RADIUM AND THE PETROLOGY OF CERTAIN GRANITES OF FINLAND.

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ABSTRACT.

The radium content of various types of granites of Finland is compared with certain petrologic characteristics of the several rocks. No relation is found between radium and potash or ferrous oxide, but for granites belonging to the same type the radium content can be correlated with the amount of biotite.

GEOLOGY OF THE FINNISH GRANITES.

Finland forms the eastern part of the great Fenno-Scandian shield, which, like the Canadian shield, is preponderantly composed of crystalline rocks of pre-Cambrian age. It is generally believed that various regional mountain foldings took place in pre-Cambrian time and that most pre-Cambrian areas show vestiges of these old mountain chains. In Finland detailed geological mapping has shown the existence of several zones of pre-Cambrian folding, the relative age of which has been worked out by Sederholm and his school, who succeeded in demonstrating several distinct pre-Cambrian cycles of sedimentation defined by their relation to tectonic movements. By referring the various granites of Finland to their respective zones of folding, a chronological classification has been obtained.

Svecofennian Zone in Southwestern Finland.

The rocks of this zone strike about E—W and dip more or less vertically (see map, Fig. 1). The oldest are the leptites—fine-grained, metamorphic rocks of partly volcanic, partly sedimentary origin. The leptite formation is penetrated by the so-called *granites of the first group* frequently exhibiting a quartz dioritic composition with differentiation products of more basic character. The typical mode of occurrence is that of anticlinal batholiths—regular massives anticlinally surrounded by layers of schists and gneisses. These rocks are probably among the oldest granites known in the earth's crust; their geological age may therefore be close to 2,000 million years. They almost always show gneissic structure, and are

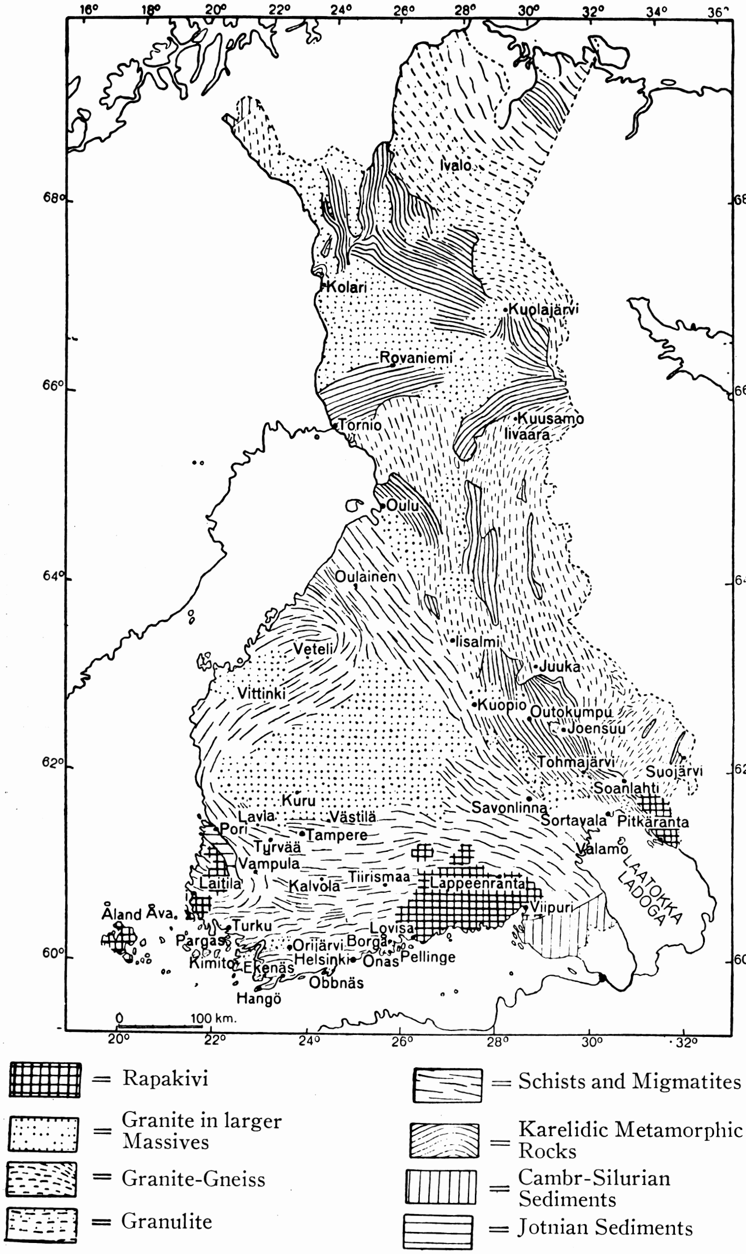

Fig. 1. Rocks of Finland (after Eskola).

often referred to as "gneissose granites." Samples from Åland (No. 71), and from the southern shore of Finland (Nos. 72, 73, and 74) belong to this group.

Younger than the leptites is the Bothnian Formation, comprising a great variety of crystalline rocks of sedimentary as well as eruptive origin, penetrated by the so-called *granites of the second group* which are usually rich in microcline and consequently rich in potash. They evidently intruded the sediments at a time of very active mountain folding. They are typical "serorogenic" granites,[1] intimately connected with migmatization and anatexis. Over great areas they form, with the sediments, injection gneisses and other types of mixed rocks strongly influenced by assimilation and palingenic processes. Several granites of the second group have been sampled: Nos. 75, 76, and 79 from the southern coast of Finland, Nos. 77, 78, 80, 81, and 82 from the interior.

Karelidic Zone in Eastern and Northern Finland.

The rocks of this zone strike northerly and dip more or less vertically. Large areas of post-Karelian granites, the so-called *granites of the third group*, are encountered in northern Finland. But these granites have been sampled from one locality only: Rovaniemi (No. 86).

Rapakivi Granites.

Rapakivi Granites (*granites of the fourth group*) and related basic rocks of southern Finland are younger than any of the pre-Cambrian mountain foldings. Their absolute age has been estimated by Holmes[2] as 1,000 million years. The rapakivi granites of Finland are famous in petrographic literature; it is hardly necessary, therefore, to devote much space to them here, but references to the newest literature are given, and it should be consulted for further information. Quite recently the question of the genesis of the rapakivi granites has aroused much discussion because of Backlund's propounding a

[1] Cf. Wahl, W.: Om granitgrupperna och bergskedjeveckningarna i Sverige och Finland, Geol. För. Förh., 58, 90, 1936.

[2] Holmes, A.: On radioactivity and geologic age, abstracted in Compt. Rend. Réunion int. étude du précambrien et des vieilles chaînes des montagnes, edited by Sederholm, Helsinki, 1933.

granitization-theory disclaiming the primary, magmatic character of the rapakivi granites and similar rocks.[3]

Be this as it may, it is practical to discriminate petrographically between the "true rapakivi" with large ovoids of potash feldspar encompassed by a shell of oligoclase, and the coarse, porphyritic "rapakivi granite" without any shells of oligoclase. Wahl[4] has named these types "Viborgite" and "Pyterlite" respectively. The rapakivi bodies are very homogeneous, so the chemical analyses quoted in Table IV would seem to be quite representative of the samples collected, although in no case was the sample taken from exactly the same locality as the material analyzed. Characteristic of all rapakivi rocks is idiomorphic quartz; the occurrence of orthoclase as primary potash feldspar that only in part has been inverted to microcline; the reddish-brown pigmenting of the feldspar; the general occurrence of fluorite which can be recognized in almost any hand specimen; the abundance of miarolitic interstices; and finally the absolutely massive structure.

RELATION BETWEEN PETROLOGY AND RADIUM CONTENT.

From measurements on granites of Finland by Poole and Joly,[5] Holmes[6] has concluded that potash-rich granites are also rich in radium (uranium). Other authors have concurred. In a recent synopsis, Urry[7] states that a rough correlation

[3] See Backlund, H. G.: Der "Magmaaufstieg" in Faltengebirgen, Bull. comm. géol. Finlande, No. 115, 293-347, 1936 (Compt. rend. soc. géol. Finlande, No. 9); The rapakivi puzzle, Geol. För. Förh., 60, 105-112, 1938; Problems of the rapakivi granites, J. Geol., 46, 339-396, 1938; Zur Granitisationstheorie, Geol. För. Förh., 60, 177-200, 1938. See also Eckermann, H. v.: The genesis of the rapakivi granites, Geol. För. Förh., 59, 503-524, 1937; 60, 113-115, 1938.

[4] Wahl, W.: Die Gesteine des Wiborger Rapakiwigebietes, Fennia, 45, No. 20, 1925.

For a more comprehensive treatise of the geology and petrology of the granites in Finland the reader is referred to the following publications: Eskola, P.: Petrographische Charakteristik der kristallinen Gesteine von Finnland, Fortschr. Mineral. Krist. Petrog., 11, 57-112, 1927; Sederholm, J. J.: Pre-Quaternary rocks of Finland, Bull. comm. géol. Finlande, No. 91, 1-47, 1930; On the geology of Fennoscandia, idem., No. 98, 1-30, 1932.

[5] Poole, J. H. J., and Joly, J.: The radioactivity of basalts and other rocks, Phil. Mag. (6), 58, 819, 1924.

[6] Holmes, A. (Contribution to the theory of magmatic cycles, Geol. Mag., 63, 1926, p. 306) gives the following summary of radium in granites of Finland:

	Group I.	Group II, III.	Group IV.
Ra 10^{-12} g./g.	2.36	4.60	6.21
K_2O %	2.51	3.61	5.06

[7] Lane, A. C., Editor: Report of the Committee on the Measurement of Geologic Time, National Research Council, 1936.

between the Ra and the K content of all types of rocks is still found.

In Fig. 2 the radium content of the granites of Finland examined by us has been plotted against their potash content.

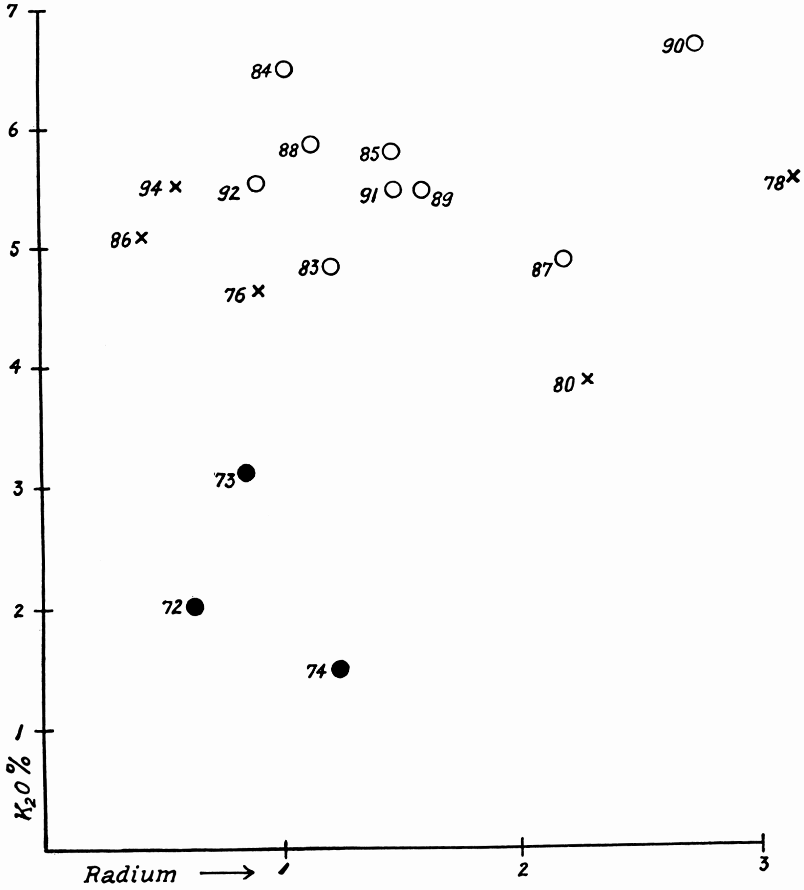

Fig. 2. Content of radium expressed as grams $\times 10^{-12}$ Ra per gram of rock plotted against the percentage of K_2O in the rock. Closed circles = granites of group I, crosses = granites of group II, open circles = granites of group IV.

If any such relation exists in these rocks it is very rough, and more data would be needed to demonstrate it.

Microscopic studies of these granites indicated that biotite-rich granites were also rich in radium. A determination of the biotite content of the Finnish granites was made with the microscope, using the Rosiwal method. At the same time the

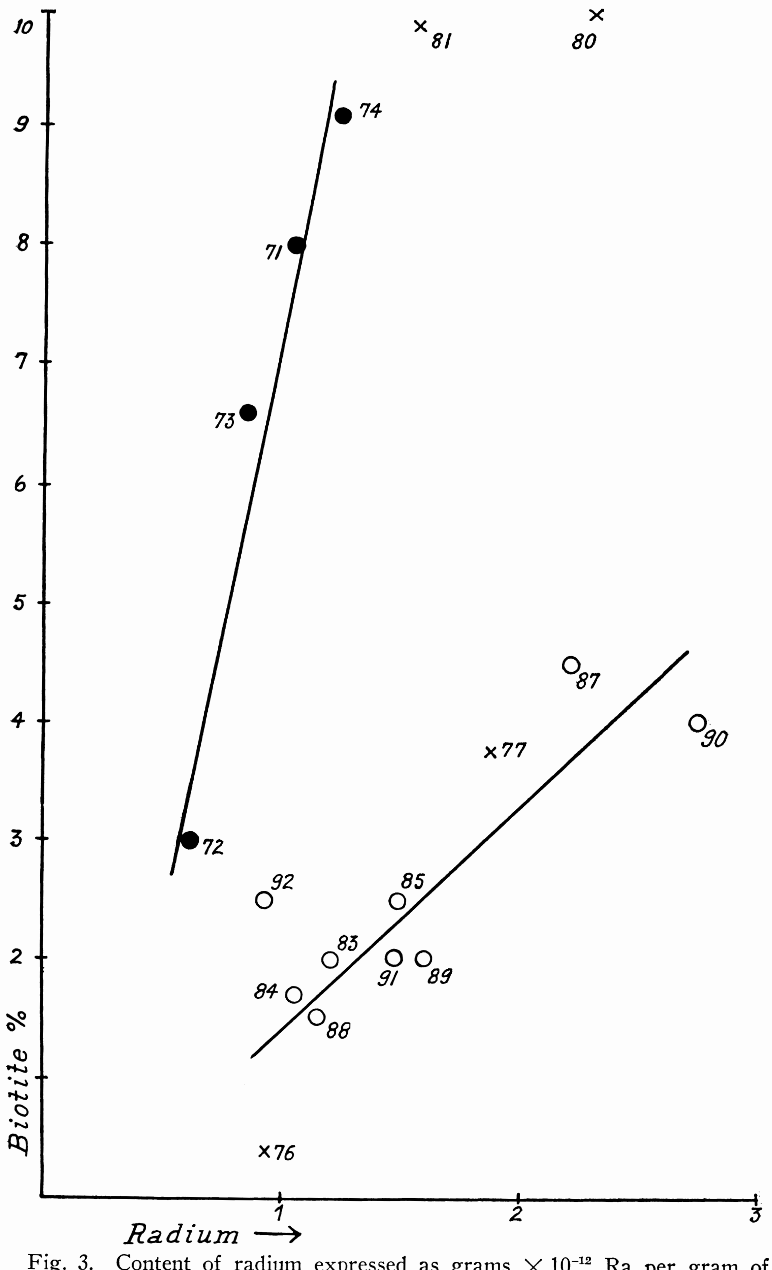

Fig. 3. Content of radium expressed as grams $\times 10^{-12}$ Ra per gram of rock plotted against the volume percentage of biotite in the rock. Symbols as in Fig. 2.

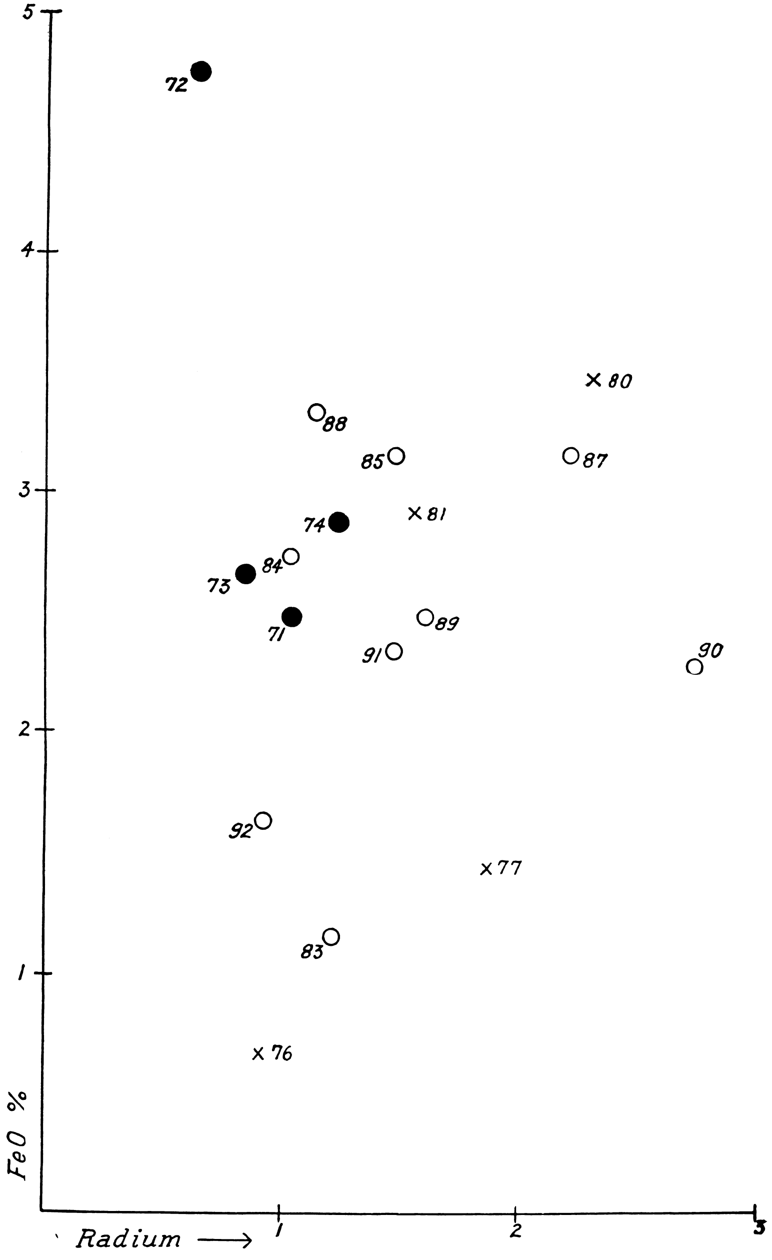

Fig. 4. Content of radium expressed as grams $\times 10^{-12}$ Ra per gram of rock plotted against the percentage of FeO in the rock. Symbols as in Fig. 2.

hornblende content was measured, and as a check ferrous iron was determined by titration in each sample. These data are entered in Tables I to IV and are plotted in the graphs 3 and 4.

Consider the four granites of group I. If the biotite content is plotted against the radium content, the four points lie nearly on a straight line which intersects the horizontal axis not far from the origin. Thus the data on these four rocks would agree with an assumption that most of the radium was in the biotite and that the quantity per gram was nearly the same in each case.

Consider now the nine granites of group IV. If again the biotite content is plotted against the radium content we get similar results; the points lie fairly close to a straight line that passes not far from the origin. Again it appears that there is a tendency for the radium to be concentrated in biotite and for the radium content per gram of biotite to be constant.

Consider finally the eight granites of group II. As stated in a previous section, geologically and petrologically these granites differ from the others. Most of the rocks of group II have been subjected to anatectic processes as well as to contamination from sedimentary material. Some (Nos. 79 and 82) have recrystallized in the helsinkite facies (unakitic facies) in which biotite is unstable and chlorite and epidote are formed instead. The unusually high radium content of some of these granites (Nos. 75, 78, and 82) is possibly due to some special cause. Excluding rocks of the helsinkite facies and rocks with an exceptionally high radium content, only four rocks of the second group are left: Nos. 76, 77, 80, and 81. The data for these are plotted as crosses in Fig. 3. The points are too few and too scattered to locate a line properly, but the best line that can be drawn indicates that here again the quantity of radium per gram is greater in the biotite than in the rest of the rock.

It is interesting to note that in two granites previously examined by Piggot and Merwin[8] the radium was concentrated in the biotite:

Stone Mountain granite,

3.80×10^{-12} g. radium per g. of rock, and
11.3×10^{-12} g. radium per g. of biotite.

North Jay granite,

3.4×10^{-12} g. radium per g. of rock, and
20.7×10^{-12} g. radium per g. of biotite.

[8] Piggot, C. S., and Merwin, H. E.: Radium in rocks: IV, This Journal, *23*, 49-56, 1932.

And in rock No. 75 Piggot found (see preceding paper):

5.51×10^{-12} g. of radium per g. of rock, and
13.47×10^{-12} g. of radium per g. of biotite.

Unfortunately, the data of the present paper are too scanty to give any quantitative information regarding the more exact location and association of the radium in the granites here considered. "To reason without data," says Tutton, "is nothing but delusion." There is, however, qualitative agreement between Piggot's findings as quoted above and the relation between radium and biotite in the Finnish granites. In each group plotted in Fig. 3 the radium content per gram of biotite, calculated from the straight line, is greater than that of the remainder of the rock. Some of these granites carry hornblende, others do not. If the radium content of the hornblende is higher than that of the salic minerals this is a disturbing factor. If graphs analogous to Fig. 3 are prepared plotting biotite + hornblende against radium the points are very scattered. If, however, we plot biotite + some fraction of the hornblende against the radium content the scattering is decreased, and when the fraction of hornblende used is ¼ or less the points lie on straight lines about as well as they do in Fig. 3. In the present granites the content of ferrous iron must be roughly proportional to the content of biotite + hornblende, accordingly a rough relationship might possibly be expected between Ra and FeO. As seen from Fig. 4, however, no such relation is evident.

TABLE I.
Granites of Group I.

Serial No.*	P-71	P-72	P-73	P-74	Average
Ra, 10^{-12} g./g.	1.04	0.63	0.85	1.23	0.94
FeO, weight %	2.47	4.77	2.65	2.88	3.17
Biotite, volume %	8.0	3.0	6.6	9.1	9.1
Hornbl., volume %	0.6	9.2	...	...	
SiO_2	...	70.75	67.36	71.69	...
TiO_2	...	0.32	0.61	0.34	...
Al_2O_3	...	14.54	15.20	13.58	...
Fe_2O_3	...	0.48	0.85	0.62	...
FeO	...	2.15	2.80	3.78	...
MnO	...	...	0.06	0.10	...
MgO	...	0.98	1.30	1.16	...
CaO	...	3.86	3.40	2.23	...
Na_2O	...	3.64	3.93	3.90	...
K_2O	...	2.03	3.12	1.53	...
P_2O_5	...	0.88	...	0.21	...
H_2O	...	0.53	0.84	0.61	...

* Serial numbers correspond to those used in the preceding paper by Piggot.

P-71. Granite from Bockholm, Enklinge, in the Åland Archipelago. A description of this locality has been given by Sederholm [Sederholm, J. J.: On migmatites, etc. (Part III), Bull. comm. géol. Finlande, No. 107, 1934]. The granite is here overlain by a conglomerate separating it from the sediments of the second cycle, and this conglomerate contains also pebbles of the same granite, which therefore necessarily must be older.

P-72. Gneissose granite from Påvskär, ca. 40 km. W. of Helsingfors. This locality has been thoroughly investigated by Sederholm [On migmatites, etc. (Part II), Bull. comm. géol. Finlande, No. 77, 1926]. The Påvskär granite, which is obviously older than granites of the second group by which it is partly penetrated, contains more than 50 per cent feldspar of which the bulk is oligoclase, biotite is present, but the typical colored mineral in this rock is hypersthene, the content of which may attain 10 per cent. A chemical analysis by A. Zilliacus on a sample taken within a few thousand feet of the same locality is entered in Table I.

P-73. Gneiss-granite from Bergholm, E. of Pellinge, 80 km. E. of Helsingfors. This is a granite of the so-called Våtskär type. The locality has been studied in great detail by Sederholm [On migmatites, etc. (Part I), Bull. comm. géol. Finlande, No. 58, 1923]. As shown by the contact phenomena, the granite of the Våtskär type is obviously older than the granites of the second group. The Våtskär granite is so gneissose that it might properly be designated as a granitic gneiss. The predominant feldspar is oligoclase. Biotite is typical, but hornblende is sometimes present. The chemical composition of this gneissose granite taken from a locality about 2 km. N.N.W. of Bergholm has been determined by E. Mäkinen and is quoted in Table I.

P-74. Granite from the western shore of Orijärvi. This granite has been thoroughly investigated by Eskola. [Eskola, P.: Petrology of the Orijärvi Region, Bull. comm. géol. Finlande, No. 40, 1914]. It is an oligoclase granite which in the middle of the Orijärvi batholith contains 36 per cent oligoclase and 1 per cent biotite. Towards the selvages of the batholith the content of both oligoclase and biotite increases. A sample of this contact rock analyzed by Laitakari was taken from the western shore of Orijärvi, but it contains more mica (17.5 per cent) than the rock investigated by us. Laitakari's analysis is quoted.

TABLE II.

Granites of Group II.

	Coast Granites			Central Granites				
Serial No.*	P-75	P-76	P-79	P-80	P-81	P-78	P-77	P-82
Ra, 10^{-12} g./g.	5.51	0.91	1.55	2.30	1.55	3.17	1.87	3.28
FeO, weight %	1.34	0.64	0.50	3.48	2.94	1.34	1.44	2.08
Biotite, volume %	4.9	0.4	0.1	10.0	9.9	0.7	3.7	0.1
Hornbl., volume %	...	...	...	3.0	...	1.4	...	...
SiO_2	...	74.76	...	66.18	...	73.03	...	...
TiO_2	...	0.02	...	0.48	...	0.20	...	...
Al_2O_3	...	13.37	...	16.25	...	14.41	...	...
Fe_2O_3	...	0.72	...	0.50	...	0.68	...	...
FeO	...	0.86	...	4.35	...	1.25	...	...
MnO	...	...	...	...	...	tr.	...	...
MgO	...	0.23	...	2.17	...	0.38	...	...
CaO	...	1.11	...	3.46	...	1.41	...	...
Na_2O	...	3.65	...	2.80	...	3.03	...	...
K_2O	...	4.62	...	3.90	...	5.58	...	...
P_2O_5	...	tr.	...	...	...	...	...	...
H_2O	...	0.50	...	0.35	...	0.39	...	...

* Serial numbers correspond to those used by Piggot (see preceding paper).

P-75. Granite from Kumlinge, Åland Archipelago, has been described by Sederholm [On migmatites, etc. (Part III), Bull. comm. géol. Finlande, No. 107, 1934]. It is of certain post-Bothnian age. It penetrates the gneissose granite (No. P-71) and the Bothnian sediments of the same locality.

P-76. Granite from Ingå, ca. 40 km. W. of Helsingfors. The region has been thoroughly investigated by Sederholm [On migmatites, etc. (Part II), Bull. comm. géol. Finlande, No. 77, 1926]. The Ingå granite forms a special type characterized by having fewer inclusions than the ordinary coast granite. Microcline predominates, oligoclase is also present; it is poor in colored constituents: biotite and chlorite; a red garnet sometimes occurs. The analysis (by A. Zilliacus) was made on a sample from Svenviken in Ingå.

P-77. Granite W. of Kalvolanjarvi, N.W. of Hämeenlinna (Tavastehus). This rock is from a great post-Bothnian granite massive, the exact geological relations of which have not been worked out in detail. Microcline predominates but oligoclase is not uncommon. Biotite is the only colored mineral The structure is gneissose.

P-78. Granite from Kuru, 40 km. N. of Tampere (Tammerfors), again belongs to the younger subgroup. This locality is in the center of a large area of equi-granular, medium-grained, grey granites in central Finland. A sample from this exact locality has been analyzed by N. Sahlbom. The rock is a typical microcline granite with a small amount of oligoclase-albite; both biotite and hornblende occur as colored constituents. The reason for the very high radium content of this rock is not known. It is probably due to the presence of some radioactive mineral (nothing, however, could be detected in the thin sections), so the normal relation between radium and biotite does not hold in this rock.

P-79. Granite (Helsinkite) from Kajholmen, *ca.* 20 km. E. of Helsingfors, is a typical coast granite of the so-called Hangö type. It is always full of inclusions and is quite likely a palingenic granite originated by anatexis of older gneisses. Microcline is the typical feldspar. The original oligoclase is usually broken up in an aggregate of sericite and albite. Biotite seems not to be stable, chlorite and serpentine having crystallized instead. Along shear zones a red epidote is plentiful. It is obvious that the relation between radium and biotite does not hold since the biotite is unstable in this granite. The age is also uncertain in so far as the replacement processes may be younger than the granite.

P-80. Granite from Lavia belongs to the younger subgroup of the post-Bothnian granites. It has been studied and analyzed by Mäkinen [Mäkinen, E.: Ein archäisches Konglomerat von Lavia, Geol. För. Förh., 37, 418, 1915] and by him called granodiorite (the analyzed specimen, however, was taken west of Välimäki, several miles west of the locality of our sample). Andesine is the typical feldspar, microcline being rather unimportant; both biotite and hornblende are usually abundant.

P-81. Granite from Siuro (on the highway between Tampere [Tammerfors] and Suodenniemi) belongs to the oldest subgroup of the post-Bothnian granites. This locality has not been specially studied but neighboring areas have been intensively examined by Sederholm and Mikkola [Sederholm: On the sub-Bothnian unconformity, etc., Bull. comm. géol. Finlande, No. 95, 1931]. The typical feldspar is andesine, microcline is unimportant, biotite is the only colored constituent. The structure is gneissose. Mineralogically the granite closely resembles its younger congener, No. 80.

P-82. Granite (Unakite, Helsinkite) from Torvala in Laukaa. This is a typical post-Bothnian unakite (or helsinkite) from central Finland as described by Wilkman [Wilkman, W. W.: Über Unakite in Mittel Finnland, Fennia, 50, No. 15, 1928]. It is characterized by the mineral association albite and epidote (both plagioclase and biotite being unstable). Strictly speaking, it is not a granite, and thus does not fall within the scope of the present paper. For a more comprehensive petrographic description and chemical analysis the paper of Wilkman should be consulted.

TABLE III.

Granites of Group IV.

Serial No.*	P-83†	P-84	P-85	P-87	P-88	P-89	P-90	P-91	P-92	Average
Ra, 10^{-12} g./g.	1.21	1.03	1.48	2.21	1.13	1.60	2.74	1.47	0.92	1.53
FeO, weight % ...	1.16	2.72	3.15	3.16	3.32	2.47	2.29	2.33	1.62	2.47
Biotite, volume %	2.0	1.7	2.5	4–5	1–2	2	4	2	2–3	5.2
Hornbl., volume %	....	2.0	4.2	5–6	6–7	3	....	3	....	
SiO_2	72.63	73.78	68.40	70.56	71.43	70.24	71.53	75.81	75.26	....
TiO_2	0.29	0.24	0.52	0.44	0.83	0.35	....	0.32	0.25	....
Al_2O_3	13.33	11.52	14.57	12.27	12.29	14.28	13.70	11.22	12.71	....
Fe_2O_3	0.72	1.35	0.87	2.74	1.09	0.63	1.79	0.86	0.97	....
FeO	1.72	2.37	3.57	2.93	3.33	2.88	2.35	1.91	1.11	....
MnO	0.04	0.06	....	0.14	0.06	0.04	....	tr.	0.02	....
MgO	0.63	tr.	0.72	0.65	0.22	0.22	0.48	0.34	0.29	....
CaO	1.88	0.92	2.84	1.87	2.10	2.09	2.08	1.25	0.66	....
Na_2O	3.07	2.50	2.21	3.20	2.38	3.16	2.82	2.27	2.65	....
K_2O	4.82	6.49	5.79	4.92	5.87	5.50	6.71	5.49	5.56	....
P_2O_5	0.19	0.05	0.25	0.13	0.08	....	....	....	0.04	....
H_2O	0.12	0.66	0.68	0.60	0.66	0.41	0.34	0.40	0.89	....

* Serial numbers correspond to those used by Piggot, see preceding paper.

† The analysis of this granite shows also the following additional constituents: S = 0.11, SrO = 0.00, BaO = 0.08, Cl = 0.09, CO_2 = 0.21.

P-83. Granite from Åva, N. of Brändö, Åland Archipelago [Sederholm: On migmatites, etc. (Part III), Bull. comm. géol. Finlande, No. 107, 1934], forms an isolated body which is certainly younger than the granites of the second group. Some of it is fine-grained, but coarse types are also found. Quartz usually has a bluish tinge. Microcline is by far the dominant feldspar, only a very small amount of oligoclase being present. Biotite represents the only colored constituent.

P-84. Granite from Onas, 30 km. E. of Helsingfors, has been described by Borgström [Borgström, L.: Das Granitgebiet von Onas. Helsingfors 1931 (Centraltryckeriet)]. According to two chemical analyses it resembles chemically the rapakivi granite type. An analysis by Sandelin is quoted in Table III. This granite forms a homogeneous, transgressive body measuring about 270 km.^{2} It is obviously the youngest formation in this area and may be contemporaneous with the rapakivi granites (of the fourth group). Microcline is the typical feldspar. Both biotite and hornblende occur as colored constituents. Fluorite and zircon are accessories. The granite is homogeneous and coarse-grained.

P-85. Granite from Obbnäs, 40 km. W. of Helsingfors, has been studied by Sederholm [On migmatites, etc. (Part II), Bull. comm. géol. Finlande, No. 77, 1926]. It constitutes a coarse-grained aggregate of red microcline, greyish white oligoclase, dark grey quartz, and black biotite and hornblende. Titanite, apatite, zircon, and fluorite are accessories. A chemical analysis by Eskola is quoted in Table III. Geologically the granite forms a structureless body, about 250 km.^{2} in surface area, which pierces through all the other rocks of this region.

P-87. Rapakivi from Rödglasskär, N. of Enklinge, Åland Archipelago, is characterized by small ovoids of oligoclase (usually 1 to 2 cm. in diameter). The locality has been described by Sederholm [On migmatites, etc. (Part III), Bull. comm. géol. Finlande, No. 107, 1934]. Chemical analysis by Sahlbom.

P-88. Rapakivi from Storskär, Gustaf Sokn, Åbo-Archipelago. A good description and detailed map of the rapakivi area of which this sample is a representative have been published by Kanerva [Kanerva, I.: Rapakiwigebiet von Vehmaa, Fennia, 50, No. 40, 1928]. The chemical analysis was made by E. A. O. Nordensvan and has been quoted from the paper by Kanerva.

P-89. Rapakivi Granite, Pulsa, center of the Viborg area. It is a "true rapakivi," as is also

P-90. Rapakivi from Viborg (eastern end of the Viborg area) with ovoids of potash feldspar encompassed by a shell of oligoclase.

P-91. Rapakivi S. of Bockholm, E. of Pellinge (western end of the Viborg area) has no oligoclase ovoids and should thus be called pyterlite. The three last-mentioned granites (Nos. 89, 90, and 91) are all from the so-called Viborg Rapakivi Area, 20,000 km.^{2} in extent, and thus the largest of the rapakivi occurrences. For detailed petrographical and chemical information the reader should consult a paper by Wahl [Wahl, W.: Die Gesteine des Wiborger Rapakiwigebietes, Fennia, 45, No. 20, 1925], from which analyses 89, 90, and 91 are all taken.

P-92. Rapakivi Granite from Salmi, Ladoga area, is a pyterlite without shells of oligoclase around the potash feldspar. The analysis (by G. Sundell) was made on a sample from the Pitkäranta mine.

TABLE IV.

Other Granites from Fennoscandia.

Serial No.	P-86	P-93	P-94
Ra, 10^{-12} g./g.	0.43	3.14	0.57
FeO, weight %	0.85	...	2.11
Biotite, volume %	1.1	0.2	4.2
Hornbl., volume %	...	1.0	...

The granites of the third group in northern Finland and Sweden, i.e. the Lapland granites (No. 86), have been paralleled by Sederholm with the Småland granites of middle Sweden (No. 93) and the Telemark granites of Norway (No. 94). Results of studies of representative samples of these granites have been entered in the above table. The analyzed sample of the Småland granite seems to have an abnormally high radium content. The other samples, if representative, seem to correspond most closely to the granites of the first group in Finland.

CONCLUSIONS.

As far as the present data go they indicate that radium is associated more with the biotite of Finnish granites than with the other mineral components and that in each group (Fig. 3) the total amount of radium increases with the biotite content. No correlation is found between Ra and FeO or between Ra and K_2O. It seems rational, therefore, to correlate radium with the mineralogy rather than with the chemistry of a granite. Granites of group I contain less radium than do granites of group IV (both total radium and radium per gram of biotite). But more data are required to show whether this is fortuitous or conditioned by such factors as geologic age (which must have some influence), mineral composition, or, as Backlund thinks, special mode of origin (granitization of sediments).

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