SPHENE-ALLANITE PEGMATITES OF GRIFFITH TOWNSHIP, RENFREW COUNTY, ONTARIO[1]

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ABSTRACT

Small pegmatites in Griffith Township, Ontario, contain chiefly quartz, microcline, plagioclase, pyroxene and sphene, and accessory hornblende, biotite, apatite, allanite, zircon, scapolite, chlorite, calcite, pyrite and molybdenite. The dikes are weakly to moderately radioactive, which stems chiefly from the sphene and allanite and to a lesser extent from the apatite and zircon. Paragenetic relations indicate that microcline began to crystallize first and that most of the augite is relatively late. The pegmatites are also geochemically peculiar, both in the abundance of calcium-bearing minerals they contain despite their general granitic character, and their content of accessory elements, titanium, cerium, PO_4 and CO_3. They differ from other well-known sphene-bearing dikes in the region in the near-absence of zircon and the relative abundance of allanite.

INTRODUCTION

As early as 1888, Coste (1888) commented on the fine sphene crystals from Renfrew County, Ontario, stating (p. 775) "As crystals, however, they are unexcelled, and many thousand dollars worth have been sold as specimens." Probably the most famous locality in the area has been Turner's Island in Lake Clear in Sebastopol Township, where an 80-lb sphene twin had been recovered by 1888 (Coste, 1888). Spence (1930) in his summary of the pegmatite minerals of Ontario also noted occurrences of sphene in Sebastopol Township, characteristically associated with zircon and apatite, as well as in North Crosby Township near Westport, Ontario. Not far from the latter locality, four miles south of Perth, were found the extraordinary zircon crystals described by Palache & Ellsworth (1928). Zircons, up to 15 lbs in weight, also have been found in Lot 2, Concession V in Brudenell Township, Renfrew County, at Kuehl Lake, about $5\frac{1}{2}$ miles west-southwest of the Turner's Island occurrence (Parsons, 1931).

The geology and mineral deposits of the Renfrew area have been described by Satterly (1946), who records that the Turner's Island deposit was worked between 1879–1882 and yielded 200 tons of apatite. Thus the entire Renfrew area and its environs have long been famous for crystals of sphene, zircon, and apatite, exceptional in abundance, size, and quality.

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In 1955, during the uranium prospecting boom, the area was searched for radioactive deposits. Many of the sphene-bearing pegmatites were found to be weakly to moderately radioactive. The writer examined several occurrences in October 1956. He is indebted to Michigan Memorial-Phoenix Project No. 150 for providing funds defraying costs of some laboratory aspects of the study.

General Geology

The pegmatites studied are between Strain and Burns lakes in Griffith Township and occur in the area shown on the map (Satterly, 1946) to be underlain by a Precambrian unit designated "Granite-pegmatite, granite, granite-gneiss, hybrid gneissies of igneous and sedimentary origin (migmatites)." Northeast of Strain Lake, extending across Highway No. 41, is a series of north-trending belts of hornblende gneiss and marble.

In the vicinity of the deposits the country rock consists chiefly of gray, fine-grained, slightly gneissoid granite, light colored, streaked granite gneiss and less common injection gneiss. The foliation of these rocks strikes north to N. 15° E., dipping 10–30° to the east and southeast. Outcrops generally are scarce, and the dikes are only imperfectly exposed in shallow prospect pits.

Pegmatites

Geology

The pegmatites are generally dikes, tabular to lensoid in shape. Most range in strike from N. 80° W. to E–W and dip steeply or are vertical. About 25 were examined, most of them in four groups. Four showed noteworthy radioactivity and were studied in detail. Their general geology is summarized in Table 1. The dikes show no clear-cut zoning; quartz cores are absent. Dike No. 4 displays a lensoid unit at its eastern contact, about 10 inches across, finer-grained and somewhat more quartzose than the rest and containing a remarkable sphene concentration.

Dikes 1, 2, and 4 are generally similar in texture, color, and bulk mineralogy, consisting in the main of grains (0.4–0.6 inches) of gray quartz and gray to buff feldspar. Dike 2 is coarser, more irregular in grain, and rich in deep red feldspar.

A distinct gneissoid texture distinguishes much of the pegmatite, owing to near parallelism of minute sphene and larger augite crystals. Many specimens also show a porphyritic texture with scattered subhedral to euhedral microcline crystals (1.5–2.5 inches) in the finer-grained quartz-

feldspar matrix. Locally the dikes become vuggy, with one end of the microcline phenocrysts projecting into slit-like cavities. Some vugs are as much as 10 inches long, but rarely exceed an inch in width.

Dike No. 1 also contains small blocky fragments as much as 1 × ½ inch, of fine-grained quartz-biotite-feldspar rock, rimmed by an aggregate of slightly coarser biotite flakes and a few crystals of olive green apatite. These appear to be granitoid xenoliths.

TABLE 1. GEOLOGY OF RADIOACTIVE PEGMATITES, GRIFFITH AREA

No.	Location	Attitude, shape, country rock	Size	Texture and structure	Radioactivity
1	1/4 mi S of southern edge Burns Lake. Claim 18741	N77° W, dips steeply NE. Tabular. In hornblende-bearing granite gneiss	10 ft+thick HW only exposed. Exposed 80 ft along strike	Unzoned. Uniform, even-grained aggregate chiefly of quartz and light gray microcline. Gneissoid and porphyritic; locally vuggy	Area 3×3 1/3 ft near center of dike gave 0.3–0.5% eU_3O_8; rest 0.05–0.15% eU_3O_8
2	NE part claim 18740 SW of No. 1	E–W	At least 5 ft thick. Contacts not exposed. May be as much as 300 ft long	do. Allanite plates as much as 2 in. across locally in western part	Locally as high as 0.4% eU_3O_8
3	East central part of claim 18737. W of No. 2	E–W	At least 15 ft thick; at least 200 ft long	Unzoned. Highly feldspathic. Coarse and irregular grained aggregate chiefly of brick red microcline and subordinate smoky quartz with minor biotite and pyroxene	0.35% eU_3O_8 at eastern end. Max. 0.2% eU_3O_8 at western end
4	SW corner claim 18909	N25° E; steeply dipping or vertical. In gray fine-grained granitic gneiss	About 6 ft thick	Consists chiefly of smoky quartz and gray microcline in even-grained aggregate with minor pyroxene, scapolite and molybdenite. Eastern embryonic wall zone finer grained, quartzose and rich in sphene	Highly variable 0.05–0.8% eU_3O_8. Sphene-rich wall zone as high as 1.0–1.5% eU_3O_8

Mineralogy

All of the pegmatites contain quartz, microcline, plagioclase, pyroxene, and sphene.

Quartz: The quartz is anhedral, except in vugs of Dike 1, where small crystals are perched on microcline crystals. Generally it is clear or slightly milky, except in those parts of dikes where sphene is abundant and coarse or where allanite forms large crystals; here it is gray to deep smoky.

Feldspar: The microcline of the phenocrysts of Dike 1 is very slightly perthitic and contains abundant, minute, oriented microlite needles of an unidentified, probably exsolved, species. Microcline from Dike 2 also contains the needle microlites, concentrated especially in central parts of crystals and oriented at right angles to the (010) cleavage. The red microcline of Dike 3 owes its color to exceedingly minute, irregularly distributed hematite aggregates. It is not perthitic, and the exsolved needles

are absent. Plagioclase is rather variable in composition, ranging between Ab_{87} and Ab_{72}; much of it is calcic oligoclase.

Pyroxene: Pale olive green pyroxene forms blades an inch or less long, most of which are clad in a thin jacket of fibrous hornblende. The pyroxene shows weak pleochroism in pale green tints and has an extinction angle $\gamma \wedge c = 45°+$; it is probably closer to augite than to diopside.

Most of the augite is anhedral and was anhedral even prior to the marginal uralitization. In vugs of pegmatite 3, pyroxene forms single euhedra a half inch or less long and flattened parallel aggregates as much as an inch long. The perched sequence from the outside to the center of the slit vugs is: microcline (forming the walls), augite, apatite, calcite. Vug pyroxene shows no uralitization.

Some of the non-vug pyroxene in Dike 2 has been altered to a very fine-grained mixture of calcite and chlorite. The augite of Dike 4, which shows essentially no uralitization, forms the largest crystals, which range in size from about $\frac{1}{2}$ inch to some over 6 inches long and four inches across. Inclusions are pyrite grains in the outermost $\frac{1}{2}$ inch and large brown apatite crystals in the outer parts.

Hornblende: Hornblende (pleochroic from dark green to olive green) appears only as thin uralitic rims on augite. It is apparantly absent in Dike 4.

Biotite: Biotite is a relatively rare mineral, appearing in scattered flakes usually less than 0.2 inches across. Much of it in Dike 1 appears to be xenocrystic in origin. It is most abundant in Dike 2, which has the least augite and the most allanite. This pegmatite also contains a few muscovite flakes.

Sphene: Sphene, in all cases euhedral, ranges in size from microscopic to about $1\frac{1}{2}$ inches long. It is uniformly dark brown and invariably radioactive. The largest crystals and highest concentrations were found in Dike 4 in the quartzose marginal unit.

Analyses of sphenes from "Renfrew" and "Grenville" were made by Busz (1887), but these show neither radioactive nor rare-earth elements. Modern analyses of sphenes from Turner's Island, Lake Clear, presented by Prince (1938), are unusual in the large amounts of Al_2O_3 obtained (6.32 and 5.96%). These sphenes, which are chocolate brown to nearly black in color, also contain considerable iron ($Fe_2O_3 = 2.73$ and 4.40%). Semi-quantitative *x*-ray fluorescence analyses of two sphenes from Griffith Township (Dike 1, fine-grained; Dike 4, coarse-grained) show that yttrium is present in both, in amounts not exceeding 0.5%. For these analyses I am indebted to Dr. A. A. Levinson. Jaffe (1947), in his study of the chemical composition of sphene, analysed two sphenes from Ontario. One locality is listed only as "Ontario"; the other is "Bancroft,

Ontario." Both sphenes contain fluorine as a minor element, and the latter also contains minor Nb and rare earths.

The radioactivities of minerals from this type of pegmatite have been determined by Larsen *et al.* (1952):

	α/mg/hr	Calculated age
Zircon	84	900 m.y.
Apatite	35.7	1070
Sphene (S_2)	260	490
Sphene (S_3)	122	630

The age of Ontario pegmatites based on Pb isotope determinations on uraninite is 1000 m.y. (Tilton *et al.*, 1955); thus determinations on zircon and apatite check well, but those on sphene are much too low.

Hurley (1952) has also determined the radioactivities of a large number of zircons and sphenes from Ontario pegmatites. Not all of these, however, are from the sphene-rich type of pegmatite. Some are from zoned granitic pegmatites, a few from nepheline syenite dikes, but the type of deposit is not listed, and some localities are by county only. Determinations of radioactivity made by Hurley (1952) on those sphenes that are probably from this type of pegmatite range from 38–254 α/mg/hr. The considerable range in radioactivity agrees with the determinations by Larsen *et al.* (1952) and with field measurements by the writer.

Some of the sphene crystals are wholly or in large part altered to a very fine-grained, grayish white leucoxene. *X*-ray determinations of this aggregate show it is a mixture chiefly of anatase with minor rutile and quartz and some relict sphene (Table 2).

The habit of sphene is uniform throughout the dikes, being virtually identical with that described for sphene from Lake Clear (Prince, 1938, Fig. 8). Crystals are of the "envelope type", i.e. of an inclined prismatic habit owing to dominance of (111) and subordinance of (001), (100), and (110).

Despite some variations in color, probably as the result chiefly of variations in Fe^{+3} content, and despite marked variations in radioactivity, largely owing to Th variations, the optical properties are relatively constant, commonly with α = *ca.* 1.995. This type of pegmatitic sphene is much lower in radioactivity and rare-earth content than the variety yttrotitanite, which characteristically appears in zoned granitic pegmatites associated with radioactive multiple oxide mineral assemblages (Heinrich, 1958).

Apatite: Apatite crystals vary greatly in size and color. The smallest are microscopic; the largest found (Dike 4, included in augite) measured

TABLE 2. *X*-RAY DATA ON ALTERED SPHENE, DIKE NO. 4, GRIFFITH TOWNSHIP, RENFREW COUNTY, ONTARIO

Leucoxene		Anatase		Rutile		Sphene	
d(Å)	I	*d*(Å)	I	*d*(Å)	I	*d*(Å)	I
5.23	1						
3.54	10	3.52	1.00				
3.37	4	(due to quartz)					
3.23	4			3.24	0.80	3.20	1.0
2.98	1					2.98	0.9
2.6	2					2.59	1.0
				2.49	0.60		
2.36	4	2.37	0.24				
				2.19	0.30	2.26	0.7
1.91	4	1.88	0.40				
1.69	3	1.70	0.28	1.69	1.00		
		1.66	0.24	1.62	0.30	1.63	0.7
1.49	2	1.48	0.24	1.48	0.20	1.48	0.7
		1.362	0.08	1.45	0.20	1.41	0.9
1.34	2	1.335	0.08	1.35	0.30		
1.26	1	1.262	0.11				

2 inches long and ½ inch across. The colors are pale green, pale blue and brown (in the largest crystals). Vug apatite tends to be bluish, whereas that in solid pegmatite is usually pale green. Dadson (1933), who has analysed Eganville apatite, also reports a color variation from dull reddish brown to light greenish yellow. The apatite is slightly radioactive (Larsen *et al.*, 1952), usually the least radioactive of the uranium- and thorium-bearing species.

Zircon: Zircon, which is relatively common as large euhedra in other sphene-bearing pegmatites of the region, is very rare in the Griffith dikes. Only microscopic crystals were found in Dike 3. These are rarely over 0.1 inch long, honey brown to red brown in color, and are partly metamict. They are typically the foci for sets of radial fractures. All are radioactive (Buttlar & Houtermans, 1951; Larsen *et al.*, 1952; Hurley, 1952; Hurley & Fairbairn, 1957). The zircons of this type of deposit are markedly lower in radioactivity, other minor elements, and degree of structural damage than the cyrtolitic type of zircon from zoned ordinary granitic pegmatites of the Bancroft-Haliburton region (Ellsworth, 1932, pp. 270–271.)

Allanite: Allanite forms microscopic grains in Dikes 1 and 4, but in Dike 2 a few plates as large as 2 inches across and 0.2 inches thick are present. From the allanite fractures radiate out into surrounding feldspar and dark smoky quartz, and microscopic examination shows that the allanite is strongly damaged structurally but not completely metamict. It shows small scale color variation in brown and red brown, and has abnormally low birefringence, with $\beta = 1.687$. It is the most radioactive

mineral of the dikes, but contributes to the overall radioactivity of the deposits only locally because of its scarcity.

Scapolite: Pale grayish to greenish blue euhedra of scapolite were noted only in Dike 4, in which it occurs near the walls in prismatic crystals as much as 4 inches long and an inch across. Many of the larger crystals have their *c* axes generally normal to the wall rock contacts. The habit varies somewhat; crystals showing nearly square cross sections with second order prisms predominate, but a few are lozenge-shaped in cross section, with first order prisms more strongly developed. Optical properties indicate a probable meionite content of about 50%.

Chlorite: Very fine-grained chlorite, in part admixed with calcite, replaces augite in two of the dikes. Microscopically the chlorite appears a dirty greenish brown, with a mean index of about 1.56.

Calcite: Coarse buff-colored calcite is the youngest mineral in vugs in Dike 3, in which it forms plates measuring as much as 2.2×1.4×0.2 inches.

Pyrite: Minute pyrite cubes were noted in heavy residues from Dike 1, and the mineral also occurs as inclusions 0.1 inches across in the outer parts of large augite crystals in Dike 4.

Molybdenite: Molybdenite scales and plates 0.05 to 0.5 inches across occur in pegmatite exposed in a small prospect pit in Dike 4. The euhedral platelets tend to occur in quartz.

Discussion

The Griffith pegmatites are generally similar to other sphene-bearing dikes in the Renfrew area but differ conspicuously in the near absence of zircon and the relative abundance of allanite. The deposits owe their radioactivity chiefly to sphene and allanite and to a much lesser extent to apatite and zircon. The unzoned pegmatites appear to have been consolidated in an extended but single period of crystallization in which several stages are readily distinguishable:

1. *Phenocryst stage*: Microcline, sphene, allanite, zircon; scapolite (?), apatite I(?), molybdenite (?)
2. *Main magmatic stage*: Microcline, oligoclase, augite, quartz, biotite
3. *Vug stage*: (*a*) Microcline, (*b*) quartz, biotite, augite, (*c*) apatite II, (*d*) calcite I
4. *Early deuteric stage*: Horblende, pyrite (?)
5. *Late deuteric stage*: Chlorite, calcite II, leucoxene (?).

Considerable uncertainty accompanies the placing of scapolite, molybdenite, and pyrite. Muscovite is unassigned; it may belong to stage 2.

Leucoxene may well be supergene. Certainly, the three main stages, 1, 2, and 3, overlapped. Despite this overlap most of the pyroxene crystallized after much of the microcline—an unusual sequence. The dikes are intrusive and their emplacement appears to have been fracture-controlled. The vugs are primary.

Although the dikes contain principally microcline, oligoclase, and quartz, they are geochemically peculiar, first, in the abundance and variety of calcium-bearing minerals that they contain: sphene, allanite, augite, hornblende, apatite, scapolite and calcite. Secondly, their accessory compositional assemblage, namely, Ti, Ce, PO_4, CO_3, and minor Zr, is more suggestive of consanguinity with a feldspathoidal syenite province than with a granitic one. On the other hand, Mo is more characteristically granitic in its association.

It appears at least possible that the unusual composition of these dikes has resulted from modification of granitic pegmatitic magma by means of syntexis of dolomitic marble. The dikes occur near the eastern margins of the granitic complex, which is bordered both to the east and southeast chiefly by marble. If assimilation were to have occurred, it might have taken place shortly after initiation of crystallization in the original granitic pegmatite magma. Thus a granitic silicate fluid, containing crystals of microcline and sphene, may have incorporated additional Ca, Mg, and CO_3. Continued upward migration with concomitant crystallization of this mixture of crystals and modified fluid resulted in the emplacement and consolidation of porphyritic gneissoid pegmatite bodies rich in Ca-bearing minerals.

Such a hypothesis is, of course, highly speculative, for geological evidence for syntexis is absent. Clearly assimilation did not take place at or close to the sites of consolidation.

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