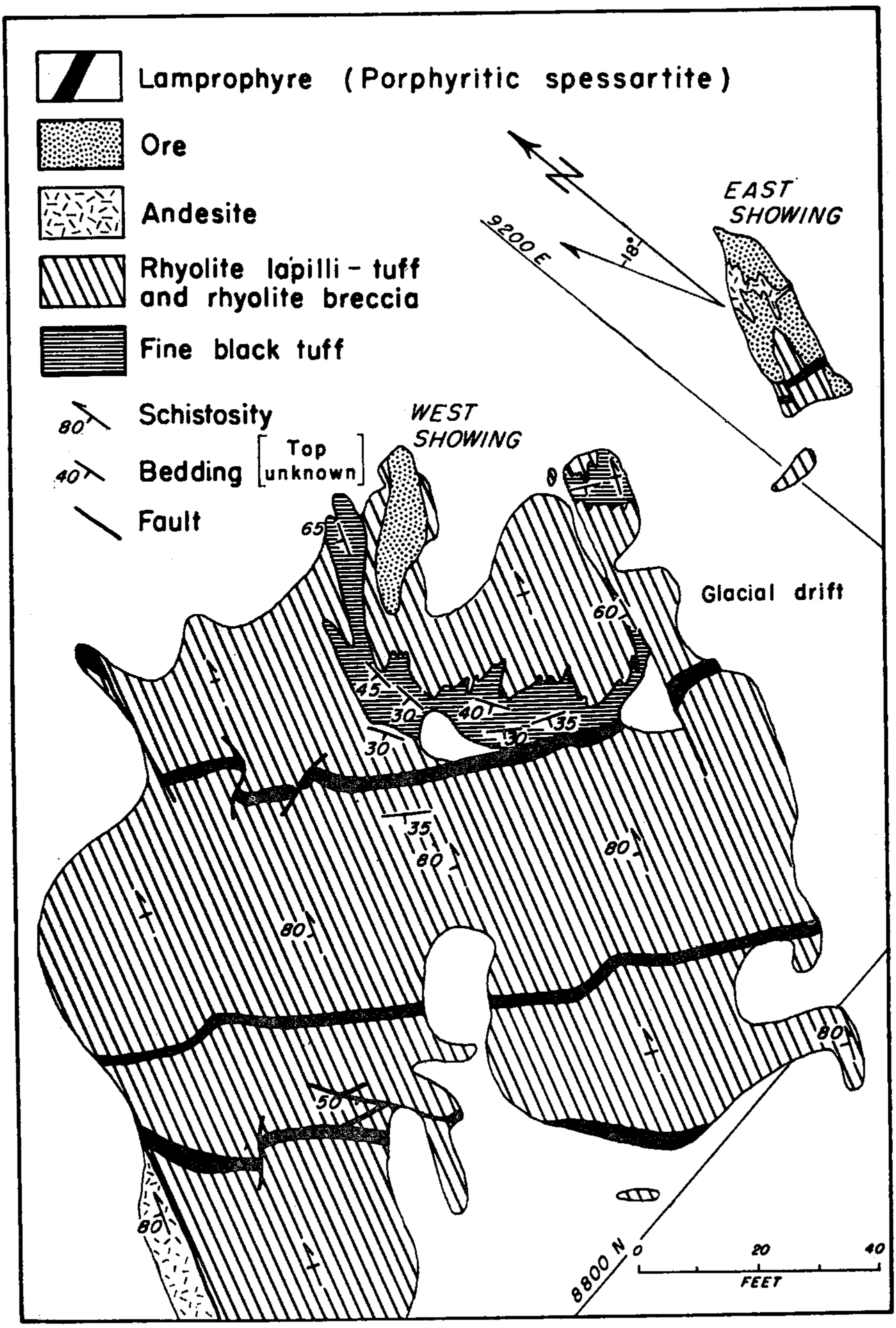


FIG. 3. Spessartite dykes exposed near the main showings. Ore plunging to the southwest beneath the fold outlined by the black tuff is cut by the dykes below the surface.

Eucrite, Olivine Gabbro, and Gabbro

The unaltered eucrite, which forms numerous outcrops near the centre of the pluton, is dark gray, massive, medium-grained, and xenomorphic granular. The mineralogical composition of a representative specimen of this eucrite, determined by micrometric analyses of four thin sections, is recorded in Table 1. Its chemical analysis is listed in Table 2 and that of the well-known eucrite from Mull is included for comparison. The plagioclase of the Quebec eucrite is unzoned calcic bytownite (*ca* An_{85}); the metallic minerals are magnetite and a small amount of ilmenite. The properties of the hornblende are: X = pale yellow, Y = medium olive brown, Z = medium olive greenish brown; $X < Y = Z$; $(-)\ 2V = 75° - 80°$; $Z \wedge c = 24°$. Some unaltered eucrite nearby contains intermediate bytownite (*ca* An_{80}), small amounts of hypersthene and green hornblende, and traces of pleonaste. The order of crystallization of the

TABLE I. MINERALOGICAL COMPOSITION OF EUCRITE & SPESSARTITE*

	1		2	3	4	5	6	7	8
Olivine	9	Phenocrysts							
Tremolite after olivine			10	5	4	2	1		
Magnetite after olivine			tr	tr	1				
Augite	30		20	10	10	4			
Uralite			5	14	10		19	2	
Sphene after augite			tr	1	tr	tr	tr	tr	
Carbonate after uralite							1		
Chlorite after uralite						1			
Brown hornblende			10			25	2	21	
Green hornblende			tr			3	tr	2	
Chlorite after hornblende						2			
Brown hornblende	7	Groundmass	15	15	25	20	20	20	20
Green hornblende			10	15	5	10	5	15	20
Feldspar (dominantly plagioclase)	50 (An_{85})		3	15	15	4	15	20	30
White mica after plagioclase			10	9	5	1	10	5	10
Clinozoisite after plagioclase			15	8	25	23	10	10	15
Sphene			tr	2	tr	1		1	1
Apatite				tr					tr
Metallic minerals	4			tr				1	tr
Quartz			1			1	10	1	1
Epidote			1	2		3	2	2	3
Chlorite				3			2		
Carbonate				1			3		

*Percent by volume; number 1 measured, others estimated. Number 1 is eucrite, others are spessartite. Numbers 1, 7, and 8 correspond to 1, 2, and 3 respectively, in Table 2.

TABLE 2

	1	2	3	4	5	6	7	8
			CHEMICAL ANALYSES					
SiO_2	44.60	47.21	52.50	46.66	48.55	51.86	53.52	40.70
TiO_2	.64	.84	.61	.47	1.91	1.50	1.24	3.86
Al_2O_3	18.86	17.92	17.60	16.71	16.52	16.40	14.57	16.02
Fe_2O_3	3.82	3.09	3.31	2.69	3.16	2.73	3.52	5.43
FeO	6.31	6.32	3.18	5.87	8.00	6.97	5.29	7.84
MnO	.16	.28	.10	.12	.22	.18	.38	.16
MgO	8.93	6.14	5.74	12.36	6.71	6.12	6.60	5.43
CaO	14.69	11.31	9.61	12.57	9.49	8.40	7.03	9.36
Na_2O	1.19	3.13	3.66	1.16	3.10	3.36	3.48	3.23
K_2O	.11	1.07	1.31	.27	.95	1.33	2.28	1.76
H_2O+	.54	1.74	1.43	1.24	1.11	.80	1.75	2.62
H_2O-	.02	.03	.03	.13	.00	.00	.00	.00
P_2O_5	.00	.22	.24	.13	.28	.35	.34	.62
CO_2	.02	.44	.19	.18	n.d.	n.d.	n.d.	2.97
S	.01	.10	.12	.00	n.d.	n.d.	n.d.	n.d.
Total	99.90	99.80	99.59	100.56	100.00	100.00	100.00	100.00
			NORMS					
Q	—	—	.84	—	—	.3	1.45	—
C	—	—	—	—	—	—	—	.17
or	.67	6.34	7.79	1.61	5.6	7.8	13.47	10.40
ab	10.07	26.53	31.14	9.75	26.2	28.3	29.41	27.31
an	45.84	31.73	27.79	39.47	28.4	25.8	17.41	23.56
wo	11.27	8.44	7.23	8.63	7.1	5.6	6.36	—
en	8.66	.98	14.35	17.38	9.2	15.3	16.43	.26
fs	2.98	.53	2.42	4.51	5.0	8.5	5.47	.08
fo	9.53	10.10	—	9.29	5.3	—	—	9.29
fa	3.65	6.00	—	2.66	3.3	—	—	2.90
mt	5.51	4.31	4.61	3.89	4.6	3.9	5.09	7.87
il	1.21	1.59	1.15	.89	3.6	2.9	2.35	7.33
ap	—	.54	.57	.30	.7	.8	.81	1.48
pr	.02	.18	.22	—	—	—	—	—
cc	.05	1.00	.43	.41	—	—	—	6.75
H_2O+	.54	1.74	1.44	1.23	1.1	.8	1.75	2.62
Total	100.00	100.01	99.98	100.02	100.1	100.0	100.00	100.02
			NORMATIVE FELDSPAR					
or	1	10	11	3	9	12	22	17
ab	19	42	48	20	45	47	50	46
an	80	48	41	77	46	41	28	37
			NORMATIVE PYROXENE					
wo	47	84	28	26	32	18	21	—
en	42	11	64	62	48	58	63	82
fs	11	5	8	12	20	24	16	18
			NORMATIVE OLIVINE					
fo	79	71	—	83	70	—	—	82
fa	21	29	—	17	30	—	—	18

EXPLANATION OF TABLE 2

1. Eucrite, 1200 feet S10°W of northeast corner of Mistassini Lead Corporation property, Lesueur Township, Quebec; near centre of pluton; specimen 1 in Table 1; E. H. Oslund, analyst.
2. Spessartite, 100 feet S70°W of West Showing (Fig. 3); specimen 7 in Table 1; E. H. Oslund, analyst.
3. Spessartite, 900 feet N45°E of West Showing (Fig. 3); specimen 8 in Table 1; E. H. Oslund, analyst.
4. Eucrite, Mull, Scotland (Bailey *et al*, 1924, p. 23).
5. Average of ten hornblende diorites and hornblende-augite diorites (Nockolds, 1954, p. 1019).
6. Average of 50 diorites (Nockolds, 1954, p. 1019).
7. Average of ten spessartites (Daly, 1933, p. 28).
8. Average of 15 camptonites (Daly, 1933, p. 28).

mafic minerals is deduced as: olivine, hypersthene, augite, brown hornblende, and green hornblende. The plagioclase appears to have crystallized contemporaneously with hypersthene, augite, and brown hornblende.

Some of the eucrite shows alteration of plagioclase to clinozoisite and white mica, augite to uralite, and olivine to talc, magnetite, tremolite, bowlingite, and antigorite.

Relatively unaltered olivine gabbro occurs locally in the southeast part of the pluton. It differs from the eucrite by having a less calcic plagioclase (An_{60-70}), less olivine, brown hornblende, and magnetite, no hypersthene, and more green hornblende. The green hornblende has X = pale yellow, Y = medium yellowish green, and Z = medium green; $X < Y = Z$. Some of the olivine gabbro contains 5–10% of brown biotite partly altered to chlorite, epidote, and sphene, and 2–3% of apatite. The biotite and apatite crystallized later than most of the green hornblende.

Most of the gabbro and olivine gabbro in the southeast part of the pluton is highly altered mineralogically. Typically, it is a gray, medium-grained, massive rock composed of about equal amounts of mafic minerals which tend to be subhedral and euhedral, and of altered plagioclase. The mafics include mainly actinolite pseudomorphous after augite, and hornblende. The latter, which is a brown variety with green rims, is commonly molded on the pseudomorphs after augite and it is altered locally to chlorite and epidote. The plagioclase is completely changed to albite containing small inclusions of white mica and clinozoisite or epidote. Some of the gabbro specimens contain a little tremolite and magnetite after olivine; others show no pseudomorphs after olivine, and few or no pseudomorphs after augite but contain abundant hornblende and some primary interstitial quartz. Sphene and apatite are common as minor accessories.

Hornblende Gabbro Pegmatite

Many small dykes and irregular bodies of hornblende gabbro pegmatite cut the fresh eucrite near the centre of the pluton. Most of them are only a few inches wide and only a few feet to a few tens of feet long. In most places, the contacts between pegmatite and eucrite are gradational through distances of several millimeters. The pegmatite is a gray, coarse, xenomorphic-granular, massive rock composed chiefly of plagioclase and hornblende. Commonly, these two minerals occur in approximately equal amounts and form irregular crystals ranging from one fourth to one inch in diameter. The plagioclase is unzoned and is labradorite (*ca* An_{65}). Much of the labradorite shows alteration to clinozoisite, epidote, and white mica. In some specimens, narrow irregular veinlets of albite cut the labradorite crystals and occur along their boundaries. Microscopically, most of the hornblende is brownish colored (X = pale yellow; Y = medium olive brown, Z = medium olive greenish brown; $X < Y = Z$, (—) $2V = 75°–80°$; $Z \wedge c = 23°$). Some hornblende crystals, however, become distinctly greenish toward their margins and in some specimens, all the hornblende is brownish green. Locally, the hornblende is slightly altered to epidote, actinolite, and chlorite. A small amount of augite, which is mantled and extensively replaced by hornblende, is found near the edges of some dykes. Occasional crystals of augite are almost completely pseudomorphed by single crystals of actinolite containing fine-grained sphene. The margin of one pegmatite dyke contains a few clusters of fine-grained talc, magnetite, and tremolite which appear to be pseudomorphs after olivine. Magnetite is present as a minor accessory in some sections.

From the foregoing descriptions, it is apparent that the pegmatite contrasts with the enclosing eucrite not only in grain size but also in:

(1) composition of plagioclase (*ca* An_{65} in the pegmatite and An_{80-85} in the eucrite)

(2) dominant mafic mineral (hornblende is far more abundant than the other mafics in the pegmatite but is greatly surpassed in amount by augite and olivine in the eucrite)

(3) degree of alteration (in the pegmatite, plagioclase and the small amounts of augite and olivine present are considerably altered whereas in the adjacent eucrite these minerals are remarkably fresh).

The marked contrast between the amount of alteration of the hornblende gabbro pegmatite and that of the adjacent eucrite shows that the alteration of the pegmatite is deuteric and thus confirms the testimony of their coarse grain size that they crystallized from a magma rich in volatiles.

Spessartite

The term—lamprophyre—was introduced by von Gümbel in 1879 and since then, it and the names of particular types of lamprophyres have been used with a variety of meanings. In 1936, Knopf (pp. 1745–1749) reviewed the somewhat chaotic development of the lamprophyre concept and recommended the use of "... descriptive names, without genetic implications: in short," adherence "to a petrographic rather than a genetic classification" (p. 1748). He suggests that the term, lamprophyre, be used "... only for mesotype (= mesocratic) or melanocratic rocks carrying solely ferromagnesian phenocrysts in an aphanitic or microgranular groundmass, and in which the ferromagnesian minerals in the groundmass show notable idiomorphism" (pp. 1748–1749). Knopf's recommendation seems to have found wide acceptance in recent years and is followed in this paper. Almost all the dykes described here clearly meet the requirements of the foregoing definition and all have mineralogical compositions that place them among the type of lamprophyre known as spessartite.

Figure 2, which depicts a typical part of the swarm, indicates that practically all the spessartite dykes are porphyritic but a few are equigranular. Some microscopic features of the porphyritic spessartites are shown in Fig. 4.

The mineralogical compositions of seven representative specimens of spessartite are listed in Table 1 and chemical analyses of two of the specimens are given in Table 2. As can be seen from Table 1, one analyzed specimen (No. 7) contains phenocrysts that are almost exclusively hornblende, and the other (No. 8) is an equigranular spessartite rich in hornblende and feldspar. Comparison with the chemical analyses of some other rocks included in Table 2 shows that the hornblende-rich spessartites from Lesueur Township have considerable similarity to average hornblende diorite and hornblende-augite diorite, average diorite, and average spessartite, and have some distinct differences from average camptonite.

The typical porphyritic spessartite is a dark greenish gray rock containing mainly medium-grained euhedral and subhedral phenocrysts of mafic minerals in an aphanitic to fine-grained panidiomorphic groundmass. The groundmass commonly shows flow structure, especially in the chilled margins and adjacent to large phenocrysts. The phenocrysts, which constitute about 30 per cent of most dykes, included, before alteration, augite, olivine, hornblende, and very rarely, plagioclase. Many of the augite phenocrysts are partly or completely replaced by single crystals of uralite containing very finely disseminated sphene (Fig. 4B).

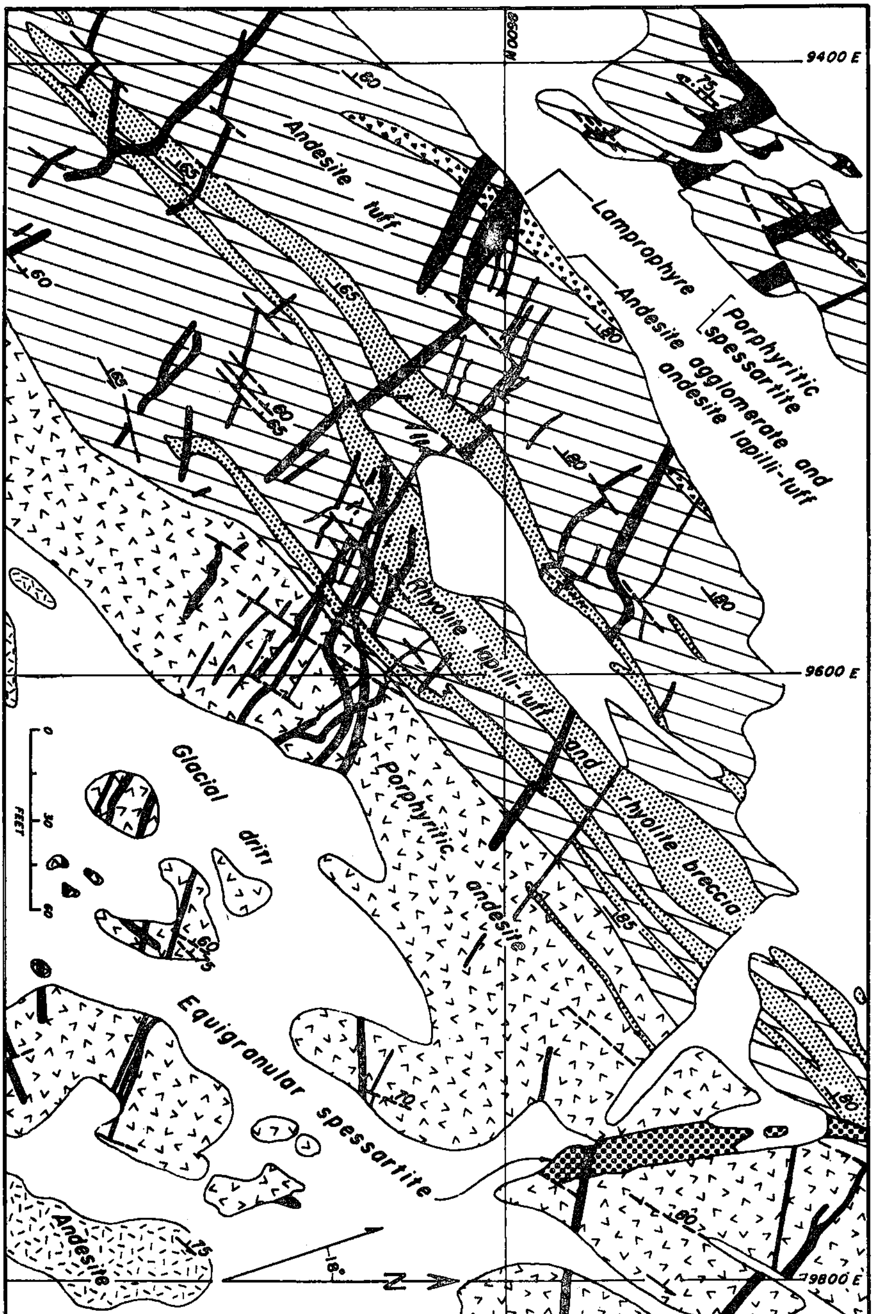


FIG. 2. Part of the swarm of spessartite dykes. The area shown is approximately 1000 feet southeast of the margin of the eucrite pluton; although outcrops are scarce in the intervening area, those that are present and drill holes indicate about the same density of dykes as shown here.

Some grains of augite are mantled by brown hornblende which grades outward to green hornblende. The former olivine phenocrysts are entirely altered to aggregates of randomly-oriented tremolite fibres and minor magnetite (Fig. 4B). Hornblende phenocrysts, which are present in most but not all of the porphyritic dykes, have brown cores with very narrow green rims (Fig. 4A). The properties of the brown hornblende are: X = pale yellow, Y = medium olive brown, Z = medium olive greenish brown; $X < Y = Z$; (—) $2V = 75°–80°$; $Z \wedge c = 24°$.

Before alteration, the groundmass consisted mainly of about equal amounts of hornblende prisms and tabular crystals of zoned plagioclase. The hornblende crystals, which are green with brown cores, are unaltered except for a small amount of locally-occurring chlorite and epidote. (The pleochroism of the green hornblende is: X = pale yellow, Y = medium yellowish green, and Z = medium green; $X < Y = Z$.) The feldspar crystals, on the other hand, are generally altered completely to aggregates of clinozoisite, white mica, and albite. Clinozoisite generally predominates at the centres of the aggregates; clear albite commonly forms the margins of the pseudomorphs and probably represents unaltered rims of zoned crystals. Labradorite was identified in the cores of a few relatively unaltered grains. A few porphyritic spessartites have small amounts of quartz in the groundmass. Biotite, microcline, primary sphene, and apatite are present in small quantities in a few sections. Some of the porphyritic dykes have no pseudomorphs after olivine, less augite, and more hornblende than most and thus approach the equigranular spessartite in composition.

The equigranular spessartites are similar mineralogically to the groundmass of the porphyritic dykes. Their textures are panidiomorphic and although most are equigranular, some are slightly seriate. The largest crystals, which are medium-grained, are mainly hornblende and minor plagioclase. The hornblende crystals, like those of the porphyritic spessartite, have brown cores and green rims but the green rims are much wider than in the porphyries. Plagioclase, which formed zoned tabular crystals, has been largely altered to aggregates of clinozoisite, white mica, and albite. Quartz is present in small amounts in the finest grained parts and apatite and sphene are minor accessories.

The porphyritic and equigranular spessartites generally contain small amounts of epidote (Table 1), and occasionally chlorite and carbonate, that occupy interstices among the euhedral and subhedral crystals of the rocks. There is no evidence that these interstitial minerals are secondary.

The dykes are commonly cut by veinlets of prehnite, clinozoisite, epidote, carbonate, quartz, or chlorite.

The porphyritic and equigranular spessartites are undoubtedly related for they show great similarity in mineralogy, some individual dykes grade from one texture to the other, and dykes of intermediate type are present. In one place, a porphyritic dyke cuts an equigranular one (Fig. 2). This age relationship might be explained by the assumption that the more fluid upper part of a body of differentiated magma was intruded first and it crystallized to form equigranular spessartite. Later, more deformation caused intrusion of the lower less fluid part of the magma—a part containing many pyroxene, hornblende, and olivine crystals—and it formed a porphyry. This assumption should not be used as an explanation of all age relationships, however, for in one place where porphyritic spessartite dykes intersect (Fig. 2), the older one is much richer in phenocrysts than the younger one.

Relationship between Spessartite Dykes and a Zinc–Lead–Silver Orebody

An orebody containing approximately 365,000 tons of zinc-lead-silver ore to a depth of 600 feet has been indicated by drilling on the property of Coniagas Mines three miles southwest of Bachelor Lake. The ore has replaced mainly rhyolitic lapilli-tuff and breccia and sericite schist derived therefrom. Ore deposition was controlled chiefly by northeasterly-striking steeply-dipping stratification and schistosity in these rocks and locally by southwesterly-plunging minor folds. The principal metallic minerals in the orebody, in order of decreasing abundance, are sphalerite, pyrite, pyrrhotite, galena, chalcopyrite, native silver, polybasite[1], and pyrargyrite[2]. In addition to these, marcasite, arsenopyrite, and magnetite occur sparsely in a few parts of the orebody. Textural relations show that the sphalerite, pyrite, and pyrrhotite were deposited before the galena, chalcopyrite, native silver, polybasite, and pyrargyrite. A minute amount of medium reddish brown sphalerite occurs with galena in narrow veinlets that cut the abundant light brown sphalerite, and for this reason, is placed in the second stage of deposition. The chalcopyrite is intimately associated not with sphalerite as is common in other deposits, but with galena and with native silver. The close association of native silver and chalcopyrite is not unusual for it has been noted at Great Bear Lake (Kidd & Haycock, 1935), Wickenburg, Arizona (Bastin, 1923), Kongsberg, Norway (Neumann, 1944), Laver mine, Sweden (Ödman, 1945), and Andreasberg, Germany (Stelzner & Bergeat, 1905, p. 720).

Part of the swarm of spessartite dykes, which strike northwesterly, cuts the orebody, which strikes northeasterly. Most contacts between spessartite and ore are very sharp. In several drill cores, almost massive sulphide ore, containing 25% or more zinc, is in abrupt contact with

[1,2]Identification based partly on spectrographic analyses.

spessartite that is wholly barren of zinc. Several dykes cut ore rich in sphalerite, pyrite, or pyrrhotite and contain, themselves, sparse native silver, chalcopyrite, and galena. These dykes are not mineralized along their entire lengths but only where they cut the orebody. Minute amounts of medium reddish brown sphalerite were seen in three places in spessartite cutting massive light brown sphalerite. In a few dykes, for example, in the one exposed at the East Showing (Fig. 3), the content of native silver and chalcopyrite is locally very high. The mineralized part of this dyke differs from typical unmineralized spessartite mainly in having the hornblende extensively replaced by actinolite, in having an unusually large amount of clinozoisite-epidote in the groundmass, and in having the actinolite, tremolite, and hornblende slightly replaced by biotite. The metallic minerals occur chiefly as replacements of actinolite and clinozoisite-epidote and to a lesser extent as replacements of augite, tremolite, biotite, and white mica.

Although gold is absent from most of the orebody, its presence has been shown by a few assays of ore from the northeast part of the deposit. Its presence in spessartite also has been shown by assays of a dyke cutting this part of the orebody.

The determination of the relative ages of dykes and ore might seem to be among the simplest of geological problems and indeed it is commonly treated as such. However, in some mineral deposits where the relationships have been carefully studied, the problem has proved far from simple and has even led to controversy (see Watson, 1954, pp. 407–408 for a discussion of some examples). The relationships between the spessartite dykes and the ore minerals described above might have originated in the following ways:

1. The dykes were emplaced before any of the ore minerals were deposited but they were relatively unfavorable to replacement and hence resisted it until the last ore minerals were being deposited.

2. The dykes were emplaced after all the ore minerals had been deposited and their intrusion caused local migration of some silver, chalcopyrite, galena, sphalerite, and gold.

3. The dykes were emplaced after deposition of most of the ore minerals but before deposition of the silver, chalcopyrite, galena, and a small amount of reddish brown sphalerite and gold. At present, there is not enough information to allow one to select the right explanation.

Conclusions

Although some types of lamprophyres may require complex conditions for their origin (Bowen, 1928, chaps. 13–14; Eskola, 1954, pp. 334–335), the spessartites of Lesueur Township have chemical and mineralogical compositions that one would expect among differentiates produced by fractional crystallization and filter-pressing of basaltic magma. Moreover, a genetic connection between the spessartite dykes and the pluton of eucrite, olivine gabbro, and gabbro may be deduced from the following observations:

1. The dykes and the pluton are in close spatial association.
2. The principal minerals of the unaltered eucrite near the centre of the pluton—plagioclase, augite, hornblendes, and olivine—are also present, or were present before alteration, in important amounts in most of the spessartite dykes.
3. The optical properties of the hornblendes in the two rock types are similar.
4. The sequence of crystallization is similar in both rock types and the minerals of late crystallization in the eucrite are those most abundant in the spessartites.
5. Gabbro and olivine gabbro forming part of the southeastern margin of the pluton are somewhat similar to the spessartites in texture and very similar in mineralogical composition, and degree and character of alteration.
6. Bodies of gabbro pegmatite within the eucrite, which are evidently differentiates of the eucrite, show great similarity to the spessartite dykes in original mineralogical composition and in type of alteration products.

Recently, others have deduced that hornblende lamprophyres have been derived by fractional crystallization from basaltic magma, although they used evidence somewhat different from that summarized above. Vincent (1953) has described a series from olivine dolerite and dolerite with ophitic and sub-ophitic textures, through oligoclase-dolerite with augite-idiomorphic texture, to camptonitic hornblende lamprophyres with typical panidiomorphic texture among the dykes of the Skaergaard peninsula, East Greenland. He has, moreover, found an oligoclase-dolerite dyke that appears to indicate a link between dolerite and the hornblende lamprophyre for it contains ocelli composed mainly of sodic plagioclase and hornblende. Ramsay (1955) has studied a suite of dykes comprising monchiquite, olivine basalt, olivine dolerite, and hornblende lamprophyre (camptonite) near Monar, Scotland. He observed dykes transitional in composition between the various types of the suite, variation from monchiquite through olivine basalt and olivine dolerite to camptonite within a single dyke, and numerous ocelli of camptonitic composition within the olivine dolerite dykes.

The idiomorphic tendency of many of the crystals in the groundmass of a typical lamprophyre presents an interesting problem. The spessartites from Lesueur Township contain small amounts of anhedral epidote, chlorite, and carbonate in the interstices among the euhedral and subhedral crystals and lamprophyres from various other localities commonly contain considerable quantities of these minerals as space-filling elements of the groundmass fabric. The writer interprets the textural relationships of these interstitial minerals as evidence of their primary origin, while clearly recognizing that the same minerals may occur in abundance as secondary products replacing other minerals in the rock. The presence in many lamprophyres of these hydrous and carbonate minerals as primary constituents and as abundant deuteric alteration products shows that these lamprophyres crystallized from magmas rich in volatiles. The tendency toward idiomorphism shown by many of the crystals in the groundmass may be partly attributed to unhindered growth in the volatile-rich liquid and completion of their crystallization before the interstitial hydrous and carbonate minerals were finally deposited.

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References

Bailey, E. B., *et al* (1924): Tertiary and Post-Tertiary geology of Mull, Loch Aline, and Oban, *Scotland Geol. Survey*, Mem., 1–445.

Bastin, E. S. (1923): Primary native-silver ores near Wickenburg, Arizona, and their bearing on the genesis of the silver ores of Cobalt, Ontario, *U.S. Geol. Surv.*, Bull. 735, 131–155.

Bowen, N. L. (1928): *The evolution of the igneous rocks*, Princeton University Press, Princeton.

Daly, R. A. (1933): *Igneous rocks and the depths of the earth*, McGraw-Hill, New York.

Eskola, Pentti (1954): Ein Lamprophyrgang in Helsinki und die Lamprophyrprobleme, *Tschermaks miner. u. petrog. Mitt.*, F. 3, Bd. **4**, H. 1–4, 329–337.

Graham, R. B. (1950): Southwest part of Lesueur Township, Abitibi-East County, *Quebec Dept. Mines*, Prelim. Rept. **243**, 1–15.

Kidd, D. F. & Haycock, M. H. (1935): Mineragraphy of the ores of Great Bear Lake, *Geol. Soc. America*, Bull. **46**, 879–960.

Knopf, Adolph (1936): Igneous geology of the Spanish Peaks region, Colorado, *Geol. Soc. America*, Bull. **47**, 1727–1784.

Longley, W. W. (1951): Bachelor Lake area, Abitibi-East County, *Quebec Dept. Mines*, Geol. Rept. **47**, 1–38.

NEUMANN, HENRICH (1944): Silver deposits at Kongsberg (the mineral assemblage of a native silver-cobalt-nickel ore type), *Norges Geologiske Undersökelse*, Nr. **162**, 1–133.

NOCKOLDS, S. R. (1954): Average chemical compositions of some igneous rocks, *Geol. Soc. America*, Bull. **65**, 1007–1032.

ÖDMAN, Olaf H. (1945): A nickel-cobalt-silver mineralization in the Laver copper mine, N. Sweden, *Sveriges Geologiska Undersökning*, Ser. C, No. 470, Årsbok **39**, No. 3, 1–10.

RAMSAY, JOHN G. (1955): A camptonitic dyke suite at Monar, Ross-shire and Inverness-shire, *Geol. Mag.*, **92**, 297–309.

SPROULE, J. C. (1940): Puskitamika Lake, Abitibi Territory, Quebec, *Canada Geol. Surv.*, Map 570A.

STELZNER, A. W. & BERGEAT, A. (1905): *Die Erzlagerstätten*, vol. **2**, pt. 1, Verlag von Arthur Felix, Leipzig.

VINCENT, E. A. (1953): Hornblende-lamprophyre dykes of basaltic parentage from the Skaergaard area, East Greenland, *Geol. Soc. London*, Quart. Jour., **109**, 21–49.

VON GÜMBEL, C. W. (1879): *Die palaeolithischen Eruptivgesteine des Fichtelgebirges*, München.

WATSON, K. D. (1954): Paragenesis of the zinc-lead-copper deposits at the Mindamar mine, Nova Scotia, *Econ. Geol.*, **49**, 389–412.

——— (1955): Kimberlite at Bachelor Lake, Quebec, *Amer. Mineral.*, **40**, 565–579.