

SUOMEN GEOLOGINEN TOIMIKUNTA

BULLETIN

DE LA

COMMISSION GÉOLOGIQUE
DE FINLANDE

N:o 137

ON THE GEOCHEMICAL DIFFERENTIATION
IN THE EARTH'S CRUST

BY

KALERVO RANKAMA

WITH 18 TABLES

HELSINKI
JANUARY 1946

SUOMEN GEOLOGINEN TOIMIKUNTA
BULLETIN DE LA COMMISSION GÉOLOGIQUE DE FINLANDE N:o 137

ON THE GEOCHEMICAL DIFFERENTIATION
IN THE EARTH'S CRUST

BY
KALERVO RANKAMA

WITH 18 TABLES

HELSINKI
JANUARY 1946
GOVERNMENT PRESS

ABSTRACT.

The content of trace elements in granites of various geological ages is discussed on the basis of spectrochemical and radioactivity determinations available in literature.

The geochemical migration of the elements on global scale, based on the results obtained, is discussed, and a theory of the geochemical differentiation in the earth's crust is put forward. It is suggested that a group of elements, consisting of Li, Be, Rb, Cs, Ba, Rare Earths, Ta, and Pb, called the granitophile elements, tends to concentrate into the outermost parts of the earth's crust due to a secular geochemical migration, while the siderophile and the chalcophile elements, together with another group of elements, which, according to the results so far available, is represented only by yttrium, are pushed down towards the basaltic substratum.

An attempt at the geochemical characterization of the Pre-Cambrian of Finland on the basis of the granites is presented, and a marked poorness in the content of many of the trace elements as compared with chronologically younger granites is established.

CONTENTS:

	Page
INTRODUCTION	5
THE GEOCHEMICAL MIGRATION OF THE ELEMENTS ON GLOBAL SCALE	6
THE GEOCHEMICAL DIFFERENTIATION IN THE EARTH'S CRUST	7
EVIDENCE ABOUT THE SECULAR DIFFERENTIATION BROUGHT FORTH BY CERTAIN TRACE ELEMENTS	8
GLOBAL GEOCHEMISTRY AND THE EVOLUTION OF THE EARTH'S CRUST	16
GEOCHEMICAL CHARACTER OF THE PRE-CAMBRIAN IN FINLAND AS ILLUSTRATED BY ITS GRANITES	21
RETROSPECT AND SUMMARY	22
REFERENCES	25
TABLES	28

INTRODUCTION.

»Alles fliesst und strömt, in innerer und äusserer Bewegung, in immer neuen Formen, in ewiger Evolution.«

L. KOBER: Das Weltbild der Erdgeschichte.
Jena 1932. p. 12.

Perhaps the most important step towards our present knowledge of the chemistry of the earth, greatly extended during the last two or three decades, is the establishing of the laws of distribution for a great number of elements, carried out mainly by V. M. Goldschmidt and his school in a masterly fashion. However, as I have pointed out in a previous paper (Rankama, 1944, p. 63), the laws of distribution are commonly presented without much comment on the geological character of the material serving as a basis for the investigation. Accordingly, the samples seem mostly have been selected in accordance with purely petrological principles, and no attention has been paid to their geological setting or their geological age. The resulting investigations thus illustrate very neatly the roles played by the various elements during the course of endogeneous and exogeneous differentiation.

It is very interesting to note, however, that geochemical literature of the later years deals also with regional geochemical problems; this, in addition, happening on an increasing scale, as may be seen, e. g., from the papers published by van Tongeren (1938), Landergren (1943), Rankama (1944), and Sahama (1945 a and b). Their scale varies from the description of a single mining field to rock provinces, and even to geographical and geological units. As to the general results obtained by these investigations, they have laid foundations for what I should like to call the application of geochemistry to geological problems.

When considering the term regional geochemistry it becomes apparent that, apart from the effects of local or regional factors or both, the distribution of the various elements may be considered either from a geographical or a geological point of view. As to the geographical distribution of the elements, one may recall the concepts of minerogenetic or metallogenetic provinces, as expressed and developed to a system of the minero-genetic evolution of the various continents by, e. g., Lindgren (1928). In this connection also the descriptions and calculations dealing with the geographical variations in the composition of the earth's crust, as pre-

sented by Clarke and Washington (1924) must be taken into account. Fascinating results may be gained already by coupling the results of geochemistry with geography, but for a geologist the combination of the results of his own science with those of geochemistry may be even more interesting.

Among the more important recent theories dealing with the chemical evolution of the earth's crust, I should like to list those of the granitization and the origin of granitic magmas by partial re-fusion of older rocks set forth by Eskola — the former theory being largely extended by Backlund and Wegmann — and that of the division of granites on the basis of their age during the orogenesis, as presented by Wahl. In the following pages I shall try to couple these principles and theories with the geochemical evidence available of some of the trace elements in granites belonging to various geological eras. This may, perhaps, be interpreted as piling hypothesis upon hypothesis, and, due to the scarcity of the facts available, we surely cannot expect other than a very feeble picture of the evolution. Anyway, we shall find, sooner or later, geochemistry developed on a global scale, and with its aid we may, perhaps, be able to trace something about the processes leading to the evolution of the earth's crust. These processes evidently have originated in the very remote times of the formation of the primordial crust of the earth, and are found still working to-day.

THE GEOCHEMICAL MIGRATION OF THE ELEMENTS ON GLOBAL SCALE.

The geochemical migration of the elements will be understood, according to Fersmann (1929, p. v) as their wandering in the earth's crust, a legitimate physical, chemical, and geological phenomenon. Fersmann further points out the importance of establishing the relations between the elements and certain geological epochs, furnishing thereby the concept of geochemical epochs (*op. cit.*, p. 4).

However it is, in my belief, evident that the migration of the elements takes place not only during certain privileged times, but also during the whole evolution of the earth's crust, from the remote beginnings up to the present day. It is also evident that the optimum conditions for the migration *en grand* will coincide with the orogenic periods, during which times, due to the rising temperatures even in the outermost parts of the earth's crust, ample opportunity is found for the wandering of elements. On the other hand, the migration must take place also during the intervals between the orogenies, on a more moderate scale, however, and in the deeper parts of the crust only. The latter kind of migration must be ascribed to processes and reactions in solid state. The migration must

now also be more passive in its nature, gaining no activation from the orogenic movements.

If this kind of the wandering of the elements, the geochemical migration on global scale, is supposed to take place, it is considered merely as a planetary phenomenon, independent of the geographical or geological settings.

THE GEOCHEMICAL DIFFERENTIATION IN THE EARTH'S CRUST.

Let us now consider the problems connected with a possible geochemical differentiation in the earth's crust upon the basis of a geochemical migration on global scale. According to the common belief the earth's crust consists of an outer shell of granitic composition, under which is situated a basic layer, gabbroic or basaltic in composition. This gravitational stratification of the outer crust is, according to Eskola (1932 b, p. 480), probably due to processes of two different kinds, *viz.* crystallization differentiation and squeezing out of the residual magma on the one hand, and differential anatexis of older rocks on the other, with subsequent squeezing out of the liquid. In a recent paper Ramberg (1945, p. 315) suggests that there exist chemical potentials responsible for the gravitational arranging of the different minerals in homogeneous spheres, and acting in the same direction as the gravitational force. In addition, Ramberg (*op. cit.*, p. 324) points out that the light granitic minerals are the most mobile ones, and that the increase in the chemical activity alongside with pressure is greater for light minerals than for heavy ones. This accordingly results in a selection and concentration of the elements of the lightest minerals and their rise upwards into the mountain chains during the orogenesis and the cratogenesis.

Ramberg's theory might well be understood as a supplement to the granitization theory put forward by Eskola. Granitization, in Ramberg's belief, is »nothing but a contact metasomatism of regional dimensions occurring around the crystalline granitic shell of the earth's crust» (*op. cit.*, p. 320). However, the granitic ichor, so important a fluid according to Sederholm and Eskola, in Ramberg's explanation is not a separate liquid phase, but merely the mobilized atoms of the solid solutions and minerals charged with kinetic energy great enough to make them able to move inside and outside the lattice (*loc. cit.*).

In my opinion, the above-mentioned theories presented by Eskola and Ramberg, connected with that by Wahl (1936 a and b, 1943) on the division of the granites into separate groups according to their occurrence during the orogenesis, can be applied to and made responsible for the secular migration of certain elements in granitic rocks, for which the term

geochemical differentiation in the earth's crust has here been specially coined. The elements in question include the trace elements with the best-developed lithophile character.

This differentiation may be listed as a fifth member in the series of geochemical differentiations as presented by Goldschmidt (1933). To these differentiation and migration phenomena in the lithosphere applies what has been pointed out by Goldschmidt (1922, p. 25) re the ever-continuous differentiation proceeding until the decreasing temperature temporarily stops the migration. Also in the migration in the earth's crust the extinction of the era of the heavy metals becomes evident.

In the following chapter the evidence obtained from literature regarding the above hypothesis will be presented. Unfortunately, the number of investigations dealing with the distribution of the trace elements is still much too small. For causes presented above (on p. 5) many of the figures contained in various geochemical treatises are of no value whatever for the present purpose.

EVIDENCE ABOUT THE SECULAR DIFFERENTIATION BROUGHT FORTH BY CERTAIN TRACE ELEMENTS.

In the following tables the content of some trace elements in granites from the four corners of the world will be presented. A somewhat surprising fact will be seen from the tables, *viz.*, that of the little which is known about the geochemistry of granitic rocks, the greatest part covers the Pre-Cambrian formations.

Lithium. The greatest part of spectrographic lithia determinations has been made of Pre-Cambrian rocks. The values for granites presented in Table I (on p. 28) are based upon analyses carried out by Strock (1936), van Tongeren (1938), Landergren (1943), Wager and Mitchell (1943), and by Sahama (1945 a and b).

If the lithia contents in the samples of Table I are compared with one another — which must be done with due caution and suspicion arising from the limited number of analyses, the differences in methods of determination, apparatus, choice of spectrum lines, and even the subjective errors in the spectrochemical determinations by various authors — there seems, however, to be a rising tendency in lithia towards the younger end of the table, in favor of our hypothesis. The Early Pre-Cambrian leptites, representing the perhaps oldest rocks so far known to exist are, as a group, somewhat lower in lithia than are the younger representatives of the various rock complexes in South Lapland. The Late Pre-Cambrian rapakivi granites of East Fennoscandia form a coherent group and can, perhaps, be placed alongside the South Lapland rocks as to their lithia content. On the other hand, an abrupt rise can be established in Paleozoic granites, following next in Table I, and many of the Mesozoic granites from the Dutch East Indies reveal a rather high lithium content, perhaps even higher and more uniform if the comparatively low sensitivity (0.01 % Li₂O) of the line used by van Tongeren be taken into account. The Skaergaard analysis is exceptional, but this rock, though chemically of granitic composition, represents merely a residual magma of a basic intrusion, probably contaminated by the gneiss country rock (Wager and Mitchell, 1943, p. 289).

It may be added that Sahama (1945 a, p. 72), when discussing the lithia content in South Lapland rocks, points out that the content in acidic igneous rocks is on an average decidedly lower than the values presented by Stroock (1936). He believes, however, that this divergency, of a second-rate nature, might be interpreted as a regional feature of the area in question.

Beryllium. The contents in the following table (Table II on p. 28) are compiled according to Goldschmidt and Peters (1932 a), Rankama (1939), Sahama and Vähätalo (1939), Landergren (1943), and by Sahama (1945 a and b).

It seems to be evident from Table II that so far as the beryllium determinations will allow, a quite uniform content of this element in granites throughout the whole Pre-Cambrian in Fennoscandia can be established. The granites belonging to the Caledonian and Variscan orogenic cycles, on the other hand, contain decidedly greater amounts of this element. Unfortunately, no spectrographic beryllia determinations in Mesozoic and younger granites have been made.

Boron. A quite small number of suitable boron determinations are available for the present purpose, the figures being obtained from the papers by Goldschmidt and Peters (1932 b and c), and by Sahama (1945 a and b). In addition, some facts about the distribution of this element are given by Landergren (1945). The B_2O_3 values are listed in Table III (on p. 29).

Landergren (1945, pp. 22, 24) has analyzed Pre-Cambrian granites of Sweden, giving a variation in B_2O_3 percentage of these rocks as 0.001—0.010, for 17 samples of different ages and of varying distribution. He states that the boron content of these granites presents variations, the lowest boron amounts being contained in the oldest Archean gneiss granites and, partly, in the Småland granites, while a somewhat higher boron content is found in some palingenic granites. As a whole, the amount of boron in Swedish granites seems to be somewhat higher than the average for the Variscan granites.

As to the Finnish Archean granites, the present material includes only a few South Lapland rocks. A somewhat higher boron content is found in the East Fennoscandian rapakivi granites, but the Paleozoic granites seem to be comparable with the older granite groups of South Lapland.

According to Sahama (*op. cit.*, pp. 55, 56) this element is especially concentrated in South Lapland in ultrabasics while the content of same in acidic magmatic rocks is quite small. Taking into account the role played by the contamination by sedimentogeneous or pegmatitic material during the formation of the granitic magmas, it becomes evident that the question of the wanderings of this element during the geochemical differentiation in the lithosphere cannot as yet be definitely answered.

Rubidium. Spectrographic rubidia determinations have been carried out in a fairly large quantity of East Fennoscandian rocks by Erämetsä, Sahama, and Kanula (1941), and by Sahama (1945 b); other analyses are presented by Goldschmidt, Bauer, and Witte (1934), van Tongeren (1938), Landergren (1943), and by Wager and Mitchell (1943). The united results are presented in Table IV (on p. 29).

Conclusions of the same kind as in respect of lithium can be made in regard to rubidium as well. The leptites and the Orijärvi oligoclase granite, representing the older Archean rocks, compared with the younger palingenic granites of Hanko, Kalvola, and Hämeenkyrö, seem to be relatively poor in rubidia. In the Sveco-fennian and Karelian postorogenic granites the rubidia contents are of the same order of magnitude. As stated by Sahama (1945 a, p. 69), the younger granites in South Lapland contain, on an average, somewhat higher amounts of rubidia than the gneissose granites and the granulites; Sahama has included in his calculations also some granodioritic rocks which are here neglected. As to the rapakivi rocks, they evidently form a very coherent group also in regard to their rubidia content. There is, on an average, an enrichment of rubidium in these granites also, when

compared with the earlier Fennoscandian granites, as stated by Sahama (1945 b, p. 50). — Thus far the Pre-Cambrian.

As regards the granites belonging to younger eras, the facts relating to their rubidium content are very scarce. To base any conclusions upon the four values presented in Table IV would lead us to guesswork and is accordingly omitted.

C a e s i u m. The number of caesia determinations available for the present purpose is quite low and is furnished by papers published by Goldschmidt, Bauer, and Witte (1934), Erämetsä, Sahama, and Kanula (1941), and by Sahama (1945 a). The results are reproduced in Table V on p. 30.

In addition, note must be made of the statement by Sahama (1945 a, p. 69) that the whole material used by him for a geochemical study of South Lapland proved entirely devoid of caesium. According to Sahama (1945 b, p. 50) it might be possible that this element is relatively rarer in the Finnish Archean than in the Variscan granites. In my belief, there is no reason to doubt that this might be otherwise. However, the quantity of facts needed to prove the correctness of this assumption must be greater than that furnished by Table V.

As to the relative amounts of Cs in the Finnish Archean granites, the rocks of Kalvolä and Hämeenkyrö seem to occupy a special position. This might perhaps be due to the fact that they are serorogenic granites, in the formation of which the juvenile component of magma may have played an important role.

S t r o n t i u m and b a r i u m. The facts collected from the papers published by Noll (1934), v. Engelhardt (1936), van Tongeren (1938), Landergren (1943), Wager and Mitchell (1943), and by Sahama (1945 a and b) are presented in Table VI, p. 30.

According to Noll (1934), strontium is an element typical of syenitic and alkali syenitic magmas, and shows no great variations in the intermediate and acidie members of the calci-alkaline rock series. The amount of this element in Pre-Cambrian granites and leptoites of Fennoscandia seems to be fairly uniform, with occasional maxima in some exceptional leptite type and in the Hetta granites of South Lapland (*cf.* Sahama, 1945 a, p. 38). As to the younger rocks, the Variscan and Mesozoic granites and the Tertiary granophyre contain, on an average, somewhat larger amounts of this element in favor of our hypothesis, and the rather high content of strontia in the granites of the Dutch East Indies must be especially noted. The question of the occurrence of strontium — and barium — has aroused considerable interest among petrologists. As stated by Hillebrand and Lundell (1929, p. 649), the igneous rocks of the Rocky Mountain region show much higher average percentages of these metals than do the rocks of the eastern and more western parts of the United States. Holmes and Harwood (1932, p. 423; 1936, p. 49) state that the variation in SrO is much more erratic than that of BaO, and that the factors controlling it are still unclear, geographical distribution being, however, important. The rocks of East Australia are abnormally poor in both oxides, especially in SrO, while the pyroxenites of India are conspicuously rich in SrO. It must be taken into consideration, however, that these authors pay no special attention to the granites, merely dealing with the separate areas as petrological units.

Seeing that all chemical strontia determinations cannot claim a high accuracy for reasons referred to by Noll (1934, p. 512), such values available of some Pre-Cambrian granites of South and East Finland will not be consulted here. If the theory of the origin of granitic magmas by a partial re-fusion is adopted, the fairly uniform strontia content in the Finnish Archean granites may be explained as a result of the considerable diadochic replacement of Ca by Sr in mineral lattices, in virtue whereof the greatest part of this element will be retained in the insoluble residue after the squeezing out of the granitic liquor rich in potassium.

Barium, on the other hand, seems to be present in the rocks of South Lapland in higher amount than in the Swedish leptites, but the average amounts in the

former are fairly uniform. Strong enrichment can, in addition, be established in the rapakivi granites, as stated by Sahama (1945 b, p. 49), and the Paleozoic and Mesozoic granites as well as the Tertiary granophyre are generally further enriched in this element. These facts again seem to be in favor of our hypothesis.

Radium. A relatively large number of radium determinations in granites have been presented in literature. The investigations may be divided into two chronological groups, the first of which includes the earlier works by Joly (1912), Smeeth and Watson (1918), Poole (1920), and by Poole and Joly (1924), while the more recent papers by Piggot (1931, 1938) form the second group. As to the results presented in these papers, they seem to be very inconsistent. The radium contents will be listed in Table VII on pp. 31—32.

Consider now the Ra contents listed in Table VII. It is evident that no general conclusions can be drawn from the Ra values, due to their great inconsistency. In the Finnish Pre-Cambrian granites the values presented by Poole and Joly, when compared with the recent values by Piggot, appear to be much too high. The Poole and Joly values from the Lewisian complex of North Scotland and those presented by Smeeth and Watson of the Mysore rocks of India might, however, be better comparable with the Fennoscandian values. No great differences can be established between the granites belonging to the Pre-Cambrian orogeneses on the one hand, and those of Variscan and Alpidic mountain cycle on the other.

To compare the various granites more intimately with one another, it is very difficult to establish any differences in the Ra content of the Sveco-Fennian primorogenic and serrogenic granites in Finland. In the primorogenic granites the radium content seems to be quite low, but the amount of this element in the serrogenic granites of the second granite group in Sederholm's classification is evidently not much higher, if some rocks with what seems to be an addition of juvenile material are left out of consideration, *i. e.*, the granites of Kumlinge (with a biotite high in Ra; *cf.* Piggot, 1938, p. 228), Lavia, and Kuru. Also the Tranås granite in Sweden shows an abnormally high radium content, as pointed out by Barth (1938, p. 244). The postorogenic granites of South Finland (Åva, Obbnäs, Onas) seem to be fairly coherent in their radium content and it may be of a certain interest to note that the Ra content in the Port Manvers »strawberry granite« of Labrador, which, according to Kranck (1939, p. 23), closely resembles the Obbnäs and Onas rocks, is of the same order of magnitude as well. As to the radium content of the rapakivi rocks, the recent determinations show percentages decidedly lower than the older ones, thus undermining the belief that they are among the most strongly radioactive rocks. Accordingly, the views presented by Backlund (1938, p. 394) as to the origin of these rocks seem largely to be deprived of their point.

According to the results presented by Poole and Joly (*op. cit.*) the radium content in the Lewisian granites and orthogneisses might be quite stable. In the granitic rocks of the Kolar Gold Field in Mysore, India, there seem to be also some chronological differences in the Ra content, but in these details the interested reader is referred to the original paper by Smeeth and Watson (1918).

The high Ra content in the Stone Mountain and North Jay granites of the U. S. is, according to Piggot, due to the presence of radioactive minerals.

On the whole, there do not seem to be too great differences in the radium content of granites of different ages. This may, perhaps, be explained by taking into account the addition of material brought up by juvenile magmas. Thus the amount of radium originally present in a Pre-Cambrian primorogenic granite and almost extinct in the course of time may gain a substantial increase by the introduction of juvenile magmas during the subsequent period of mountain folding and, accordingly, may to-day come up to the radium content of a Mesozoic or younger granite, derived as a product of crystallization differentiation from a big magma basin.

Scandium, yttrium, and the Rare Earths. According to Goldschmidt (1937 b) these elements form a highly coherent group. Spectrographic determinations of the above elements, suggested for use as Index or Pilot Elements in the geochemical classification of the Pre-Cambrian granites of Finland by Sahama and Rankama (1938), have been carried out in rather large number by van Tongeren (1938), Sahama and Vähätalo (1939), by Sahama (1936, 1945 a and b); a few are presented by Goldschmidt, Hauptmann, and Peters (1933). The percentages will be given in Table VIII on pp. 33—35. Except for Sc and Y, which are found most abundantly in basic igneous rocks, this table contains the values only for La, Ce, and Nd, the most common of the rare earth elements in rocks.

There seem to be no substantial differences in the Sc content of the granites belonging to the different orogenic cycles, nor is this element impoverished in geologically young granites, by which phenomena the present hypothesis would be supported. Seeing that scandium favors basic magmas entering the mineral lattices as Sc^{3+} , replacing Mg^{2+} (cf. Goldschmidt, 1937 a, p. 34), the amounts of this element mobilized during the anatexis from the ferromagnesian minerals to the palingenic granites must be quite negligible.

In regard to yttrium, this element in South Lapland rocks according to Sahama (1945 a, p. 52) favors the basic igneous rocks, as does also scandium. As may be seen from the figures presented by the said author (*op. cit.*, p. 51), the yttrium content in the older gneissose granites and granite gneisses as well as in the granulites of Lapland is, on an average, considerably higher than in the younger granites. On the other hand, the figures for the Sveco-Fennian granites in South Finland present the contrary case. It must, however, be taken into account that these granites were explicitly chosen for analysis as comparatively rich in the Rare Earths. Accordingly, there seem to be no striking differences in the yttrium content of the Finnish Pre-Cambrian granites.

Compared with the Pre-Cambrian granites, the Variscan granites seem to be decidedly impoverished in yttria. As to the Mesozoic granites of the Dutch East Indies, there seems, at least, to be a tendency towards impoverishment in yttria, more marked in the Sumatra and the New Guinea granites. The Y_2O_3 average in the Dutch East Indies, calculated on the basis of the values set forth in Table VIII, is 0.0035 %. However, it is evident that the samples include granites exceptionally rich in yttria, as may also be seen from the general lanthanide composition of the rock samples investigated, and accordingly the above value might well represent the maximum average.

Leaving aside the exceptionally high content of the Rare Earths proper in the analyzed Archean granites of South Finland, it seems to be evident that the granites richest in Rare Earths can usually be found among the youngest granites, although also the older ones may sometimes contain appreciable amounts of these elements, as has been stated already by Sahama and Rankama (1938). As to the fluctuations in the Rare Earth content in South Lapland granites, the analyses of the standard mixtures carried out by Sahama (1945 a, pp. 38, 39) give the following results, expressed in percentage:

	La_2O_3	CeO_2	Nd_2O_3
Gneissose granites and granite gneisses . . .	0.003	0.006	0.003
Hetta granites	0.006	0.006	0.003
Young granites	0.008	0.01	0.01

It thus becomes evident that there exists a rising tendency in the content of the lanthanides from the older towards the younger granites. This tendency, however, can only be very poorly discerned according to the only too few analyses presented in Table VIII.

In the Late Pre-Cambrian rapakivi granites the Rare Earths are very conspicuously enriched when compared with the older Pre-Cambrian granites. As stated by Sahama (1945 b, pp. 47, 48), the case as regards the youngest Archean granites does not seem to be quite clear, but the rapakivi granites are, in any case, relatively rich in these elements.

No facts are thus far available on the lanthanide composition of Paleozoic granites.

The comparison of the Archean granites of Finland with the Mesozoic granites of the Dutch East Indies is greatly restricted by the exceptional nature of many samples of the former. When the average percentages of the latter, *viz.*

La_2O_3	0.0035 %
Ce_2O_3	0.0045
Nd_2O_3	0.003

are compared with the South Lapland averages, they would quite nearly represent the values for gneissose granites and granite gneisses. On the whole, we must conclude that the Dutch East Indian granites would seem to be what can be termed rocks remarkably poor in the Rare Earths; Sumatra, New Guinea, and many of the lesser islands furnishing the biggest number of samples leading us to this conclusion.

Zirconium. The ZrO_2 percentages presented in Table IX (p. 35) are furnished by van Tongeren (1938), Wager and Mitchell (1943), and by Sahama (1945 a and b). In order to obtain values more comparable with one another, only percentages determined by the aid of spectrographic methods have been included in this table.

Based on these values the following conclusions can be drawn.

The distribution of zirconium in the granites of South Lapland seems to be quite uniform. According to Sahama (1945 a, pp. 38, 40) the Hetta granites, on an average, contain somewhat less ZrO_2 than the other granites. However, this difference does not seem to be too well-developed. The zirconium contents of the rapakivi granites are decidedly higher, but the Mesozoic granites of the Dutch East Indies seem to be well comparable with the Pre-Cambrian granites of South Lapland. No support for the present hypothesis can thus be obtained by the aid of the zirconia content, but we might, perhaps, take into account also the fact that zirconium is an element more typical of syenitic residual magmas than of granitic ones, and that the mineral zircon, being insoluble and highly refractive, will forward only negligible amounts of zirconia to palingenic magmas produced by differential anatexis.

Hafnium. Only a single hafnium determination, suitable for the present purpose, has been thus far published, *viz.* that by Sahama (1945 b) of the hafnium content in East Fennoscandian Rapakivi Standard Mixture.

Thorium. Determinations of this element in granites have been carried out in rather large number by Joly (1912) and by Poole and Joly (1924). They have been carried out by the use of methods based upon radioactivity measurement. In addition, determinations based upon chemical pre-enrichment with a subsequent X ray spectrographic analysis are presented by Sahama and Vähätalo (1939) and Sahama (1945). A single spectrographic determination has been given by Wager and Mitchell (1943). The thorium figures available will be quoted in Table X (pp. 35—36).

The thorium determinations of Table X might, however, be looked upon with a certain reserve. As to the values arrived at by radioactivity methods, no recent determinations by which the reliability of the older ones could be estimated lie at hand. On the other hand, it does not seem to be quite clear whether the X ray determinations will stand a critical examination, if the possible contamination of platinum vessels by thorium is considered as a potential source of error, due to the same causes as contamination by radium. However, with these factors urging to

caution in mind, we may nevertheless state, that the Pre-Cambrian granites of Finland, save for occasional exceptions, are lower in thorium than the rapakivi rocks, but that the Lewisian of Scotland shows, perhaps, a still lower thorium content, its average being 0.00126 p. et. ThO₂, as calculated from the analyses. Compared with the Lewisian average, the Alpine gneissic granites would seem to be a little higher in thoria.

V a n a d i u m. The material for the following Table XI, on p. 36, is furnished by the investigations carried out by van Tongeren (1938), Rankama (1939), Landergren (1943), Wager and Mitchell (1943), and by Sahama (1945 a and b).

The V₂O₅ averages given by Sahama (1945 a, p. 39) for the three granite groups of South Lapland are identical (0.003 %). Compared with one another, which, owing to the irregularities in the intensity of the V line 4379.24 pointed out by Kvalheim (1941), must be done with due caution in some cases, no well-marked differences in the vanadium content of the Archean granites become visible. The high V content of a leptite from Grängesbergsfältet is clearly exceptional and might be attributed to the hematite content of the rock in question. No concentration of vanadium in the Late Pre-Cambrian rapakivi granites can be established, but the Mesozoic granites of the Dutch East Indies would seem to carry a somewhat higher amount of this element.

As in the case of Sc and Y, we must also here remember that vanadium is not characteristic of granitic rocks, but occurs especially enriched in the more basic rocks of gabbroic composition.

N i o b i u m (c o l u m b i u m). The niobium determinations available in respect of granites are limited strictly to the Pre-Cambrian. The figures, reproduced in Table XII (on p. 37), are based upon the results published by Rankama (1941) and Sahama (1945 b).

The figures presented in Table XII, due to their scarceness, allow of but one conclusion, which seems to point to a quite regular occurrence of this element in the Pre-Cambrian granites of East Fennoscandia.

T a n t a l u m. As in the case of niobium, also the tantalum determinations available have been made exclusively of Pre-Cambrian granites. The percentages will be given in Table XIII, p. 37, and they are reproduced from Rankama (1941 and 1944) and Sahama (1945 b).

I have shown in an earlier paper (Rankama 1944, p. 69) that in the granites belonging to the Sveco-Fennian mountain cycle of South Finland the tantalum content increases with decreasing geological age. For further details of these deductions, largely based upon the use of the maximum possible content of tantalum in the rock samples, the interested reader is referred to the original paper mentioned above. In Table XIII two serorogenic granites are remarkable for their high tantalum content, *viz.* the microcline granite from Tammela and the porphyritic granite from Kankaanpää. In these an addition of juvenile material on a larger scale than usual might well be suggested.

The rapakivi granites, according also to their tantalum content, form a coherent group, independent of the older Pre-Cambrian granites, as is shown both by their geological occurrence and their petrological properties.

C h r o m i u m. The material for Table XIV, on pp. 37—38, is furnished by the following investigations: van Tongeren (1938), Rankama (1939), Wager and Mitchell (1943), and by Sahama (1945 a and b).

The first impression obtained from Table XIV is that of a universally low chromium content in granites of various ages. Excepting the granulites, which show a considerably higher content of this element, its amounts in leptites, Archean and rapakivi granites, and in the Mesozoic granites seem to be quite well comparable with one another. The possible reason for this behavior may be found in a state-

ment by Goldschmidt (1937 b, p. 662), according to which chromium is not characteristic of residual magmas, but is strongly concentrated in the early differentiates crystallizing out of a magma. Accordingly, this element seems to be of little value for the present purpose.

Molybdenum, tungsten. Nothing positive is known about the amounts of these elements in granites.

Cobalt and nickel. The percentages of these elements in granites will be presented in Table XV (on p. 38). The values are quoted from papers published by van Tongeren (1938), Rankama (1939), Landergren (1943), and Sahama (1945 a and b).

As is known from the report by Goldschmidt (1937 b, p. 662), both these elements are especially enriched in basic rocks. Accordingly, they are not elements characteristic of magmatic rest liquors giving rise, *i. a.*, to granitic rocks. Seeing that the content of these elements is not subject to great fluctuations, their use as Index Elements for the present purpose is out of the question.

Zinc. The spectrographic data concerning the distribution of this element are too scarce to allow of any conclusions being drawn. The Pre-Cambrian granites of Huopalahti, Leppävirta, and Nattanen, Sodankylä, all in Finland, contain 0.02, 0.01, and 0.03 % ZnO, respectively (Rankama, 1939) while the Mesozoic granite of P. Nongsa in Riouw-Lingga Archipelago, Dutch East Indies, contains c. 1 % ZnO (van Tongeren, 1938).

Gallium. It has been suspected by Sahama and Rankama (1938) that the changes in the content of this element in the Finnish Archean are relatively small. To illustrate this, the results of gallium determinations in Finnish granites, as given by Rankama (1939) and Sahama (1945 a and b) will be presented in Table XVI, p. 39, completed with other determinations by Goldschmidt and Peters (1931), van Tongeren (1938), and by Wager and Mitchell (1943).

In all Pre-Cambrian granites the Ga₂O₃ content has been found to be uniformly 0.01 per cent. In Paleozoic granites the amount is decidedly lower, but it does, on the other hand, rise again in Mesozoic granites. Accordingly, there seem to be differences between the Pre-Cambrian and younger granites as to their gallium content. Taking into account the enrichment of gallium not only in granites but also in acidic plagioclase rocks and nepheline-bearing rocks, as stated by Goldschmidt and Peters (1931), we may say that the role played by this element during the geochemical differentiation in the earth's crust cannot be definitely deciphered.

Germanium. The germanium values for certain granites from the papers by Goldschmidt and Peters (1933), Rankama (1939), and Sahama (1945 b) are presented in Table XVII on p. 39.

According to Goldschmidt and Peters (1933) germanium is found especially enriched in residual magmas. As for granites, the few determinations available would seem to point to a rising content of this element towards the younger granites, in favor of the present hypothesis. It must, however, be taken into account that the germanium content in the rapakivi standard mixture was too low to allow of the determination being made without a chemical pre-enrichment, and that according to Sahama (1945 a) the Ge content in South Lapland rocks is evidently less than 0.001 % GeO₂. Accordingly, it may well be possible that future investigations will reveal the above deductions to be merely guesswork.

Tin. No positive spectrographic determinations of the tin content of granites are available for the present purpose.

Lead. The values presented in Table XVIII, on p. 39, are based upon investigations by van Tongeren (1938), Rankama (1939), and Sahama (1945 a and b).

As is known, lead is often found concentrated in granites. If the lead content of the Pre-Cambrian granites is considered, with due attention paid to the PbO averages for South Lapland as presented by Sahama (1945, p. 39), it will become

evident that the highest lead contents are shown by the youngest Archean granites of South Lapland. In the Late Pre-Cambrian rapakivi granites the lead content is still higher (*cf.* Sahama, 1945 b, p. 51), while the Mesozoic granites are comparable with the youngest South Lapland granites (average 0.003 % PbO).

GLOBAL GEOCHEMISTRY AND THE EVOLUTION OF THE EARTH'S CRUST.

Looking back to Tables I—XVIII presented in the previous chapter and to the discussions connected therewith, there seems to appear a tendency towards a certain number of elements, peculiar to granites, occurring in these rocks in amounts increasing with the decrease of the geological age of the rock. These elements would include the following: Li, Be, Rb, Cs, Ba, Rare Earths, Ta, and Pb, the evidence for the last three being, however, restricted exclusively to Pre-Cambrian granites. There seems also to be some evidence indicating the occurrence of some elements in ever-decreasing amounts towards the geologically younger granites, the only representative thus far proved to be of this group being yttrium. It is evident that just the above elements will best serve as Pilot Elements the purposes of a geochemical classification of granites, connected with the determination of the absolute or relative geological ages of these rocks.

The secular migration of the elements, mentioned above (on p. 7) as the possible cause of the variation in the amounts of some trace elements present in granitic rocks, is supported by the migration history of the above elements. Accordingly, I feel myself entitled to put forward, in the following, a more detailed description of the theory of the geochemical differentiation in the earth's crust.

The formation of the first crust of the earth can be pictured as a reversible process, including numerous phases of re-melting of the solidified parts of the solid crust thus far formed. Here evidently the last phases of the first geochemical differentiation were mixed with the first ones of the second differentiation, to use Goldschmidt's (1933) terms for these processes. Granitic magmas with relatively low specific gravity then began their slow rise towards the uppermost parts of the crust, this process continuing through the geological eras.

No traces have ever been found of the initial consolidation crust of the earth. The Early Pre-Cambrian leptites, belonging to the oldest Archean periods, already represent a rather high degree of differentiation. Their original make-up as tuffs and lavas, as claimed by various Swedish geologists, would render necessary that they should be regarded as late stages of residual crystallization. As stated by Eskola (1932 a, pp. 69, 70), their chemical character would presuppose the existence of granites or granite gneisses, situated next before the leptites in the differentiation series and nowadays, perhaps, exposed as the vast granite gneiss areas

of West Sweden and East Karelia. A general picture of the conditions during remote Archean times includes a crust largely built up of leptites, with huge granitic magma masses underlying the crust at a rather shallow depth, this magma being generated by partial re-fusion of leptitic materials. The solid crust has increased in thickness by extrusions of the crystallizing granitic magma.

By the above considerations set forth by Eskola, we might be able to picture the first consolidation crust of the earth as one of granitic composition, according to Eskola's leading principle: »Aus einem Gemisch von Flüssigkeit und Kristall steigt die leichtere Phase aufwärts» (1936, p. 64).

By the formation and decay of the first granitic crust of the earth also the processes of the fifth geochemical differentiation have commenced. In the following, we shall consider the phenomena connected with this differentiation during an Archean revolution period, say, the Sveco-Fennide orogenesis.

According to Wahl (1936 a and b, 1943) the story of the granites connected with any mountain chain can be told in the following way: The first group of these rocks, called primorogenic granites, has been introduced as intrusive masses into the overlying sediment beds and older magmatic rocks. Petrologically these granites mostly have a granodioritic character, the features of gneissose granites being added to them during the later stages of the orogenic cycle. The second group, the serorogenic granites, comprises rocks with a decidedly pegmatitic character, which mostly are microcline granites, rich in potash, and approaching a residual granitic magma in composition. The latter granites, formed through palingenesis of older rocks, including primorogenic granites, take an active part in the formation of migmatites. The postorogenic granites, which form a third group, have been intruded after the period of revolution as granite magmas now present as more independent *massifs*.

If the theory of granitization, set forth by Eskola (1932 b, 1933) is applied to the formation of the serorogenic granites, the general tendency during the re-melting will work towards enrichment of high-melting or poorly soluble minerals in the residue, while the low-melting constituents are the first ones to re-fuse, *viz.* potash feldspar and sodic plagioclase, the micas, at least partly, and quartz. It is highly interesting to note that according to the opinion of Ramberg (1944, p. 108) just these minerals (»potash feldspar, quartz, albite, and perhaps some minerals rich in Fe in relation to Mg») are furnished with the highest chemical activities, and accordingly are able to migrate long distances. Ramberg has arrived at this important result by the use of thermodynamic principles.

It has been especially pointed out by Eskola that crystallization and re-fusion are reversible phenomena, provided that the melt once formed is not removed (1932 b, p. 473). Water and the other *agents minéralisateurs* evidently needed in large amounts for the formation of the comparatively

liquid serorogenic granite magmas of pegmatitic character have, according to Wahl (1943, p. 214), been collected from the material undergoing re-fusion and from the emanations from the subjacent magmas. Accordingly, solution phenomena will occur simultaneously with the re-melting.

The granitization theory introduced by Eskola involves a possible mode of origin of granitic magmas by differential anatexis and effective squeezing out of all silicate rocks containing the potential components of a granite, accordingly also of the rocks formed on the earth's surface. I have discussed in a previous paper (Rankama, 1944, pp. 69—72) the possibility that the younger Pre-Cambrian granites could originate from the older ones by processes of re-fusion. Evidence obtained mainly by the aid of some chemical features of Finnish Archean granites, including the use of a couple of trace elements as geological indicators, pointed to a possible successive series of re-meltings, starting with the primorogenic and ending in the postorogenic Archean granites¹ with the idea in mind that a granitic magma formed by re-fusion might most easily and naturally be derived from the granites themselves. The resulting anatetic granites I portrayed as highly potassic in composition, with, perhaps, a little more silica than their predecessors, and with a decisive impoverishment in iron, magnesia, and lime, when compared with their mother granites, illustration of these features being sought among the granites of the Sveco-Fennide orogenesis. As to their minor elements, I have suggested that a relative concentration of those found to be present in the re-fusible minerals of the mother rocks might well be expected in the anatetic granites.

With the views presented on the above pages in mind it might now be possible to generalize the picture obtained from the Sveco-Fennide orogeny in a larger way.

During the processes of mountain folding in the outer silicate shell of the earth, the phenomena acting in the vertical direction evidently include a self-repeating ever-recurring granitization. With the formation of the first mountain chain on the earth the granite masses have begun to rise, and the products from the decomposition and decay of the first mountains have been folded into the depths where the elevated temperature effected the formation of intergranular palingenic granitic magma. Mobilized by the orogenic movements, this magma tends to rise into the uppermost parts of the crust, on its way metasomatically altering the over-

¹ A similar conclusion, based on similar principles and suggestions, has been presented by Holmes (1926) in a paper which, due to War-time conditions, has not previously been available to me. Holmes' results may, however, be considered as purely fortuitous seeing that he uses the average chemical compositions for the different granite groups in Finland, including the rapakivi granites, as expressed by Sederholm (1925, p. 4) who does not divide the granites of the various orogenic cycles into separate groups.

lying rocks. The orogenic movements may also have opened the way from some large crystallizing magma chamber, by which action the last granitic residual magmas contained therein have the chance of a juvenile rejuvenation of the palingenic magma. These processes, including the slow chemical ones aiming at the attainment of complete thermodynamic equilibrium during the development of the crust, *viz.* dispersion, migration, and consolidation, according to Ramberg (1944, p. 111), are thought to be reproduced during the whole orogenic history of the earth, and it might thus become evident that the intrusion of granites upon granites, whether truly magmatic or palingenic, will greatly add to the acidic character of the outermost layers of the silicate shell of the earth. As a matter of fact, granites and granodiorites are found to constitute 95 per cent of all known areas consisting of intrusive rocks.

As to the role played by the trace elements listed above (on p. 16) during such a process of global scale, the first group, consisting of the elements Li, Be, Rb, Cs, Ba, Rare Earths, Ta, and Pb, is extremely characteristic of granitic magmas, and pegmatitic or hydrothermal residual liquors. During differential re-fusion of older rocks these elements, if present, evidently would tend to concentrate into the anatetic magmas containing the constituents of the low-melting and easily soluble minerals of the parent rock entering their lattices owing to the diadothic replacement. Assuming the parent rock to be granitic, it would already in the beginning contain considerable amounts of these elements, as has been shown by the mineralogical geochemistry of the same for which, as a group, the term *granitophile elements* may be coined. Thus the anatetic rock would be considerably richer in these elements. By a continuous series of such reactions an enrichment of these elements, carried out by Nature herself, will be effected in the outermost parts of the lithosphere during the march of geological time.

On the other hand, the presence of another group of trace elements may be suggested, all of which show a marked tendency towards secular impoverishment in the outermost parts of the lithosphere. These elements, true shunners of the granites, may be called *granitophobe*, and they are represented, until the presence of others can be established, only by yttrium. The behavior of this element during anatexis can be explained by the easy diadothic replacement of calcium by yttrium, as stated by Sahama (1945 a, p. 52), in virtue of which property this element will be relatively concentrated in the residue after differential re-fusion, seeing that the soda-rich members of the plagioclase series will be present in the anatetic magma. The group of granitophobe elements would include all the siderophile and chalcophile ones, separated into the inner spheres of the earth in the primordial first geochemical differentiation.

The division of the igneous masses into those of juvenile and palingenic origin, as presented by Eskola (1932 b, p. 475), might be recalled

here; the masses genetically connected with large ore bodies or skarn masses at their contact can be suspected to be mainly juvenile, while sterile masses are rather of palingenic origin.

The application of regional geochemistry to global scale will thus lead us to the assumption of a continuous migration in the outermost parts of the lithosphere, causing the secular increase in the amounts of some compounds, decrease in others, with a tendency towards pushing the chalcophile and siderophile elements back to the basic substratum, distilling and sublimating the granitophile ions into the granitic crust of the earth, until a limit is set by the proceeding refrigeration of the earth. This is the fifth geochemical differentiation.

The above considerations are based solely upon the assumption that there exist chemical forces causing a secular enrichment of granitophile elements in the outermost granitic layers of the earth's crust and driving the granitophobe elements back to their more proper environments, the subjacent basaltic layer. Thus, it has been assumed that the primary distribution of these elements in the outer parts of the crust has been uniform in all parts of the globe. It might be possible, on the other hand, that a primordial differentiation has taken place, causing primary differences in the content of the elements in the earth's crust. As a present day instance, the abundance of uranium and radium in some parts of the Pre-Cambrian of Canada, compared with the quite rare occurrence of these elements in the similarly Pre-Cambrian granites of Finland may be quoted. We shall submit these views to a closer consideration.

A possible explanation of this difference can, perhaps, be sought in the zonal theory of arrangement of metals in ore deposits. It might be possible that the different Archean terrains represent sections of different depths with subsequent differences in their minor element composition. However, as stated by Lindgren (1928, p. 139), the zonal theory upon close examination seems to be a rather weak structure.

Perhaps a more generally acceptable explanation for the above discrepancy may be found in regional geochemical differences in the content of the trace elements in the earth's crust. There are numerous examples of element associations characteristic of certain chemical elements in certain geographical zones, termed minerogenetic and metallogenetic provinces and regions, or, according to Fersmann (1929, p. 5), geochemical provinces. The chronological connection of the element associations with certain sequences of geological happenings leads to the concept of metallogenetic or geochemical epochs of the earth's crust.

However, the primary differences in the content of certain elements, pronounced as they may have been, will most certainly tend to decline during geological time, if the theory of the secular migration of the elements is adopted. That this process so far has not resulted in an even division of the elements may be seen, *e. g.*, in the distribution of the Rare Earths in the Dutch East Indian granites (*cf.* Table VIII on p. 33).

GEOCHEMICAL CHARACTER OF THE PRE-CAMBRIAN IN FINLAND AS ILLUSTRATED BY ITS GRANITES.

It is a common belief among Pre-Cambrian geologists that there exists a sharp contrast between the Pre-Cambrian phenomena and later igneous activity, distinguishing the terrains belonging to these eras from Paleozoic and later rocks. No mutual understanding has been thus far reached in regard to the fundamental differences. It has been suggested by Daly (1933, p. 423) that igneous activity during Archean times would have taken forms peculiarly its own with, according to Alling (1936, p. 254), gradational changes during later times, seeing that the evolution of the earth is characterized by great differences peculiar to various geological epochs.

Leaving aside the discussion of the origin of the Archean and later granites, we may direct our attention to the question of the special geochemical character of the Pre-Cambrian. As has been stated by Fersmann (1929, p. 16), certain independent areas may be recognized in the earth's crust, characterized by definite physical and chemical processes resulting in a given complex of chemical elements, called by Fersmann the natural geochemical combination of elements. The comparison of such associations is considered by the said author as being of high importance in the geochemical investigation of the earth's crust, and Fennoscandia is given as one of the examples of areas in question.

As is well-known, one of the most conspicuous petrological features of the Pre-Cambrian terrains is the large areal extension of granites, perceptible *ad oculis*, more than nine-tenths of the area of the world's granites and orthogneisses belonging to the Pre-Cambrian. Accordingly, the geochemistry of the Pre-Cambrian is largely identical with the geochemistry of the granites contained therein. Seeing that the Pre-Cambrian eras cover the greatest part of the geological time-table of the earth, we must readily share the opinion of Landergren (1943, p. 67) that it might be very important, from a geochemical point of view, to become well-informed concerning the migration of the elements in the upper parts of the lithosphere during Pre-Cambrian time.

The Pre-Cambrian granites are among the rocks best known as to their geochemical features. A comparison of the contents of trace elements in the Archean granites on the one hand, and the Late Pre-Cambrian, Paleozoic, and Mesozoic granites on the other, will reveal for many lithophile elements — besides the special position of the rapakivi granites — a marked decrease in content towards the downmost parts of the stratigraphic ladder as being the perhaps most conspicuous feature of the Archean granites. This would include a hypothesis of a unique trace element composition of the oldest crust of the earth, caused by the primary

differentiation by crystallization of the primary non-differentiated silicate mantle. We must, however, take into account that the use of the name »granite» very poorly characterizes many of the rocks in question, and that the magmatic processes, *e. g.*, the addition of juvenile ichors, and regional metamorphism, such as granitization, metasomatism, and metamorphic differentiation, will lead to an addition or subtraction of material, or both, these processes being highly characteristic of Archean times, while the Post-Archean geology tells little or nothing of regional palinogenesis or anatexis near the earth's surface (*cf.* Daly, 1933, p. 294).

However, there are still too few points of comparison between the Archean and Post-Archean granites to allow conclusions beyond the one presented above to be drawn. It is to be hoped that future investigations, based upon more ample material than at present available especially as regards the Caledonian and Variscan granites, will reveal a clearer picture of the interrelations of the Archean and younger granites in respect of their content of the trace elements.

RETROSPECT AND SUMMARY.

Based on the variations in the content of certain trace elements in granites of various geological ages, the theory of secular geochemical differentiation in the earth's crust is presented in the above pages. The material for the present study has been furnished by spectrochemical analyses of granites carried out by different authors, the differences in their *modus operandi* setting certain limits as to the equality of the values obtained. The rock material in question, the granites, may reveal, as a group, considerable inconsistencies due to the fact that the petrological and general chemical character of a very large proportion of the material is unknown. Attention may be given to a statement by Sahama (1945 b, p. 38) that the term »granite», when used in geochemical investigations, is generally understood in too broad a sense. It is to be hoped that in future geochemical investigations the petrological features and the chronological relations of the rock material used will be duly recorded.

Several analyses of standard mixtures of granites have also been exploited for the present study. It must be taken into account that analyses of such mixtures, taken from rocks without attention to suitable geological or chronological backgrounds, will be of importance only for purposes dealing with the determination of the mineralogical and petrological geochemistry of the various elements.

It has occasionally been necessary to discard analyses, due to the lack of suitable geographical or chronological data.

It will also be evident that the products of both magmatic and metamorphic differentiation, camouflaged in the material, will affect the anal-

ytical figures also in regard to the minor elements. The degree of metamorphism should accordingly always be duly recorded.

As in many earlier geochemical investigations, attention has also in the present case been paid only to igneous rocks. With regard to the possible use of metamorphic rocks, we may state that their geochemistry is known very poorly indeed, and accordingly the results obtained by their study cannot, at present, be of any greater geochemical moment. However, if the biography of the metamorphic rocks is adequately known, noteworthy results may be obtained, as is shown by the recent investigation of the trace elements in the rocks of Southern Lapland, carried out by Sahama (1945 a).

As will be seen from these considerations, the above picture of the present theory is greatly obscured by the lack of much needed data. To describe *multa paucis* it seems, in any case, to be possible to introduce the concept of a geochemical migration of the elements on global scale, by choosing the largest possible unit for phenomena usually thought to occur in smaller units of the earth's crust. Instead of the term »*regional geochemistry*» that of »*global geochemistry*» can thus be coined.

The evidence presented in Tables I—XVIII on the following pages seems to point to a secular migration of some minor elements in the earth's crust, the group consisting of Li, Be, Rb, Cs, Ba, Rare Earths, Ta, and Pb (*granitophile elements*) increasing in its content in granites originated during the later steps of the march of geological time, while the content of yttrium, thus far the sole representative of another group of elements (*granitophobe elements*), decreases with the decline in the geological ages of the elements. These views are set forth on the foregoing pages in detail, consistently seeking support from the theories of granitization and differential anatexis presented by Eskola, and from the principles of the division of the granites given by Wahl. The continuous secular migration in the outer part of the silicate crust of the earth is termed the fifth geochemical differentiation; it is described as a phenomenon pushing the siderophile and chalcophile (*granitophobe*) elements back into the basaltic substratum, distilling and sublimating the *granitophile* elements into the granitic crust of the earth.

Based on the views of the natural geochemical combinations of the elements, set forth by Fersmann, the Archean of Finland, illustrated by its granites, is shortly characterized as remarkably poor in many of the lithophile elements efflorescing in the granites of the later geological eras.

Future investigations will evidently reveal whether this theory of the global wanderings of the elements in the granitic crust of the earth will stand a critical examination. They may also furnish definitive facts by which the *experimentum crucis* of this theory can be executed. In the

present state of our knowledge of geochemistry this theory may be regarded merely as geological philosophy, seeing that its leading principles are not adequately supported by facts. However, this problem, with all its difficulties, discloses itself as a fascinating one, and I hope that the present solution, claiming no more than the value of synthesis, the first of its kind, may perhaps stimulate future workers to fill one of the *lacunae* in our present geochemical knowledge.

GEOLOGICAL SURVEY OF FINLAND;
GEOCHEMICAL LABORATORY, THE MINERALOGICAL AND GEOLOGICAL
INSTITUTE OF THE UNIVERSITY, HELSINKI, OCTOBER, 1945.

REFERENCES.

- ALLING, HAROLD LATTIMORE, Interpretative Petrology of the Igneous Rocks. New York 1936.
- BACKLUND, HELGE G., The Problems of the Rapakivi Granites. Journ. Geol., Vol. XLVI, p. 339. 1938.
- BARTH, TOM. F. W., Radium and the Petrology of Certain Granites of Finland. Amer. J. Sci., Vol. 35-A, p. 231. 1938.
- CLARKE, FRANK WIGGLESWORTH and WASHINGTON, HENRY STEPHENS, The Composition of the Earth's Crust. U. S. G. S., Prof. Paper 127. 1924.
- DALY, REGINALD ALDWORTH, Igneous Rocks and the Depths of the Earth. New York and London 1933.
- VON ENGELHARDT, WOLF, Die Geochemie des Barium. Chemie d. Erde, 10. Bd., p. 187. 1936.
- ERÄMETSÄ, OLAVI, SAHAMÄ, TH. G. und KANULA, VILJO, Spektrographische Bestimmungen an Rubidium und Caesium in einigen finnischen Mineralen und Gesteinen. C. R. Soc. géol. Finlande N:o XV; Bull. Comm. géol. Finlande N:o 128, p. 80. 1943 (1941).
- ESKOLA, PENTTI, Conditions During the Earliest Geological Times As Indicated by the Archaean Rocks. Ann. Acad. Sci. Fennicae, A, Vol. XXXVI. N:o 4. 1932 (1932 a).
- , On the Origin of Granitic Magmas. Min. Petr. Mitt., Bd. 42, p. 455. 1932 (1932 b).
- , On the Differential Anatexis of Rocks. C. R. Soc. géol. Finlande N:o VII; Bull. Comm. géol. Finlande N:o 103, p. 12. 1933.
- , Wie ist die Anordnung der äusseren Erdspären nach der Dichte zustande gekommen? Geol. Rdsch., Bd. XXVII, p. 61. 1936.
- FERSMANN, A., Geochemische Migration der Elemente usw. Teil I. Abh. prakt. Geol. Bergwirtsch., Bd. 18. 1929.
- GOLDSCHMIDT, V. M., Der Stoffwechsel der Erde. Videnskapss. Skr. I. Mat.-Naturv. Kl. N:o 11. 1922.
- , Geochemie. Handwörterb. d. Naturwiss., 2. Aufl., p. 886. Jena 1933.
- , Geochemische Verteilungsgesetze der Elemente IX. Die Mengenverhältnisse der Elemente und Atom-Arten. Vid.-Akad. Skr., I. M.-N. Kl., N:o 4. 1937 (1937 a).
- , The Principles of Distribution of Chemical Elements in Minerals and Rocks. J. Chem. Soc. (London), p. 655. 1937 (1937 b).
- , BAUER, H. und WITTE, H., Zur Geochemie der Alkalimetalle II. Nachr. Ges. Wiss. Göttingen, Math.-Phys. Kl., Neue Folge, Bd. 1, Nr. 4, p. 39. 1934.
- , HAUPTMANN, H. und PETERS, CL., Über die Berücksichtigung »seltener« Elemente bei Gesteins-Analysen. Naturwiss., 21. Jahrg., p. 363. 1933.
- und PETERS, CL., Zur Geochemie des Galliums. Nachr. Ges. Wiss. Göttingen, Math.-Phys. Kl., p. 165. 1931.
- , Zur Geochemie des Berylliums. Nachr. Ges. Wiss. Göttingen, Math.-Phys. Kl., p. 360. 1932 (1932 a).
- , Zur Geochemie des Bors. Nachr. Ges. Wiss. Göttingen, Math.-Phys. Kl., p. 402. 1932 (1932 b).

- GOLDSCHMIDT, V. M. und PETERS, CL., Zur Geochemie des Bors II. Nachr. Ges. Wiss. Göttingen, Math.-Phys. Kl., p. 528. 1932 (1932 c).
- »—, Zur Geochemie des Germaniums. Nachr. Ges. Wiss. Göttingen, Math.-Phys. Kl., p. 141. 1933.
- HILLEBRAND, W. F. and LUNDELL, G. E. F., Applied Inorganic Analysis. New York 1929.
- HOLMES, ARTHUR, Contributions to the Theory of Magmatic Cycles. Geol. Mag., Vol. LXIII, p. 306. 1926.
- »— and HARWOOD, HENRY FRANCIS, Petrology of the Volcanic Fields East and South-East of Ruwenzori, Uganda. Quart. J. Geol. Soc. London, Vol. 88, p. 370. 1932.
- »—, The Volcanic Area of Bufumbira, Part II: The Petrology of the Volcanic Field of Bufumbira, South-West Uganda, and of Other Parts of the Birunga Field. Geol. Survey of Uganda, Memoir No. 3. 1936.
- JOLY, J., The Radioactivity of the Rocks of the St. Gotthard Tunnel. Phil. Mag., Vol. XXIII, p. 201. 1912.
- KRANCK, E. H., Bedrock Geology of the Seaboard Region of Newfoundland Labrador. Newfoundland Geol. Survey, Bull. No. 19. 1939.
- KVALHEIM, ASLAK, On the Spectrochemical Determination of Vanadium in Iron Ores and Slags. Norsk Geol. Tidsskr., Bd. 21, p. 245. 1941.
- LANDERGREN, STURE, Geokemiska studier över Grängesbergfältets järnmalmer. Ing. Vetensk. Akad. Handl., Nr. 172. 1943.
- »—, Contribution to the Geochemistry of Boron II. The Distribution of Boron in Some Swedish Sediments, Rocks, and Iron Ores. The Boron Cycle in the Upper Lithosphere. Ark. Kemi Min. Geol., Bd 19 A, N:o 26. 1945.
- LINDGREN, WALDEMAR, Mineral Deposits. 3rd Ed. New York 1928.
- NOLL, W., Geochemie des Strontiums. Mit Bemerkungen zur Geochemie des Bariums. Chemie d. Erde, Bd. 8, p. 507. 1934.
- PIGGOT, CHARLES SNOWDEN, Radium in Rocks: II. Granites of Eastern North America from Georgia to Greenland. Am. J. Sci., Vol. XXI, p. 28. 1931.
- »—, Radium in Rocks: V. The Radium Content of the Four Groups of Pre-Cambrian Granites in Finland. Am. J. Sci., Vol. XXXV-A, p. 227. 1938.
- POOLE, J. H. J., The Radium Content of the Rocks of the Loetschberg Tunnel. Phil. Mag., Vol. XL, p. 466. 1920.
- »— and JOLY, J., The Radioactivity of Basalts and Other Rocks. Phil. Mag., Vol. XLVIII, p. 819. 1924.
- RAMBERG, HANS, The Thermodynamics of the Earth's Crust. I. Preliminary Survey of the Principal Forces and Reactions in the Solid Crust. Norsk Geol. Tidsskr., Bd. 24, p. 98. 1944.
- »—, The Termodynamics of the Earth's Crust. II. On the Theory of the Origin of Folded Mountains. Norsk Geol. Tidsskr., Bd. 25, p. 307. 1945.
- RANKAMA, KALERVO, On the Composition of the Residue from Silica in Rock-Analysis. C. R. Soc. géol. Finlante N:o XIV; Bull. Comm. géol. Finlante N:o 126, p. 3. 1941 (1939).
- »—, The Niobium and Tantalum Content of Three Finnish Archaean Granites (A Preliminary Report). C. R. Soc. géol. Finlante N:o XV; Bull. Comm. géol. Finlante N:o 128, p. 34. 1943 (1941).
- »—, On the Geochemistry of Tantalum. Bull. Comm. géol. Finlante N:o 133. 1944.
- SAHAMMA, TH. G., Akzessorische Elemente in den Granuliten von Finnisch-Lappland. C. R. Soc. géol. Finlante N:o IX; Bull. Comm. géol. Finlante N:o 115, p. 267. 1936.

- SAHAMÄ, TH. G., Spurenelemente der Gesteine im sudlichen Finnisch-Lappland. Bull. Comm. géol. Finlande N:o 135. 1945 (1945 a).
- , On the Chemistry of the East Fennoscandian Rapakivi Granites. C. R. Soc. géol. Finlande N:o XVIII; Bull. Comm. géol. Finlande N:o 136, p. 15, 1945 (1945 b).
- , and RANKAMA, KALERVO, Preliminary Notes on the Geochemical Properties of the Maarianvaara Granite. C. R. Soc. géol. Finlande N:o XIII; Bull. Comm. géol. Finlande N:o 125, p. 5. 1939 (1938).
- , and VÄHÄTALO, VEIKKO, X-Ray Spectrographic Study of the Rare Earths in Some Finnish Eruptive Rocks and Minerals. C. R. Soc. géol. Finlande N:o XIV; Bull. Comm. géol. Finlande N:o 126, p. 50. 1941 (1939).
- SEDERHOLM, J. J., The Average Composition of the Earth's Crust in Finland. Bull. Comm. géol. Finlande N:o 70. 1925.
- SMEETH, W. F. and WATSON, H. E., The Radioactivity of Archaean Rocks from the Mysore State, South India. Phil. Mag., Vol. XXXV, p. 206. 1918.
- STROCK, LESTER W., Zur Geochemie des Lithiums. Nachr. Ges. Wiss. Göttingen, Math.-Phys. Kl., IV; Neue Folge, Bd. 1, p. 171. 1936.
- VAN TONGEREN, W., Contributions to the Knowledge of the Chemical Composition of the Earth's Crust in the East Indian Archipelago, I. The Spectrographic Determination of the Elements According to Arc Methods in the Range 3 600 — 5 000 Å. II. On the Occurrence of Rarer Elements in the Netherlands East Indies. Amsterdam 1938.
- WAGER, L. R. and MITCHELL, R. L., Preliminary Observations on the Distribution of Trace Elements in the Rocks of the Skaergaard Intrusion, Greenland. Mineral. Mag., Vol. XXVI, p. 283. 1943.
- WAHL, W., Om granitgrupperna och bergskedjeveckningarna i Sverige och Finland. Geol. Fören. Förh., Bd. 58, p. 90. 1936 (1936 a).
- , The Granites of the Finnish Part of the Svecofennian Archaean Mountain Chain. C. R. Soc. géol. Finlande N:o IX; Bull. Comm. géol. Finlande N:o 115, p. 489. 1936 (1936 b).
- , Altersvergleich der Orogenesen und Versuch einer Korrelation des Grundgebirges in verschiedenen Teilen der Erde. Geol. Rdsch., Bd. 34 . . 209. 1943

TABLES.

TABLE I

Rock	Locality	Age	$\text{Li}_2\text{O} \%$
Leptite, hematite-bearing	Grängesbergsfältet, Sweden	Early Pre-Cambrian	0.004
Soda leptite	" "	"	0.002
Potash leptite, magnetite- bearing	" "	"	0.004
Leptite, magnetite-bearing	" "	"	0.006
Gneissose granite	Sodankylä, Finland	Pre-Cambrian	0.0001
" "	Savukoski, "	"	0.005
" "	" "	"	0.01
Gneissic granite	Kittilä,	"	0.006
Granite	Savukoski,	"	0.02
Granulite	Sodankylä,	"	0.005
"	Inari,	"	0.01
"	" "	"	0.001
Granite	Kittilä,	"	0.01
"	Sodankylä,	"	0.01
"	Muonio,	"	0.008
Nattanen granite	Sodankylä,	"	0.005
Rapakivi (granite porphyry)	Salmi, U. S. S. R.	Late Pre-Cambrian	0.0047
Rapakivi granite	" "	"	0.0052
" "	" "	"	0.0062
Rapakivi Standard Mixture	East Fennoscandia	"	0.0050
Biotite granite	Heggdal, Norway	Post-Silurian	0.0055
Granite Standard Mixture	Germany	Variscan	0.039
" " "	Saxony, Germany	"	0.1 — 0.15
Granite	Henneberg,	"	0.015 — 0.02
Granites ¹	Dutch East Indies	Mesozoic	0.01
Granophyre	Skaergaard, Greenland	Tertiary	0.0015

TABLE II

Rock	Locality	Age	$\text{BeO} \%$
Leptite, magnetite-bearing	Grängesbergsfältet, Sweden	Early Pre-Cambrian	0.0022
Granite	Huopalahti, Finland	Pre-Cambrian	<<0.001
"	Leppävirta,	"	0
Gneissose granites and granite gneisses, average	South Lapland, Fin- land	"	0.0003
Hetta granites, average	"	"	0.0003
Granulites, average	"	"	<0.003
Younger granites, average	"	"	0.0003
Nattanen granite	Sodankylä, Finland	"	<<0.001
Rapakivi (granite porphyry)	Salmi, U. S. S. R.	Late Pre-Cambrian	0.0003
Rapakivi granite	" "	"	0.0003
" "	" "	"	0
" "	Suistamo,	"	0
Rapakivi Standard Mixture	East Fennoscandia	"	0.001
Granitite	Heggdal, Norway	Post-Silurian	0.001 — 0.01
Hypersthene granite	Stalheim,	Caledonian (?)	<0.001
Granite	Brocken, Germany	Variscan	0.001 — 0.01
"	Wunsiedel,	"	0.001
"	Hauzenberg,	"	0.001
Hornblende granite	Kirnecktal,	"	<0.001
Granite Standard Mixture	"	"	0.002
Granite	Graustein, Austria	Alpidic (?)	<0.001

¹ Of 49 granites, 17 have a uniform Li_2O content of 0.01 %, while in the rest the Li line is not present.

TABLE III

Rock	Locality	Age	B_2O_3 %
Gneissose granite	Sodankylä, Finland	Pre-Cambrian	0
» »	Savukoski, »	»	0.001
» »	» »	»	0
Gneissic granite	Kittilä, »	»	0
Granite	Savukoski, »	»	0
Granulite	Sodankylä, »	»	0
»	Inari, »	»	0
»	» »	»	0
Granite	Kittilä, »	»	0
»	Sodankylä, »	»	0.001
»	Muonio, »	»	0
Nattanen granite	Sodankylä, »	»	0
Rapakivi (granite porphyry) ..	Salmi, U. S. S. R.	Late Pre-Cambrian	0.001
Rapakivi granite	» »	»	0.001
» »	Suistamo, »	»	0.003
Rapakivi Standard Mixture ..	East Fennoscandia	»	0.002
Biotite granite	Heggedal, Norway	Post-Silurian	0.001
Granite Standard Mixture ..	Germany	Variscan	0.001

TABLE IV

Rock	Locality	Age	Rb_2O %
Leptite, hematite-bearing	Grängesbergsfältet, Sweden	Early Pre-Cambrian	0.09
Soda leptite	» »	»	0.004
Potash leptite, magnetite- bearing	» »	»	0.22
Leptite, magnetite-bearing ..	» »	»	<0.0003
Potash leptite	» »	»	0.003
» »	» »	»	0.03
Soda leptite	» »	»	0.01
» »	» »	»	0.04
Oligoclase granite	Kisko, Finland	Pre-Cambrian	0.03
Granite	Hanko, »	»	0.16
»	Kalvolä, »	»	0.13
»	Hämeenkyrö, »	»	0.29
Bodom granite	Espoo, »	»	0.11
Lemland granite	Jomala, »	»	0.07
Åva granite	Brändö, »	»	0.2
Lamprophyre in Åva granite	» »	»	0.07
Onas granite	Porvoon pit, »	»	0.1
Obbnäs granite	Kyrkslätt, »	»	0.1
Granite	Suonenjoki, »	»	0.08
Maarianvaara granite	Kaavi, »	»	0.11
» »	Kimusjärvi, »	»	0.08
Granite	Paltamo, »	»	0.05
»	Kajaani, »	»	0.08
Gneissose granite	Sodankylä, »	»	0.1
» »	Savukoski, »	»	0.2
» »	» »	»	0.2
Gneissic granite	Kittilä, »	»	0.06
Granite	Savukoski, »	»	0.2
Granulite	Sodankylä, »	»	0
»	Inari, »	»	0.05

TABLE IV (CONT'D)

Rock	Locality	Age	Rb ₂ O %
Granulite	Inari, Finland	Pre-Cambrian	0.06
Granite	Kittilä, »	»	0.2
»	Sodankylä, »	»	0.2
»	Muonio, »	»	0.1
Nattanen granite	Sodankylä, »	»	0.1
Rapakivi granite	Kumlinge, »	Late Pre-Cambrian	0.12
» »	Hammarland, »	»	0.11
» »	Föglö, »	»	0.2
» »	» Lemland, »	»	0.2
» »	Vårdö, »	»	0.2
» »	Saltyvik, »	»	0.2
» »	Impilahti, U. S. S. R.	»	0.25
» »	» »	»	0.2
Rapakivi (granite porphyry)	» »	»	0.1
Rapakivi granite	Salmi, »	»	0.19
» »	» »	»	0.2
» »	» »	»	0.08
Rapakivi (granite porphyry)	» »	»	0.10
Rapakivi granite	» »	»	0.09
» »	» »	»	0.12
» »	Suistamo, »	»	0.11
Rapakivi Standard Mixture	East Fennoscandia	»	0.16
Granite Standard Mixture	Germany	Variscan	0.091
Aplite	P. Berhala (S. O. K.)	Mesozoic	0.n(?)
Pegmatite	Oemar Bay, New Guinea	»	0.n(?)
Granophyre	Skaergaard, Greenland	Tertiary	0.1

TABLE V

Rock	Locality	Age	Cs ₂ O %
Oligoclase granite	Kisko, Finland	Pre-Cambrian	0
Granite	Hanko, »	»	0
»	Kalvola, »	»	<0.003
»	Hämeenkyrö, »	»	0.005
Bodom granite	Espoo, »	»	0
Lemland granite	Jomala, »	»	0
Granite	Suonenjoki, »	»	0
Maarianvaara granite	Käävi, »	»	0
Rapakivi granite	Kumlinge, »	Late Pre-Cambrian	0
» »	Hammarland, »	»	0
Rapakivi Standard Mixture	East Fennoscandia	»	0
Granite Standard Mixture	Germany	Variscan	0.0042

TABLE VI

Rock	Locality	Age	SrO %	BaO %
Leptite, hematite-bearing	Grängesbergsfältet, Sweden	Early Pre-Cambrian	0.006	<0.0003
Soda leptite	» »	»	0.0035	0.02
Potash leptite, magnetite-bearing	» »	»	0.001	0.03

Kalervo Rankama: On the Geochemical Differentiation in the Earth's Crust.

TABLE VI (CONT'D)

Rock	Locality	Age	SrO %	BaO %
Leptite, magnetite-bearing	Grängesbergsfältet, Sweden	Early Pre-Cambrian	0.0035	0.001
Potash leptite	» »	»	0.002	0.02
» »	» »	»	0.02	0.45
Soda leptite	» »	»	0.007	0.03
» »	» »	»	0.001	0.01
Gneissose granite	Sodankylä, Finland	Pre-Cambrian	0.003	0.05
» »	Savukoski,	»	0.003	0.03
» »	» »	»	0.006	0.03
Gneissic granite	Kittilä,	»	0.1	0.1
Granite	Savukoski,	»	0.02	0.07
Granulite	Sodankylä,	»	0.05	0.1
»	Inari,	»	0.05	0.1
»	»	»	0.003	0.03
Granite	Kittilä,	»	0.02	0.1
»	Sodankylä,	»	0.003	0.05
»	Muonio,	»	0.02	0.01
Nattanen granite	Sodankylä,	»	0.003	0.03
Rapakivi (granite porphyry)	Salmi, U. S. S. R.	Late Pre-Cambrian	0.005	0.081
Rapakivi granite	» »	»	<0.003	0.038
» »	» »	»	0.008	0.14
Rapakivi Standard Mixture	Suistamo, U. S. S. R.	»	0.004	0.054
Granitite	East Fennoscandia	»	0.012	0.10
Hypersthene granite	Heggedal, Norway	Post-Silurian	n. d.	0.014
Pyroxene granite	Stalheim,	Caledonian (?)	n. d.	0.12
Hornblende granite	Aardal,	» (?)	n. d.	0.34
Granite Standard Mixture	Kirnecktal, Germany	Variscan	n. d.	0.028
Granulite	Gebersbach,	»	0.02	0.042
Granite (belongs to the charnockites)	Zytmierz, Poland	»	n. d.	0.026
Granites, average ¹	Dutch East Indies	Mesozoic	0.06	0.1
Granophyre	Skaergaard, Green- land	Tertiary	0.03	0.2

TABLE VII

Rock	Locality	Age	Ra 10^{-12} g./g.	Author
Granite	Enklinge, Finland	Pre-Cambrian	1.04	PJ ²
Gneissose granite	Ingå,	»	0.63	Pi
Vätskär gneiss granite	Pernä,	»	0.85	Pi
Orijärvi granite	Kisko,	»	1.23	Pi
Granite	Helsinki,	»	3.98	PJ
»	Kumlinge,	»	5.51	Pi
Hanko granite	Ingå,	»	0.91	Pi
» »	Hanko,	»	5.77	PJ
Helsinkite granite	»	»	4.62	PJ
Granite	Sibbo,	»	1.55	Pi
»	Siuro,	»	1.55	Pi
»	Lavia,	»	2.30	Pi
»	Kuru,	»	3.17	Pi

¹ These averages are calculated on the basis of 49 SrO and BaO determinations in granites from the Dutch East Indies, presented by van Tongeren (1938). The contents vary between the following limits: SrO, 0.005—0.5% (mostly 0.03 or 0.05%); BaO, 0.005—0.3% (mostly from 0.05 to 0.2%).

² J. Joly (1912); Pi, Piggot (1931, 1938); Po, Poole (1920); PJ, Poole and Joly (1924); SW, Smeeth and Watson (1918).

TABLE VII (CONT'D)

Rock	Locality	Age	Ra 10^{-12} g./g.	Author
Granite	Kuru, Finland	Pre-Cambrian	7.00	PJ
"	Orivesi, "	"	2.97	PJ
"	Kalvola, "	"	1.87	Pi
"	Kalajoki, "	"	2.45	PJ
Ava granite	Brändö, "	"	1.21	Pi
Obbnäs granite	Kyrkslätt, "	"	1.48	Pi
Ounas granite	Pörvoon pit., "	"	1.03	Pi
Granite	Rovaniemi, "	"	0.43	Pi
"	Tranås, Sweden	"	3.144	Pi
Biotite granite	Kristiansand, Norway	"	0.566	Pi
Rapakivi granite	Labrador, Canada	"	1.40	Pi
"	Kumlinge, Finland	Late Pre-Cambrian	2.21	Pi
"	Kustavi, "	"	1.13	Pi
"	Pernå, "	"	1.47	Pi
"	Pyterlahti, "	"	4.81	PJ
"	Lappee, "	"	1.60	Pi
"	"	"	5.77	PJ
"	"	"	6.65	PJ
"	Viipuri, U. S. S. R.	"	2.74	Pi
"	Salmi, "	"	0.92	Pi
Granite	Flannan Islands, Scotland	Archean	1.75	PJ
"	Loch Michard, Scotland	"	1.58	PJ
"	Cape Wrath, "	"	2.27	PJ
Hornblende orthogneiss	Tiree,	"	1.20	PJ
Granogneiss	Coll,	"	1.84	PJ
"	"	"	1.66	PJ
Orthogneiss	Tiree,	"	1.60	PJ
Grey granite	Kolar, Mysore	"	0.85	SW
Micaceous granite	" "	"	1.45	SW
Mica granite	" "	"	1.34	SW
Porphyritic granite	" "	"	0.91	SW
Dark grey granite	" "	"	0.99	SW
Fine dark grey granite	" "	"	1.28	SW
Fine light grey granite	" "	"	0.47	SW
Light crushed granite	" "	"	0.40	SW
Granite	" "	"	1.50	SW
Acid charnockite	Chamrajnagar, Mysore	"	0.04	SW
Grey porphyritic granite	Closepet,	"	0.27	SW
Grey granite	" "	"	0.63	SW
Red granite	" "	"	2.14	SW
Biotite muscovite granite	Stone Mountain, Ga., U. S. A.	Variscan	3.81	Pi
Biotite granite	Mt. Airy, N. C., U. S. A.	"	0.49	Pi
Granite (biotite diorite)	Ilchester, Md., "	"	0.91	Pi
Biotite granite	Woodstock Md., "	"	1.09	Pi
"	Milford, Mass., "	"	0.26	Pi
Hornblende biotite granite	Rockport, Mass., "	"	0.72	Pi
Biotite granite	Hurricane Is., Me., U. S. A.	"	2.79	Pi
Biotite muscovite granite	North Jay, Me., U.S.A.	"	3.39	Pi
Gneissic granite, average ¹	St. Gotthard Tunnel, Switzerland	Alpidic	6.9	J
Gastern granite, average ²	Loetschberg Tunnel, Switzerland	"	2.5	Po

¹ Ra determinations in 17 samples of gneissic granites are included in this average. The contents vary between 3.4×10^{-12} and 14.1×10^{-12} g. Ra per gram of rock.

² The average calculated from Ra determinations of 8 Gastern granites and aplites. The Ra content varies between 2.0×10^{-12} and 2.9×10^{-12} g./g.

TABLE VIII

Rock	Locality	Age	Sc ₂ O ₃	Y ₂ O ₃	La ₂ O ₃	Ce ₂ O ₃	Nd ₂ O ₃
Granite	Karjaa, Finland	Pre-Cambrian	n. d.	0.003	0.003	0.005	0.003
»	Kalvolaa, »	»	n. d.	0.005	0.004	0.007	0.005
Bodom granite .	Espoo, »	»	n. d.	0.03	0.06	0.08	0.03
Obbnäs » .	Kyrkslätt, »	»	n. d.	0.02	0.03	0.05	0.02
Onas » .	Porvoon pit., Finland	»	n. d.	0.008	0.004	0.01	0.008
Maarianvaara granite pegmatite	Kaavi, Finland	»	n. d.	0.005	0.001	0.002	0.001
Gneissose granite	Sodankylä, »	»	0.0001	0.006	0.006	0.006	0.003
» »	Savukoski, »	»	0.0001	0.003	0.006	0.01	0.01
» »	» »	»	0.0003	0.003	0.01	0.06	0.03
Gneissic granite.	Kiittilä, »	»	0	0	< 0.001	0.006	0
Granite	Savukoski, »	»	0.0001	0	0.003	0.008	0
Granulite	Sodankylä, »	»	0.003	0.003	0.006	0.004	0.003
»	Inari, »	»	0.006	0.01	0.008	0.008	0.006
»	» »	»	0.001	0.003	0.006	0.008	0.006
»	» »	»	0.0005	0.003	0.005	0.002	n. d.
Granite	Kiittilä, »	»	0.0001	0	0.001	0.006	0
»	Sodankylä, »	»	0.0001	0.003	0.008	0.01	0.01
»	Muonio, »	»	0.0001	0.003	0.008	0.008	0.01
Nattanen granite	Sodankylä, »	»	0	0	0.005	0.01	0
» »	» »	»	n. d.	0.003	0.003	0.009	0.005
Rapakivi (granite porphyry)	Salmi, U. S. S. R.	Late Pre-Cambrian	0.0001	0.003	0.01	0.03	0.006
Rapakivi granite	» »	»	0.0001	0.003	0.01	0.01	0.006
» »	» »	»	0.0001	0.003	0.01	0.03	0.006
» »	Suistamo, »	»	0.0001	0.0052	0.0046	0.0100	0.0041
Rapakivi Standard Mixture ...	East Fennoscandia	»	0.0001	0.0051	0.0040	0.0080	0.0060
Granite Standard Mixture	Germany	Variscan	0.0002	0.0015	n. d.	n. d.	n. d.
Amphibole biotite granite	Bandjoemas, Java	Mesozoic	0.0001	0.001	0.0003	0	0
» » »	Merawoe, Java	»	0.0002	0.001	0.001	0.003	0.001
Granite	Kediri, »	»	0.0003	0.0005	0.0003	0	0
Amphibole biotite granite	Kapoeas, Borneo	»	0.0001	0.0005	0.0005	0	0.001
» » »	» »	»	0.0002	0.005	0.002	0.003	0.003
» » »	Sei Mandai, Borneo	»	0.0003	0.02	0.01	0.005	0.005
Biotite granite .	Bt. Pitoeng, Borneo	»	0.0001	0.005	0.01	0.01	0.005
Pegmatite	Sei Seberoeang, Borneo	»	< 0.0001	0.0002	0	0	0
Amphibole granite	Sei Samba, Borneo	»	0.0002	0.003	0.001	0	0
Gneiss-like granite	Sei Kaso, Borneo	»	0.0001	0.0003	0	0	0
Granite	Sei Oga, »	»	0.0001	0.005	0.003	0.003	0.002
»	Sei Ketingan, Borneo	»	0.0001	0.001	0.002	< 0.003	0.001
Biotite granite .	Long Kan, Borneo	»	< 0.0001	0.003	0.002	< 0.003	0.001
» » .	Djebces, Banka	»	0.0002	0.005	0.005	0.01	0.005

TABLE VIII (CONT'D)

Rock	Locality	Age	Sc_{2}O_3	Y_{2}O_3	La_{2}O_3	Ce_{2}O_3	Nd_{2}O_3
Aplite	Djeboes, Banka	Mesozoic	0.0001	0.005	0.002	0.005	0.002
Biotite granite .	» »	»	0.0001	0.01	0.003	0.005	0.002
Biotite amphi-bole granite ..	» »	»	0.0002	0.003	0.02	0.02	0.01
Graphic granite ..	Tikoes, Billiton	»	< 0.0001	0.002	0	0	0
Biotite granite .	S.Sekoeng, Billiton	»	< 0.0001	0.003	0.005	0.01	0.005
Amphibole granite ..	Mt. René, Billiton	»	0.0005	0.005	0.005	0.005	0.005
Granite	Gg. Bloeroe, Billiton	»	0.0001	0.003	0.005	0.01	0.01
Amphibole granite ..	Gg. Menang, Billiton	»	0.0002	0.002	0.005	0	0.005
Granite	Mangkai, Anambas Islands	»	0.0001	0.003	0.01	0.02	0.005
»	Semamal, Riouw-Lingga Archip.	»	< 0.0001	0.005	0.005	0.01	0.01
»	P. Nongsa, R.-L. Archipelago	»	< 0.0001	0.001	0.005	0.01	0.005
»	Tandjoengpinang, R.-L. Archipelago	»	< 0.0001	0.001	0.005	0.01	0.005
»	P. Rangas, R.-L. Archipelago	»	0.05	0.03	0.03	0.03	0.02
Aplite	P. Berhala (S. O. K.)	»	< 0.0001	0	0	0	0
Biotite granite .	» »	»	0.0002	0.01	0.005	0.005	0.005
Granite, allanite-bearing	Atjeh, Sumatra	»	0.0001	0.0005	0.005	0.01	0.005
Granite	Soengalasi, Sumatra	»	< 0.0001	0.0001	0.0003	0	0
Muscovite granite	» »	»	< 0.0001	0.0003	0.0005	< 0.003	0
Amphibole granite	Sibahoe, »	»	0.0001	0.002	0.0003	0	0
Amphibole biotite granite	Bt. Barisan, Sumatra	»	0.0002	0.001	0.0003	0	0
Granite, rich in ore	Lampoengsche Distr., Sumatra	»	0.0002	0.003	0.002	0.005	0.003
Biotite granite .	Paloppo, Celebes	»	0.001	0.01	0.01	0.02	0.01
Amphibole granite	Gorontalo, Celebes	»	0.0005	0.005	0.001	< 0.003	0.002
Amphibole granitite	» »	»	0.0003	0.003	0.003	0.003	0.003
Quartz tourmaline mica rock .	Lucipara Islands	»	0.0002	0.002	0.002	0.003	0.003
Biotite amphibole granite	S. E. Soemba	»	0.0002	0.0003	0.0003	0	0
Biotite granite .	Timor	»	< 0.0001	0.003	0.0003	0	0
Biotite granite ..	Ceram	»	0.0003	0.001	0.0002	0	0
» » .	Ambon	»	0.0002	0.002	0.002	0.003	0.002
» » .	Taliaboe	»	0.0001	0.0005	0.0002	0	0
» » .	Batjan	»	0.0001	0.0005	0.0002	0	0
Tourmaline granite	Geelvink Bay, New Guinea	»	0.0001	0.0003	0.0005	0.003	0

TABLE VIII (CONT'D)

Rock	Locality	Age	Sc_2O_3	Y_2O_3	La_2O_3	Ce_2O_3	Nd_2O_3
Pegmatite	Oemar Bay, New Guinea	Mesozoic	0.0002	0.0005	0	0	0
Granite	Tawnioe River, New Guinea	"	0.0001	0.0005	0	0	0
"	Digoel River, New Guinea	"	0.0001	0.0005	0.002	<0.003	0.001
Granophyre	Skaergaard, Greenland	Tertiary	n. d.	0.004	0.004	n. d.	n. d.

TABLE IX

Rock	Locality	Age	ZrO_2 %
Gneissose granite	Sodankylä, Finland	Pre-Cambrian	0.1
" "	Savukoski, "	"	0.05
" "	" "	"	0.03
Gneissic granite	Kittilä,	"	0.02
Granite	Savukoski,	"	0.03
Granulite	Sodankylä,	"	0.02
"	Inari,	"	0.05
"	" "	"	0.02
Granite	Kittilä,	"	0.07
"	Sodankylä,	"	0.02
"	Muonio,	"	0.02
Nattanen granite	Sodankylä,	"	0.02
Rapakivi (granite porphyry) ..	Salmi, U. S. S. R.	Late Pre-Cambrian	0.1
Rapakivi granite	" "	"	0.1
" "	" "	"	0.1
Rapakivi Standard Mixture ..	Suistamo, "	"	0.1
Granites, average ¹	East Fennoscandia		0.12
Granophyre	Dutch East Indies	Mesozoic	0.02(5)
	Skaergaard, Greenland	Tertiary	0.04

TABLE X

Rock	Locality	Age	ThO_2 %	Author
Granite	Helsinki, Finland	Pre-Cambrian	0.00199	PJ ²
"	Hanko,	"	0.00313	PJ
"	" "	"	0.00256	PJ
"	Karjaa,	"	0.001	SV
"	Kalvolaa,	"	0.002	SV

¹ This average includes 49 granites with ZrO_2 content varying between 0 and 0.2 %. If present, the most common ZrO_2 content is 0.01 to 0.03 %.

² J, Joly (1912); PJ, Poole and Joly (1924); S, Sahama (1945 b); SV, Sahama and Vähätalo (1939); WM, Wager and Mitchell (1943).

TABLE X (CONT'D)

Rock	Locality	Age	ThO_2 %	Author
Granite	Orivesi, Finland	Pre-Cambrian	0.00085	PJ
»	Kuru, »	»	0.00455	PJ
»	Kalajoki, »	»	0.00214	PJ
Bodom granite	Espoo, »	»	0.02	SV
Maarianvaara granite pegmatite	Kaavi, »	»	0.0006	SV
Nattanen granite	Sodankylä, »	Late Pre-Cambrian	0.003	SV
Rapakivi granite	Pyterlahti, »	»	0.00156	PJ
» »	»	»	0.00649	PJ
» »	»	»	0.00683	PJ
Rapakivi Standard Mixture	East Fennoscandia	»	0.004	S
Granite	Flannan Islands, Scotland	Archean	0.00102	PJ
»	Loch Michard, Scotland	»	0.00058	PJ
»	Cape Wrath, »	»	0.00197	PJ
Hornblende orthogneiss	Tiree, »	»	0.00073	PJ
Granogneiss	Coll, »	»	0.00059	PJ
»	»	»	0.00224	PJ
Orthogneiss	Tiree, »	»	0.00185	PJ
Gneissic granite, average ¹	St. Gotthard Tunnel, Switzerland	Alpidic	0.0025	J
Granophyre	Skaergaard, Greenland	Tertiary	0.011	WM

TABLE XI

Rock	Locality	Age	V_2O_5 %
Leptite, hematite-bearing	Grängesbergsfältet, Sweden	Early Pre-Cambrian	0.36
Soda leptite	» »	»	0.002
Potash leptite, magnetite-bearing	» »	»	0.002
Granite	Huopalahti, Finland	Pre-Cambrian	0.01
»	Leppävirta, »	»	0.003
Gneissose granite	Sodankylä, »	»	0
» »	Savukoski, »	»	0.001
Gneissic granite	Kittilä, »	»	0.001
Granite	Savukoski, »	»	0.0003
Granulite	Sodankylä, »	»	0.01
»	Inari, »	»	0.003
»	Kittilä, »	»	0.003
Granite	Sodankylä, »	»	0.001
»	Muonio, »	»	0.003
Nattanen granite	Sodankylä, »	»	0.0003
Rapakivi (granite porphyry)	Salmi, U. S. S. R.	Late Pre-Cambrian	0.0003
Rapakivi granite	» »	»	0.0001
» »	Suistamo, »	»	0.03
Rapakivi Standard Mixture	East Fennoscandia	»	0.0003
Granites, average ²	Dutch East Indies	Mesozoic	0.01
Granophyre	Skaergaard, Greenland	Tertiary	0.0018

¹ Th determinations in 17 samples of gneissic granites of the Finsteraarhorn *massif* are included in this average. The Th content varies between 0.001 and 0.005 %.

² This average has been calculated from 49 granites, ranging in V_2O_5 content from 0.0003 to 0.05 %. The most common content was 0.01 % V_2O_5 .

TABLE XII

Rock	Locality	Age	Nb_2O_5 %
Granite	Hämeenkyrö, Finland	Pre-Cambrian	0.0011
Bodom granite	Espoo, »	»	0.0100
Nattanen granite	Sodankylä, »	»	0.0045
Rapakivi (granite porphyry)	Salmi, U. S. S. R.	Late Pre-Cambrian	0.001
Rapakivi granite	» »	»	0.003
» »	» »	»	0.001
» »	Suistamo, »	»	0.003
Rapakivi Standard Mixture ..	East Fennoscandia	»	0.001

TABLE XIII

Rock	Locality	Age	Ta_2O_5 %
Granite gneiss	Impilahti, U. S. S. R.	Pre-Cambrian	0
Oligoclase granite	Kisko, Finland	»	0
Mica gneiss	Tammela, »	»	0
Perniö granite	Kemiö, »	»	0
Migmatitic gneissose granite ..	Pietarsaari, »	»	0
Granite	Kuru, »	»	0.00009
»	Hämeenkyrö, »	»	0.0002
Hornblende granite	Tammela, »	»	0
Microcline granite	» »	»	0.002
Granite	Jämsä, »	»	0
Porphyritic granite	Kankaanpää, »	»	0.004
Tourmaline granite, aplite ..	Karkku, »	»	0
Ava granite	Brändö, »	»	0
Lamprophyre in Ava granite	» »	»	0.0002
Bodom granite	Espoo, »	»	0.0026
Nattanen granite	Sodankylä, »	»	0.0021
Rapakivi granite	Sund, »	Late Pre-Cambrian	0.0003
» »	Kustavi, »	»	0.0001
» »	Eura, »	»	0.0001
» »	Vehkalahti, »	»	0
» »	Luumäki, »	»	0
» »	Lappee, »	»	0
»	» »	»	0.0001
»	Antrea, U. S. S. R.	»	0.001
» »	Salmi, »	»	0.0001
Rapakivi Standard Mixture ..	East Fennoscandia	»	0.0001
Pyroxene granite	Sviatoy Noss, U. S. S. R.	Pre-Cambrian	0

TABLE XIV

Rock	Locality	Age	Cr_2O_3 %
Leptite, hematite-bearing	Grängesbergfältet, Sweden	Early Pre-Cambrian	< 0.001
Soda leptite	» »	»	< 0.001
Potash leptite, magnetite-bearing	» »	»	< 0.001
Leptite, magnetite-bearing	» »	»	0.003
Granite	Huopalahti, Finland	Pre-Cambrian	0.001
»	Leppävirta, »	»	0.0003

TABLE XIV (CONT'D)

Rock	Locality	Age	Cr_2O_3 %
Gneissose granite	Sodankylä, Finland	Pre-Cambrian	0
» »	Savukoski, »	»	0.0003
» »	Kittilä, »	»	0.003
Gneissic granite	Savukoski, »	»	0.0003
Granite	Sodankylä, »	»	0.0001
Granulite	Inari, »	»	0.1
»	Kittilä, »	»	0.03
Granite	Sodankylä, »	»	0.03
»	Muonio, »	»	< 0.0001
Nattanen granite	Sodankylä, »	»	0.0005
» »	Salmi, U. S. S. R.	Late Pre-Cambrian	0
Rapakivi (granite porphyry) . .	» »	»	0.004
Rapakivi granite	» »	»	0.001
» »	Suistamo, »	»	0.006
Rapakivi Standard Mixture ..	East Fennoscandia	»	0.004
Granites, average ¹ ..	Dutch East Indies	Mesozoic	0.005
Granophyre	Skaergaard, Greenland	Tertiary	0.0004

TABLE XV

Rock	Locality	Age	Co_2O_4 %	NiO %
Leptite, hematite-bearing . . .	Grängesbergsfältet, Sweden	Early Pre-Cambrian	< 0.001	0.001
Soda leptite	» »	»	< 0.001	< 0.001
Potash leptite, magnetite-bearing	» »	»	0.001	< 0.001
Leptite, magnetite-bearing . . .	» »	»	0.001	0.001
Granite	Ifuopalaiti, Finland	Pre-Cambrian	0	< 0.0003
»	Leppävirta, »	»	0	<< 0.0003
Gneissose granite	Sodankylä, »	»	0	0.0003
» »	Savukoski, »	»	< 0.001	0.0003
Gneissic granite	Kittilä, »	»	< 0.001	0
Granite	Savukoski, »	»	0	0
Granulite	Sodankylä, »	»	< 0.001	0.001
»	Inari, »	»	0.001	0.003
»	Kittilä, »	»	< 0.001	0.003
Granite	Sodankylä, »	»	0	0
»	Muonio, »	»	< 0.001	0.0003
Nattanen granite	Sodankylä, »	»	0	0
» »	Salmi, U. S. S. R.	Late Pre-Cambrian	0	<< 0.0003
Rapakivi granite	» »	»	0	0
» »	Suistamo, »	»	0	0
Rapakivi Standard Mixture ..	East Fennoscandia	»	0	0.0003
Granites, average ² ..	Dutch East Indies	Mesozoic	0	0
Granophyre	Skaergaard, Greenland	Tertiary	0.0004	0.0006

¹ Included are 49 granites with Cr_2O_3 varying between 0.0003 and 0.02 %. The most usual content is 0.003 to 0.005 % Cr_2O_3 .

² This average includes 49 granites of the Dutch East Indies. It must be taken into account that the limit of sensitivity for the nickel and cobalt lines used ($\text{Ni } 3619.392 \text{ \AA}$, $\text{Co } 3995.312 \text{ \AA}$) lies at 0.01 % CoO and NiO . Accordingly, the results obtained by van Tongeren (1938) are not comparable with the other figures in this table.

TABLE XVI

Rock	Locality	Age	Ga ₂ O ₃ %
Granite	Huopalahti, Finland	Pre-Cambrian	0.01
"	Leppävirta, "	"	0.01
Gneissose granites and granite gneisses, average	South Lapland, "	"	0.01
Hetta granites, average	" "	"	0.01
Granulites, average	" "	"	0.01
Youngest granites, average	" "	"	0.01
Nattanen granite	Sodankylä, "	"	0.01
Rapakivi (granite porphyry) ..	Salmi, U. S. S. R.	Late Pre-Cambrian	0.01
Rapakivi granite	" "	"	0.01
" "	Suistamo, "	"	0.01
Rapakivi Standard Mixture ..	East Fennoscandia	Caledonian (?)	~0.01
Hypersthene granite	Stalheim, Norway	" (?)	~0.001
Pyroxene granite	Aardal, "	Variscan	~0.001
Granite	Brocken, Germany	"	0.002
Granite Standard Mixture ..	"	Mesozoic	0.007
Granites, average ¹	Dutch East Indies	Tertiary	0.002
Granophyre	Skaergaard, Greenland		

TABLE XVII

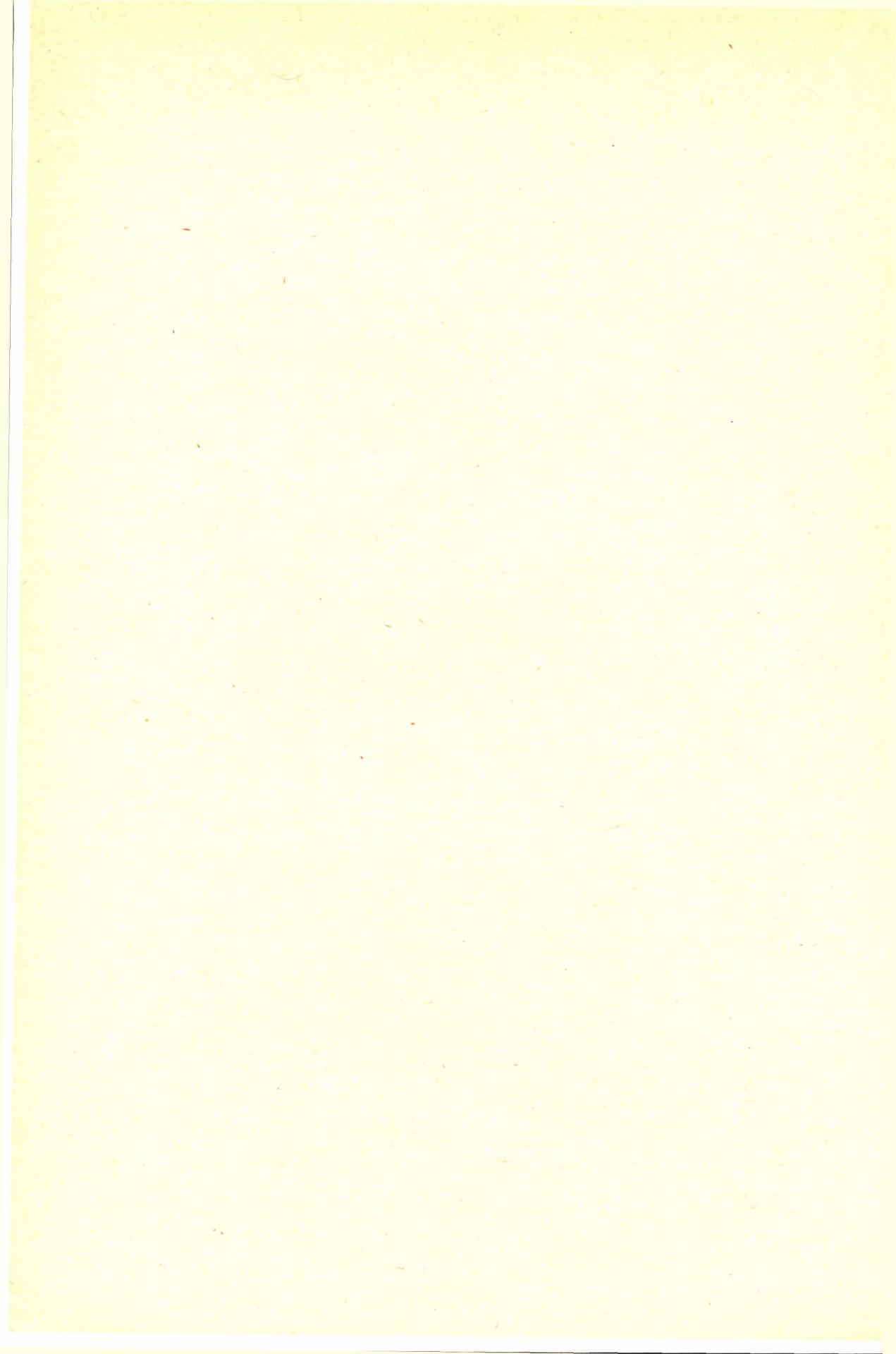
Rock	Locality	Age	GeO ₂ %
Granite	Huopalahti, Finland	Pre-Cambrian	0
"	Leppävirta, "	"	0
Nattanen granite	Sodankylä, "	"	0
Rapakivi Standard Mixture ..	East Fennoscandia	Late Pre-Cambrian	0.0001
Granite Standard Mixture ...	Germany	Variscan	0.0005

TABLE XVIII

Rock	Locality	Age	PbO %
Granite	Huopalahti, Finland	Pre-Cambrian	0.003
"	Leppävirta, "	"	0
Gneissose granite	Sodankylä, "	"	0
" "	Savukoski, "	"	0
" "	Kittilä, "	"	0.001
Gneissic granite	Savukoski, "	"	0.001
Granite	Sodankylä, "	"	0.001
Granulite	Inari, "	"	0
"	" "	"	0
Granite	Kittilä, "	"	0.003
"	Sodankylä, "	"	0
"	Muonio, "	"	0
Nattanen granite	Sodankylä, "	"	0.001
" "	" "	"	0.001
Rapakivi (granite porphyry) ..	Salmi, U. S. S. R.	Late Pre-Cambrian	0.001
Rapakivi granite	" "	"	0.001
" "	" "	"	0.003
" "	Suistamo, "	"	0.001
Rapakivi Standard Mixture ..	East Fennoscandia	"	0.006
Granites, average ²	Dutch East Indies	Mesozoic	0.003

¹ The average represents 49 granites of the Dutch East Indies with a Ga₂O₃ content varying between 0.05 and 0.001 %. The rocks most commonly contain 0.003 to 0.01 % Ga₂O₃.

² Average of 49 PbO determinations of granites showing PbO percentages from 0.0003 to 0.01, most commonly from 0.002 to 0.005 %.



Fascicules parus du Bulletin de la Commission géologique de Finlande.

- N:o 1. Ramsay, Wilhelm und Nyholm, E. T. Cancerinitisyenit und einige verwandte Gesteine aus Kuolajärvi. S. 1—12. 4 Fig. 1895 .. 60: —
- N:o 2. Sederholm, J. J. Ueber einen metamorphosirten praecambriischen Quarzporphyr von Karvia in der Provinz Åbo. S. 1—16. 12 Fig. 1895 .. 60: —
- N:o 3. Ramsay, Wilhelm, jemte Bihang 1 och 2 af Hackman, Victor och 3 af Sederholm, J. J. Till frågan om det senglaciala hafvets utbredning i Södra Finland. S. 1—44. 1 karta. Résumé en français: La transgression de l'ancienne mer glaciaire sur la Finlande méridionale, 1896 100: —
- N:o 4. Frosterus, Benj. Ueber einen neuen Kugelgranit von Kangasniemi in Finland. S. 1—38. 11 Fig. 2 Taf. 1896 80: —
- *N:o 5. Berghell, Hugo. Bidrag till kännedomen om Södra Finlands kvartära nivåförändringar. S. 1—64. 16 fig. 1 plansch. 1 karta. Deutsches Referat: Beiträge zur Kenntniss der quartären Niweauschwankungen Süd-Finlands. 1896 —: —
- *N:o 6. Sederholm, J. J. Über eine archäische Sedimentformation im südwestlichen Finland und ihre Bedeutung für die Erklärung der Entstehungsweise des Grundgebirges. S. 1—254. 97 Fig. 5 Taf. 2 Karten. 1897 —: —
- *N:o 7. Ailio, Julius. Über Strandbildungen des Litorinameeres auf der Insel Mantsinsaari. S. 1—43. 8 Fig. 1 Karte. 1898 —: —
- *N:o 8. Andersson, Gunnar. Studier öfver Finlands torfmossar och fossila kvartärfloren. S. 1—210. 21 fig. 4 tafl. Deutsches Referat: Studien über die Torfmoore und die fossile Quartärfloren Finlands. 1898 —: —
- N:o 9. Sederholm, J. J. Esquisse hypsométrique de la Finlande. P. 1—17. 1 carte. 1899 100: —
- N:o 10. Sederholm, J. J. Les dépôts quaternaires en Finlande. P. 1—28. 2 Fig. 1 carte. 1899 100: —
- *N:o 11. Hackman, Victor. Neue Mitteilungen über das Ijolithmassiv in Kuusamo. S. 1—45. 12 Fig. 1 Taf. 2 Karten. 1899 —: —
- *N:o 12. Ramsay, Wilhelm und Borgström, L. H. Der Meteorit von Bjurböle bei Borgå. S. 1—28. 20 Fig. 1902 —: —
- *N:o 13. Frosterus, Benj. Bergbyggnaden i sydöstra Finland. S. 1—168. 18 fig. 8 tafl. 1 karta. Deutsches Referat: Der Gesteinsaufbau dess südöstlichen Finland. 1902 —: —
- N:o 14. Borgström, Leon. H. Die Meteoriten von Hvittis und Marjalahti. S. 1—80. 8 Taf. 1903 100: —
- N:o 15. Hackman, Victor. Die chemische Beschaffenheit von Eruptivgesteinen Finlands und der Halbinsel Kola im Lichte des neuen amerikanischen Systemes. S. 1—143. 1905 120: —
- *N:o 16. Sundell, I. G. On the Cancerinite-Syenite from Kuolajärvi and a Related Dike Rock. P. 1—20. 1 plate. 1905 —: —
- N:o 17. Fircks, Curt. On the Occurrence of Gold in Finnish Lapland. P. 1—35. 15 fig. 1 map. Frontispiece. 1906 80: —
- N:o 18. Tanner, V. Studier öfver kvartärsystemet i Fennoskandias nordliga delar. I. Till frågan om Ost-Finmarkens glaciation och nivåförändringar. S. 1—165. 23 bild. 6 tafl. Résumé en français: Études sur le système quaternaire dans les parties septentrionales de la Fenno-Scandia. I. Sur la glaciation et les changements de niveau du Finmark oriental. 1906 200: —
- *N:o 19. Trüstedt, Otto. Die Erzlagerstätten von Pitkäranta am Ladoga-See. S. 1—333. 80 Fig. 19 Taf. 1 Karte. 1907 —: —

* Epuisée.

N:o 20.	Tanner, V. Zur geologischen Geschichte des Kilpisjärvi-Sees in Lappland. S. 1—22. 3 Fig. 2 Taf. 1 Karte. 1907	60: —
N:o 21.	Tanner, V. Studier öfver kvartärsystemet i Fennoskandias nordliga delar. II. Nya bidrag till frågan om Finmarkens glaciation och nivåförändringar. S. 1—127. 10 fig. 6 tafl. Résumé en français: Études sur le système quaternaire dans les parties septentrionales de la Fennoscandia. II. Nouvelles recherches sur la glaciation et les changements de niveau du Finmark. 1907	200: —
N:o 22.	Borgström, L. H. Granitporphyr von östersundom. S. 1—20. 3 Fig. 1 Taf. 1907	60: —
N:o 23.	Sederholm, J. J. Om granit och gneis, deras uppkomst, uppträdande och utbredning inom urberget i Fennoskandia. S. 1—110. 11 fig. 8 tafl. 1 planteckn. 1 karta. English Summary of the Contents: On Granite and Gneiss, their Origin, Relations and Occurrence in the Pre-Cambrian Complex of Fennoscandia. 1907.	200: —
*N:o 24.	Sederholm, J. J. Les roches préquaternaires de la Fennoscandia. P. 1—39. 20 fig. 1 carte. 1910	—: —
N:o 25.	Tanner, V. Über eine Gangformation von fossilienführendem Sandstein auf der Halbinsel Långbergsöda-Öjen im Kirchspiel Saltvik, Åland-Inseln. S. 1—13. 5 Fig. 2 Taf. 1911	60: —
N:o 26.	Mäkinen, Eero. Bestimmung der Alkalien in Silikaten durch Aufschliessen mittelst Chlorkalzium. S. 1—8. 1911	40: —
N:o 27.	Sederholm, J. J. Esquisse hypsométrique de la Finlande. P. 1—21. 5 fig. 1 carte. 1911	80: —
*N:o 28.	Sederholm, J. J. Les roches préquaternaires de la Finlande. P. 1—27. 1 carte. 1911	—: —
N:o 29.	Sederholm, J. J. Les dépôts quaternaires de la Finlande. P. 1—23. 5 fig. 1 carte. 1911	80: —
*N:o 30.	Sederholm, J. J. Sur la géologie quaternaire et la géomorphologie de la Fennoscandia. P. 1—66. 13 fig. 6 cartes. 1911	—: —
N:o 31.	Hausen, H. Undersökning af porfyrblock från sydvästra Finlands glaciala aflagringar. S. 1—34. 9 fig. Deutsches Referat, 1912	80: —
N:o 32.	Hausen, H. Studier öfver de sydfinska ledblockens spridning i Ryssland, jämte en öfversikt af is-recessionens förlopp i Ostbaltikum. Preliminärt meddelande med tvenne kartor. S. 1—32. Deutsches Referat. 1912	80: —
N:o 33.	Wilkman, W. W. Kvartära nivåförändringar i östra Finland. S. 1—40. 9 fig. Deutsches Referat. 1912	100: —
N:o 34.	Borgström, L. H. Der Meteorit von St Michel. S. 1—49. 1 Fig. 3 Taf. 1912	100: —
N:o 35.	Mäkinen, Eero. Die Granitpegmatite von Tammela in Finnland und ihre Minerale. S. 1—101. 23 Fig. 1913	120: —
N:o 36.	Eskola, Pentti. On Phenomena of Solution in Finnish Limestones and on Sandstone filling Cavities. P. 1—50. 15 fig. 1913	100: —
N:o 37.	Sederholm, J. J. Weitere Mitteilungen über Bruchspalten mit besonderer Beziehung zur Geomorphologie von Fennoscandia. S. 1—66. 27 Fig. 1 Taf. 1913	140: —
N:o 38.	Tanner, V. Studier öfver kvartärsystemet i Fennoskandias nordliga delar. III. Om landisens rörelser och afsmältning i finska Lappland och angränsande trakter. S. 1—815. 139 fig. 16 tafl. Résumé en français: Études sur le système quaternaire dans les parties septentrionales de la Fennoscandia. III. Sur la progression et le cours de la récession du glacier continental dans la Laponie finlandaise et les régions environnantes. 1915	600: --
N:o 39.	Hackman, Victor. Der gemischte Gang von Tuutijärvi im nördlichen Finnland. S. 1—41. 9 Fig. 1914	80: —
*N:o 40.	Eskola, Pentti. On the Petrology of the Orijärvi region in Southwestern Finland. P. 1—277. 55 Fig. 6 plates. 2 maps. 1914	—: —

* Epuisée.

N:o 41.	Borgström, L. H. Die Skapolithlagerstätte von Laurinkari. S. 1—30. 7 Fig. 1914	60: —
N:o 42.	Hackman, Victor. Über Camptonitgänge im mittleren Finnland. S. 1—18. 3 Fig. 1914	60: —
N:o 43.	Wilkman, W. W. Kaleviska bottenbildningar vid Mälönjärvi. S. 1—36. 11 fig. Résumé en français. 1915	80: —
N:o 44.	Eskola, Pentti. Om sambandet mellan kemisk och mineralogisk sammansättning hos Orijärvitraktenas metamorfa bergarter. S. 1—145. 4 fig. English Summary of the Contents. 1915	120: —
N:o 45.	Ailio, Julius. Die geographische Entwicklung des Ladogasees in postglazialer Zeit und ihre Beziehung zur steinzeitlichen Besiedelung. S. 1—158. 51 Abbild. 2 Karten. 1915 ..	200: —
N:o 46.	Laitakari, Aarne. Le gisement de calcaire cristallin de Kirmonniemi à Korpo en Finlande. P. 1—39. 14 fig. 1916 ..	80: —
N:o 47.	Mäkinen, Eero. Översikt av de prekambriska bildningarna i mellersta Österbotten i Finland. S. 1—152. 25 fig. 1 karta. English Summary of the Contents. 1916	200: —
N:o 48.	Sederholm, J. J. On Synantetic Minerals and Related Phenomena (Reaction Rims, Corona Minerals, Kelyphite, Myrmekite, etc.). P. 1—148. 14 fig. in the text and 48 fig. on 8 plates. 1916	240: —
N:o 49.	Wilkman, W. W. Om en prekalevish kvartsitformation i norra delen af Kuopio socken. S. 1—18. 7 fig. Résumé en français. 1916	60: —
N:o 50.	Sauramo, Matti. Geochronologische Studien über die spätglaziale Zeit in Südfinnland. S. 1—44. 5 Abbild. 4 Taf. 1918	120: —
N:o 51.	Laitakari, Aarne. Einige Albitepidotgesteine von Südfinnland. S. 1—13. 5 Abbild. 1918	60: —
N:o 52.	Brenner, Th. Über Theralit und Ijolit von Umptek auf der Halbinsel Kola. S. 1—30. 4 Fig. 1920	60: —
N:o 53.	Hackman, Victor. Einige kritische Bemerkungen zu Iddings' Classifikation dēr Eruptivgesteine. S. 1—21. 1920	60: —
N:o 54.	Laitakari, Aarne. Über die Petrographie und Mineralogie der Kalksteinlagerstätten von Parainen (Pargas) in Finnland. S. 1—113. 40 Abbild. 3 Taf. 1921	120: —
N:o 55.	Eskola, Pentti. On Volcanic Necks in Lake Jänisjärvi in Eastern Finland. P. 1—13. 1 fig. 1921	60: —
N:o 56.	Metzger, Adolf A. Th. Beiträge zur Paläontologie des nordbaltischen Silurs im Ålandsgebiet. S. 1—8. 3 Abbild. 1922 ..	60: —
*N:o 57.	Väyrynen, Heikki. Petrologische Untersuchungen der granitodioritischen Gesteine Süd-Ostbothniens. S. 1—78. 20 Fig. 1 Karte. 1923	—: —
*N:o 58.	Sederholm, J. J. Om Migmatites and Associated Pre-Cambrian Rocks of Southwestern Finland. Part I. The Pellinge Region. P. 1—153. 64 fig. 8 plates. 1 map. 1923	—: —
N:o 59.	Berghell, Hugo und Hackman, Victor. Über den Quarzit von Kallinkangas, seine Wellenfurchen und Trockenrisse. Nach hinterlassenen Aufzeichnungen von Hugo Berghell zusammengestellt und ergänzt von Victor Hackman. S. 1—19. 19 Fig. 1923	60: —
N:o 60.	Sauramo, Matti. Studies on the Quaternary Varve Sediments in Southern Finland. P. 1—164. 22 fig. in the text. 12 fig., 1 map and 2 diagrams on 10 plates. 1923	200: —
N:o 61.	Hackman, Viator. Der Pyroxen-Granodiorit von Kakskerta bei Åbo und seine Modifikationen. S. 1—23. 2 Fig. 1 Karte. 1923	60: —
N:o 62.	Wilkman, W. W. Tohmajarvi-konglomeratet och dess förhållande till kaleviska skifferformationen. S. 1—43. 15 fig. 1 karta. 1923	100: —
N:o 63.	Hackman, Victor, Über einen Quartzsyenitporphyrr von Saariselkä im finnischen Lappland. S. 1—10. 2 Fig. 1923	60: —
N:o 64.	Metzger, Adolf A. Th. Die jatulischen Bildungen von Suojärvi in Ostfinnland. S. 1—86. 38 Abbild. 1 Taf. 1 Karte. 1924	120: —

* Epuisée.

N:o 65.	Saxén, Martti. Über die Petrologie des Otravaaragebites im östlichen Finnland. S. 1—63. 13 Abbild. 5 Fig. auf 1 Taf. 2 Karten. 1923	120: —
N:o 66.	Ramsay, Wilhelm. On Relations between Crustal Movements and Variations of Sea-Level during the Late Quaternary Time, especially in Fennoscandia. P. 1—39. 10 fig. 1924 ..	80: —
N:o 67.	Sauramo, Matti. Tracing of Glacial Boulders and its Application in Prospecting. P. 1—37. 12 fig. 1924	80: —
N:o 68.	Tanner, V. Jordskredet i Jaarila. S. 1—18. 2 fig. 10 bild. Résumé en français. 1924	60: —
N:o 69.	Auer, Väinö. Die postglaziale Geschichte des Vanajavesisees. S. 1—132. 10 Fig. 10 Taf. 11 Beil. 1924	200: —
N:o 70.	Sederholm, J. J. The Average Composition of the Earth's Crust in Finland. P. 1—20. 1925	80: —
N:o 71.	Wilkman, W. W. Om diabasgångar i mellersta Finland. S. 1—35. 8 fig. 1 karta. Deutsches Referat. 1924	80: —
N:o 72.	Hackman, Victor. Das Gebiet der Alkaligesteine von Kuola-järvi in Nordfinnland. S. 1—62. 6 Fig. 1 Taf. 1925	120: —
N:o 73.	Laitakari, Aarne. Über das jothische Gebiet von Satakunta. S. 1—43. 14 Abbild. 1 Karte. 1925	120: —
N:o 74.	Metzger, Adolf A. Th. Die Kalksteinlagerstätten von Rus-keala in Ostfinnland. S. 1—24. 9 Abbild. 2 Karten. 1925 ..	80: —
N:o 75.	Frosterus, Benj. Ueber die kambrischen Sedimente der kare-lischen Landenge. S. 1—52. 1 Fig. 1925	120: —
N:o 76.	Hausen, H. Über die präquartäre Geologie des Petsamo-Gebietes am Eismere. S. 1—100. 1 Übersichtskarte. 13 Fig. 2 Taf. 1926	120: —
N:o 77.	Sederholm, J. J. On Migmatites and Associated Pre-Cambrian Rocks of Southwestern Finland. Part II. The Region around the Barösundsfjärd W. of Helsingfors and Neighbouring Areas. P. 1—143. 57 fig. in the text and 44 fig. on 9 plates. 1 map. 1926	240: —
N:o 78.	Väyrynen, Heikki. Geologische und petrographische Unter-suchungen im Kainuugebiete. S. 1—127. 37 Fig. 2 Taf. 2 Karten. 1928	160: —
N:o 79.	Hackman, Victor. Studien über den Gesteinsaufbau der Kit-tilä-Lappmark. S. 1—105. 23 Fig. 2 Taf. 2 Karten. 1927	160: —
N:o 80.	Sauramo, Matti. Über die spätglazialen Niveauverschiebungen in Nordkarelien, Finnland. S. 1—41. 8 Fig. im Text. 11 Fig., 1 Profildiagramm und 1 Karte auf 7 Taf. 1928	60: —
N:o 81.	Sauramo, Matti and Auer, Väinö. On the Development of Lake Höytäinen in Carelia and its Ancient Flora. P. 1—42. 20 fig. 4 plates. 1928	60: —
N:o 82.	Lokka, Lauri. Über Wiikit. S. 1—68. 12 Abbild. 1928	120: —
N:o 83.	Sederholm, J. J. On Orbicular Granites, Spotted and Nodular Granites etc. and on the Rapakivi Texture. P. 1—105. 19 fig. in the text and 50 fig. on 16 plates. 1928	200: —
N:o 84.	Sauramo, Matti. Über das Verhältnis der Ose zum höchsten Strand. S. 1—16. 1928	40: —
N:o 85.	Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 1. 1 stéréogramme. P. 1—88. 1929	200: —
N:o 86.	Sauramo, Matti. The Quaternary Geology of Finland. P. 1—110. 39 fig. in the text and 42 fig. on 25 plates. 1 map. 1929	240: —
N:o 87.	Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 2. P. 1—175. 48 fig. 8 planches. 1929	280: —
N:o 88.	Tanner, V. Studier över kvartärsystemet i Fennoskandias nordliga delar. IV. Om nivåförändringarna och grunddragen av den geografiska utvecklingen efter istiden i Ishavsförland	

- sanit om homotaxin av Fennoscandias kvartära marina avlagringar. S. 1—593. 84 fig. 4 tavl. 1 karta. Résumé en français: Études sur le système quaternaire dans les parties septentrionales de la Fennoscandie. IV. Sur les changements de niveau et les traits fondamentaux du développement géographique de la Finlande aux confins de l'océan Arctique après l'époque glaciaire et sur l'homotaxie du quaternaire marin en Fennoscandie. 1930 600: —
- N:o 89. Wegmann, C. E. und Kranck, E. H. Beiträge zur Kenntnis der Svecofenniden in Finnland. I. Übersicht über die Geologie des Felsgrundes im Küstengebiete zwischen Helsingfors und Onas. II. Petrologische Übersicht des Küstengebietes E von Helsingfors. S. 1—107. 4 Fig. 16 Taf. mit 32 Fig. 1 Übersichtskarte. 1931 160: —
- N:o 90. Hausen, H. Geologie des Soanlahti-Gebietes im südlichen Karelien. Ein Beitrag zur Kenntnis der Stratigraphie und tektonischen Verhältnisse der Jatulformation. S. 1—105. 23 Fig. im Text und 12 Fig. auf 4 Taf. 1 Übersichtskarte. 1930 200: —
- N:o 91. Sederholm, J. J. Pre-Quaternary rocks of Finland. Explanatory notes to accompany a general geological map of Finland. P. 1—47. 40 fig. 1 map. 1930 120: —
- N:o 92. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 3. P. 1—140. 29 fig. 3 planches. 1930 200: —
- N:o 93. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 4. P. 1—68. 12 fig. 6 planches. 1931 160: —
- N:o 94. Brenner, Thord. Mineraljordarternas fysikaliska egenskaper. S. 1—159. 22 fig. Deutsches Referat. 1931 280: —
- N:o 95. Sederholm, J. J. On the Sub-Bothnian Unconformity and on Archaean Rocks formed by Secular Weathering. P. 1—81. 62 fig. 1 map. 1931 200: —
- N:o 96. Mikkola, Erkki. On the Physiography and Late-Glacial Deposits in Northern Lapland. P. 1—88. 25 fig. 5 plates. 1932 200: —
- N:o 97. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 5. P. 1—77. 15 fig. 1932 160: —
- N:o 98. Sederholm, J. J. On the Geology of Fennoscandia. P. 1—30. 1 map. 1 table. 1932 120: —
- N:o 99. Tanner, V. The Problems of the Eskers. The Esker-like Gravel Ridge of Čahpatoaiiv, Lapland. P. 1—13. 2 plates. 1 map. 1932 60: —
- N:o 100. Sederholm, J. J. Über die Bodenkonfiguration des Päijänne-Sees. S. 1—23. 3 Fig. 1 Karte. 1932 200: —
- N:o 101. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 6. P. 1—118. 17 fig. 5 planches. 1933 200: —
- N:o 102. Wegmann, C. E., Kranck, E. H. et Sederholm, J. J. Compte rendu de la Réunion internationale pour l'étude du Précambrien et des vieilles chaînes de montagnes. P. 1—46. 1933 120: —
- N:o 103. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 7. P. 1—48. 2 fig. 1933 100: —
- N:o 104. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 8. P. 1—156. 33 fig. 7 planches. 1934 220: —
- N:o 105. Lokka, Lauri. Neuere chemische Analysen von finnischen Gesteinen. S. 1—64. 1934 120: —
- N:o 106. Hackman, Victor. Das Rapakiwirandgebiet der Gegend von Lappeenranta (Willmanstrand). S. 1—82. 15 Fig. 2 Taf. 1 Analysetabelle. 1 Karte. 1934 140: —

- N:o 107. Sederholm, J. J. On Migmatites and Associated Pre-Cambrian Rocks of Southwestern Finland. Part III. The Åland Islands. P. 1—68. 43 fig. 2 maps. 1934 160: —
- N:o 108. Laitakari, Aarne. Geologische Bibliographie Finnländs 1555—1933. S. 1—224. 1934 200: —
- N:o 109. Väyrynen, Heikki. Über die Mineralparagenesis der Kieserze in den Gebieten von Outokumpu und Polvijärvi. S. 1—24. 7 Fig. 1 Karte. 1935 80: —
- N:o 110. Saksela, Martti. Über den geologischen Bau Süd-Ostbothniens. S. 1—35. 11 Fig. 1 Titelbild. 1 Taf. 1 Karte. 1935 100: —
- N:o 111. Lokka, Lauri. Über den Chemismus der Minerale (Orthit, Biotit u.a.) eines Feldspatbruches in Kangasala, SW-Finnland. S. 1—39. 2 Abbild. 1 Taf. 1935 100: —
- N:o 112. Hackman, Victor. J. J. Sederholm. Biographic Notes and Bibliography. P. 1—34. With a vignette. 1935 80: —
- N:o 113. Sahama (Sahlstein), Th. G. Die Regelung von Quarz und Glimmer in den Gesteinen der finnisch-lappländischen Granulitformation. S. 1—119. 5 Fig. 80 Diagramme. 3 Taf. 1936 160: —
- N:o 114. Haapala, Paavo. On Serpentine Rocks in Northern Karelia. P. 1—88. 21 fig. 2 maps. 1936 120: —
- N:o 115. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 9. P. 1—505. 83 fig. 20 planches. 1936 400: —
- N:o 116. Väyrynen, Heikki. Petrologie des Nickelerzfeldes Kaulatunturi—Kammikivitunturi in Petsamo. S. 1—198. 71 Abbild. 36 Tab. im Text. 1 Karte. 1938 200: —
- N:o 117. Kilpi, Sampo. Das Sotkamo-Gebiet in spätglazialer Zeit. S. 1—118. 36 Abbild. im Text. 3 Beil. 1937 200: —
- N:o 118. Brander, Gunnar. Ein Interglazialfund bei Rouhiala in Südostfinnland. S. 1—76. 7 Fig. im Texte u. 7 Fig. auf 2 Taf. 1937 160: —
- N:o 119. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 10. P. 1—170. 30 fig. dans le texte. 4 planches. 1937 200: —
- N:o 120. Hyypää, Esa. Post-Glacial Changes of Shore-Line in South Finland. P. 1—225. 57 fig. in the text. 21 tab. 2 append. 1937 200: —
- N:o 121. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 11. P. 1—166. 47 Abbild. 8 Tab. im Text. 2 Karten. 1938 200: —
- N:o 122. Hietanen, Anna. On the Petrology of Finnish Quartzites. P. 1—118. 20 fig. in the text. 8 plates. 3 maps. 1938 200: —
- N:o 123. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 12. P. 1—107. 20 fig. dans le texte. 3 planches. 1938 200: —
- N:o 124. Väyrynen, Heikki. On the Geology and Tectonics of the Outokumpu Ore Field and Region. P. 1—91. 11 fig. in the text. 2 maps. 1939 200: —
- N:o 125. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 13. P. 1—119. 45 fig. dans le texte. 1 planche. 1939 120: —
- N:o 126. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 14. P. 1—140. 60 fig. dans le texte. 28 tab. 1941 150: —
- N:o 127. Mölder, Karl. Studien über die ökologie und Geologie der Bodendiatomeen in der Pojo-Bucht. P. 1—204. 7 Abbild. 1 Karte. 14 Diagr. und 14 Tab. im Text. 1943 200: —

- N:o 128. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 15. P. 1—183. 43 fig. dans le texte et 2 planches. 1943 200: —
- N:o 129. Lokka, Lauri. Beiträge zur Kenntnis des Chemismus der finnischen Minerale. Glimmer, Pyroxene, Granate, Epidote u.a. Silikatminerale sowie melnikowitähnliches Produkt und Shungit. S. 1—72. 48 Tab. 1943 150: —
- N:o 130. Hietanen, Anna. Über das Grundgebirge des Kalantigebietes im südwestlichen Finnland. S. 1—105. 55 Fig. im Text, 8 Tafeln u. 1 Karte. 1943 250: —
- N:o 131. Okko, V. Moränenuntersuchungen im westlichen Nordfinnland. S. 1—48. 12 Abb. u. 4 Tab. im Text. 1944 90: —
- N:o 132. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 16. P. 1—196. 41 diagr., 9 tabl., 3 cartes, 3 fig. 1944 200: —
- N:o 133. Rankama, Kalervo. On the Geochemistry of Tantalum. P. 1—78. 1 Fig., 8 Tables. 1944 150: —
- N:o 134. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 17. P. 1—91. 59 fig., 1 carte. 1944 150: —
- N:o 135. Sahama, Th. G. Spurenelemente der Gesteine im südlichen Finnisch-Lappland. S. 1—86. 12 Fig. 29 Tab. 1945 150: —
- N:o 136. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 18. P. I—XXXVIII; 1—67. 3 diagr., 11 tabl., 2 cartes, 11 fig., 2 planches. 1945 200: —
- N:o 137. Rankama, Kalervo. On the Geochemical Differentiation in the Earth's Crust. P. 1—39. 18 tables. 1946 100: —
- N:o 138. Paraître prochainement.

