GEOLOGINEN TUTKIMUSLAITOS

BULLETIN

DE LA

COMMISSION GÉOLOGIQUE

DE FINLANDE

N:o 143

ON THE PETROLOGY OF THE AULANKO AREA IN SOUTHWESTERN FINLAND

BY

AHTI SIMONEN

WITH 25 FIGURES IN TEXT, 6 TABLES AND ONE MAP

HELSINKI

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CONTENTS.

PREFACE.

This study was begun already in the summer 1939 on the initiative of my esteemed teacher, Professor Pentti Eskola, when by the help of the Wiik Exhibition I was able to carry out the field observations in the granodiorite area of Aulanko and its surroundings. During the years 1940—1944 I was in the army and this work was at a standstill. During the winters 1945 and 1946 the laboratory studies were carried out and in the summer 1945 many excursions were made in the Aulanko area.

The greatest part of the chemical analyses presented in this investigation has been carried out at the Geochemical Laboratory of the Geological Institute of the University in Helsinki. I wish to express my sincere gratitude to the Director of the above-mentioned Institute, Professor Pentti Eskola, for his valuable instruction during the work and for the criticism of the manuscript.

To my Chief, Professor Aarne Laitakari, Director of the Geological Survey of Finland, I am deeply indebted for his kindness in permitting the publication of this work by the Geological Survey.

Furthermore, I desire to present my thanks to Professor H. Väyrynen for placing the field material concerning the Aulanko area at my disposal; to Professor Th. G. Sahama for his valuable advice on the determinations of trace element contents and to Dr. L. Lokka for useful instruction in carrying out the chemical analyses.

Mrs. Toini Mikkola, Mr. A. Matisto and Mr. K. J. Neuvonen have assisted in the optical determinations and Mr. P. Ojanperä has carried out 6 chemical analyses. To all these I desire to express my sincere thanks and am especially grateful to Mr. A. Matisto for drawing all texture pictures presented here.

Finally, I would add a personal word of appreciation to Mrs. Lily Björling *(née* Hird) who has kindly revised the English of my manuscript.

Ahti Simonen

Geological Survey of Finland, Helsinki, January 1948.

INTRODUCTION.

The petrological study of the Archaean rocks in Southwestern Finland has been very fruitful for the development of the ideas concerning the Pre-Cambrian geology in general. There for the first time the actualistic method proved correct in the study of the oldest Archaean formations (Sederholm 1891 and 1897). The well known mineral facies principle and the ideas on the metasomatic processes in the origin of the silicate rocks have been developed largely through the detailed studies carried out by Eskola (1914 and 1915) in the Orijärvi region of Southwestern Finland. Many fundamental facts of the puzzling problem of granitization have been made clear through the studies of Sederholm (1907, 1923, 1926 and 1934) in the archipelago of Southern Finland and many geological terms (»palingenesis», »ichor» *etc.*), generally known among petrologists, have been presented in connection with these studies. Furthermore, the principle of metamorphic differentiation and the ideas on the origin of the granitic magmas presented by Eskola (1932 a and 1932 b) have in many points been based on the petrological studies carried out in Southwestern Finland.

It was chiefly on the basis of the field observations in Southwestern Finland that Sederholm developed his stratigraphical classification of the Archaean schist formations and its granites, enlarging this to contain the whole rock crust of Fennoscandia. The stratigraphical problems run like a red thread through the whole production of Sederholm and his last views on these were presented in the year 1932 in the explanation to the geological map of Fennoscandia (Sederholm 1932).

According to Sederholm, there are in Southwestern Finland two Archaean schist formations, Svionian and Bothnian, which are marked by a great hiatus. Both Svionian and Bothnian are penetrated by granites; the former by Pre-Bothnian, the later by Post-Bothnian granites. Mäkinen (1915 a) remarked, however, that also the Pre-Bothnian granites penetrate the Bothnian schists and some conglomerate occurrences in the Bothnian formation do not mean a deep denudation but show an intraformational mode of occurrence. Furthermore, Eskola (1936 a) and Wahl (1936) by help of field observations in the most remarkable Bothnian schist formations in the Kalvola—Tammela and Tampere areas have shown that the oldest gneissose granites penetrate the Bothnian schists. These conclusions show that there is no reason for a separation of the special Bothnian formation. Nowadays both Svionian and Bothnian formations have been included as formations belonging to the Svecofennidic orogeny.

The classification of the granites presented by Sederholm divides the Pre-Cambrian granites in Fennoscandia into four groups. All these groups occur also in Southwestern Finland. Nowadays, however, the granite classification is carried out according to the magmatectonical points of view. Every mountain folding process is followed by intrusion of three different kinds of granites, so-called synkinematic, late-kinematic and postkinematic granites according to the terms proposed by Eskola (1930 p. 138).

In Southwestern Finland the synkinematic intrusions are represented mainly by the gneissose granodiorites associated with more basic differentiates. Also the crystallization products of the trondhjemitic and charnockitic suite are met with among the synkinematic intrusions of the Svecofennidic territory in Southwestern Finland. The migmatite-forming microcline granites of the coast type represent the late-kinematic intrusions. In Southwestern Finland also some microcline granites occur penetrating the late-kinematic intrusions. Probably these granites are the postkinematic intrusions of the Svecofennidic orogeny, represented by the granites in Onas, Bodom, Obbnäs, Åva, Mosshaga, Lemland, and Peipohja, belonging to the third group in the granite classification of Sederholm.

The tectonical features of the Svecofennidic rock crust in Southwestern Finland have been studied by Wegmann and Kranck (1931). Many details showing similarities to the younger orogenies are presented and the evolution of the Svecofennidic rocks is discussed. Later Kranck (1933 and 1937) has continued this study and also Swedish geologists have pointed out comparisons and presented new ideas concerning the evolution of the Svecofennides in Southwestern Finland (Magnusson 1936 a and Backlund 1937).

In spite of the many pioneering investigations, the rock crust of Southern Finland, as a whole, is one of the least known regions in our country. The geological general maps of this region were made during the foregoing century and are very defective. In the year 1936, however, the new geological mapping was started. During this year Eskola with his assistants studied the Tammela—Kalvola region. The observations made during this field work are very elucidative as regards the study of the Aulanko area, and later, in many places, the writer has drawn attention to the field observations made in the Tammela—Kalvola area. In the year 1936 the Geological Survey of Finland began also a new geological mapping in Southern Finland under the direction of Erkki Mikkola. Unfortunately, the greatest part of the results of the above-mentioned work still remains unpublished and the death of Erkki Mikkola in the Winter War 1939—40 was a great loss to geological research in Finland.

As regards the newest investigations concerning the Pre-Cambrian rock crust in Southwestern Finland mention must be specially made of the discussions on the infracrustal rocks of the Svecofennidic territory. Hietanen (1943) has described the trondhjemitic suite of the synkinematic intrusions showing a beautiful differentiation series. Hausen (1944) and Metzger (1945) have studied some small areas in the coastal region in the neighbourhood of the town Turku (Åbo), showing the occurrence of the charnockitic rocks among the synkinematic intrusions of the Svecofennidic orogeny. Hietanen (1947) in her newest investigation gives a detailed description of the different kinds of the synkinematic intrusions met with in the Turku district. Simonen (1948) has discussed the petrochemistry of the infracrustal rocks in the Svecofennidic territory of Southwestern Finland on the basis of the analyses available, pointing out that all different kinds of the synkinematic intrusions have crystallized from a common parent magma, though different content of volatiles has caused different paths of the crystallization differentiation. Furthermore, there occur some small chemical differences between the late-kinematic and postkinematic intrusions.

The problem of the coarse-grained garnet- and cordierite-bearing mica gneisses, called kinzigites, occurring in wide areas of Southwestern Finland, has recently been discussed by Hietanen (1943 and 1947), Metzger (1945) and Parras (1941 and 1946). The sedimentary character of the kinzigites has been pointed out.

The metamorphism of the Svecofennidic rocks has generally occurred in the PT-conditions of the amphibolite facies according to the mineral facies classification of Eskola (1921). There occur, however, in Western Uusimaa pyroxene gneisses containing mineral assemblages which show similarities to the granulite and pyroxene hornfels facies (Parras 1941).

In the last few years the geological knowledge of the classical schist formation in the Tampere area has greatly increased by the study of the ore occurrences found there. Stigzelius (1944) has described the ore geology of the Haveri mine in the Viljakkala area and Saksela (1947) has described ore mineral parageneses met with in the Tampere area. In the summer of 1945 the Geological Survey of Finland started a detailed geological mapping in the Bothnian schist areas of the Tampere field. New observations give support to the idea that the Bothnian schists in the Tampere area belong to the Svecofennidic orogeny. From the newest observations a short description of the metamorphism of the schists in the Ylöjärvi area has been published (Simonen and Neuvonen 1947).

This investigation joins on to the above-mentioned works and strives to give a detailed study of the Svecofennidic rock crust in a region which has been earlier very poorly known. The area studied for this investigation is here called the Aulanko area, after the well known national park and hill Aulanko in the vicinity of the town Hämeenlinna. The geological map sheets, on the scale 1 : 200 000, comprising this area, are very old. The town Hämeenlinna and the region eastward form a part of the geological map sheet Hämeenlinna surveyed by Tigerstedt (1888) and the area west of the town belongs to the map sheet Tammela by Sederholm (1892). Later on Väyrynen (1919) published a short description of the rocks in the Aulanko region, but his study does not contain any geological map.

The situation of the Aulanko area is seen in the enclosed sketch map of Southwestern Finland (Fig. 1), which shows also the location of the areas studied more in detail.

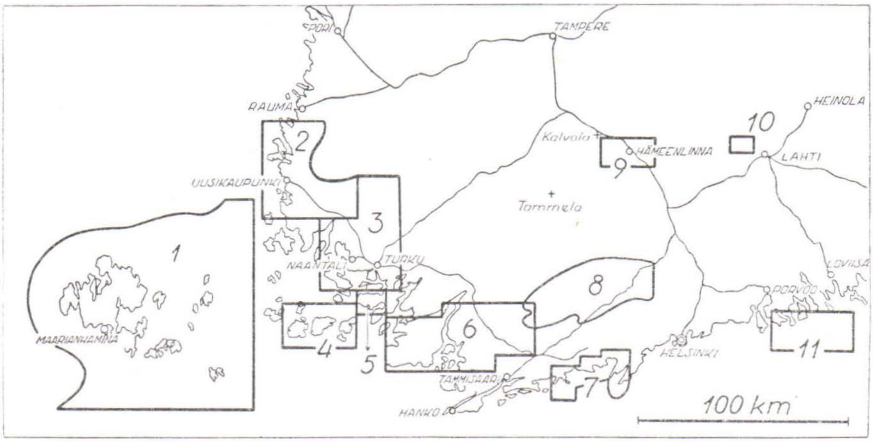

Fig. 1. The situation of the areas studied more in detail with published petrographical maps in Southwestern Finland. 1. The Åland region (Sederholm 1934). 2. The Kalanti region (Hietanen 1943). 3. The Turku district (Hietanen 1947). 4. The Korpo—Nagu region (Hausen 1944). 5. The Parainen area (Metzger 1945). 6. The Orijärvi region (Eskola 1914). 7. The Barösundsfjärd region (Sederholm 1926). 8. The pyroxene gneiss region of Western Uusimaa (Parras 1941). 9. The Aulanko region. 10. The Tiirismaa quartzite area (Eskola and Nieminen 1938 a). 11. The Pellinge region (Sederholm 1923).

The terrain of the Aulanko area is very variable and the number of the outcrops is not alike in different parts of the studied area. In those regions, where the rock crust is formed by granites and related rocks, the amount of the outcrops is the greatest and there are also the highest places of the area. The schistose rocks again have mostly been worn by the glacial processes and great parts of the rock crust are covered by Quaternary deposits. Especially a stately esker formation west of Hämeenlinna covers a great part of the rock crust. Some most remarkable Quaternary formations in the Aulanko area are seen in a map published by Sauramo (1934 p. 34). Auer (1924) has discussed some points of the Post-Glacial geology of this area in his study concerning the development of Lake Vanajavesi.

In the present investigation the ancient rocks of the Aulanko area are described in three different groups:

1. Supercrustal rocks. Effusive rocks of different kinds and mica schists of a clayey composition.

2. Infracrustal rocks. Synkinematic intrusions showing various chemical composition and texture, and late-kinematic microcline granites.

3. Metasomatic derivatives of the above-mentioned rocks developed through granitization, albitization and iron-magnesia metasomatism.

This division of the rocks has been based, in the first place, on the primary textures observed in the material studied. In the study of Pre-Cambrian one of the most important things is just the determination of the primary nature of the rocks. The rocks developed through metasomatic processes are, however, discussed as a special part of this paper.

The metamorphism has taken place in the PT-conditions of the amphibolite facies and the grade of metamorphism has been strongest in the northeastern part of the area studied. All primary textures of the metamorphic schists are there destroyed and the rocks show only a granoblastic texture. Among these rocks mica and hornblende gneisses are common. Through the studied area continues, however, a coherent zone of supercrustal rocks, where primary textures are seen in many places. Among the synkinematic intrusions also different grades of metamorphism occur.

The dips of the schists are steep and the strikes follow the general trend of the Svecofennidic zone, alternating some degrees on both sides of the direction E—W. On the eastern side of Lake Katumajärvi there is, however, one branch of the schist formation where the strike is quite at right angles to the general direction. The strike lines of the supercrustal formation follow the direction of the boundary zones against the synkinematic intrusions and the dips are in many places away from the plutons, giving an impression of a dome-like character.

The lineation of the rocks shows a very constant direction throughout the whole region (N 60°E) and the dip is 60°—80° to northeast. In Southern Finland the lineations and the folding axes are commonly, as far as known, very steep. Some exceptions are, however, the pyroxene gneiss area in Western Uusimaa, where the dip is only 20°—50°, and the Kalanti district, where the dip is about 5°—40° to the east. In the coastal region, on both sides of the City of Helsinki, the folding axes run in many directions. Probably the pushing forward of the migmatite front has changed the primary, more homogeneous directions. Unfortunately, directions of the folding axes and lineations over wide areas in Southwestern Finland are not known and therefore the time is not ripe for any far-reaching tectonical synthesis of the rock crust.

The main purpose of this investigation is to give a detailed description of the regional geology in the Aulanko area. The petrological problems are discussed mainly by the aid of field observations, of microscopical studies and of chemical analyses. Furthermore, the writer has carried out also some determinations of the trace element content in the different rock groups of the area. The material presented is, however, too scanty for far-reaching conclusions concerning the distribution of the trace elements in the different rocks as a whole. But in many cases we can complete, by this method, the ideas on the origin of the rocks received through other methods. In this sense determinations of the trace elements may have their place also in a purely petrological study.

SUPERCRUSTAL ROCKS.

VOLCANIC ROCKS.

Metamorphic rocks of basaltic bulk composition represented by uralite and plagioclase porphyrites are predominant among the volcanic rocks. They belong as an eastern part to the classical uralite porphyrite area of Tammela studied by Sederholm (1891), who was the first to show that these basic rocks have originated as basalts and that augite has changed later into hornblende, showing in many cases the crystal forms of pyroxene.

The area designated in the geological map as uralite porphyrite comprises both blastoporphyritic and amphibolitic parts in which the uralite phenocrysts are only seen as elongated grains. East and northeast of Hämeenlinna these basic porphyrites occur only as small areas intercalated as lava and tuffs in intermediate volcanics.

The boundaries between different kinds are difficult to determine quite exactly in the field, because in many cases the change from one variety to another occurs gradually. This mode of occurrence shows clearly that all volcanics in the area belong to the same effusive series.

Uralite porphyrites have been described earlier from many places in Southern Finland and everywhere they are of very similar chemical and mineralogical composition. Most of them have been originally basaltic lavas, but also tuffs, amygdaloidal varieties and agglomerates are common. Most of the uralite porphyrites in the Aulanko area are considered as basaltic lavas, but also some inhomogeneous varieties are met with, indicating a tuffitic mode of origin. Furthermore, we can find some evidences of magmatic differentiation in the basaltic volcanics.

In the most basic type of the uralite porphyrite the hornblende is very pale and nonpleochroic. Refractive indices determined by the immersion method in the cleavage splinters are $\gamma' = 1.668$, $\alpha' = 1.650$; these properties indicate [FeO] : [MgO] = 1 : 2 according to Winchell (1933). The result does not differ much from the determinations by Mäkinen (1915 b) in uralite from Pellinge (Table I). The amount of the plagioclase is very small and it does not form phenocrysts (Fig. 2).

In another type of uralite porphyrite the hornblende is darker-coloured and shows marked pleochroism like common hornblende. The refractive indices of this hornblende were found to be $\gamma' = 1.675$, $\alpha' = 1.653$. These

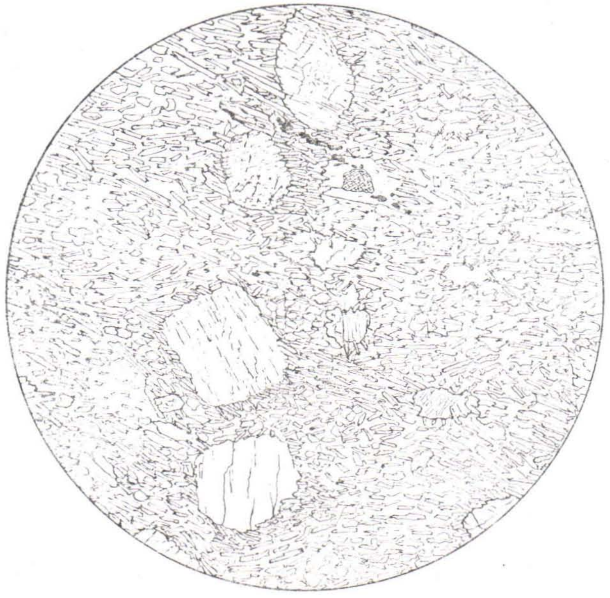

Fig. 2. Uralite porphyrite. W. of the town Hämeenlinna. 7 x.

refractive indices and a chemical analysis of uralite carried out by Pentti Ojanperä of pure material separated by Clerici solution (Table I) show that this darker-coloured hornblende is very rich in FeO. The amount of plagioclase is also greater in this variety, and the plagioclase forms small phenocrysts which cannot, however, be observed megascopically. This type of the uralite porphyrite changes gradually into plagioclase porphyrites.

Table I. Chemical analyses of uralite from the Aulanko and Pellinge areas.

	Uralite of Aulanko Anal. Pentti Ojanperä		Uralite of Pellinge Anal. Eero Mäkinen	
	%	Mol. prop.	%	Mol. prop.
SiO_2	47.03	.7799	49.58	.8222
TiO_2	0.69	.0086	0.28	.0035
Al_2O_3	8.00	.0783	6.82	.0667
Fe_2O_3	2.27	.0142	3.35	.0210
FeO	17.17	.2390	12.35	.1719
MnO	0.30	.0042	n.d.	
MgO	9.34	.2316	14.00	.3472
CaO	11.77	.2098	11.68	.2082
Na_2O	0.84	.0135	0.33	.0053
K_2O	0.44	.0047	0.28	.0030
P_2O_5	0.18	.0013	n.d.	
H_2O+	2.25	.1249	1.45	.0805
H_2O-	0.10		0.50	
	100.38		100.62	

Aulanko	Pellinge
$\alpha' = 1.653$	$\alpha = 1.6416$
—	$\beta = 1.6551$
$\gamma' = 1.675$	$\gamma = 1.6678$

A chemical analysis of a more acid type of the uralite porphyrite was carried out by the author (Table II, N:o 1). The content of different oxides is very similar to that of other uralite porphyrites in Finland and also of the plateau basalts of the world. The texture is blastoporphyritic. The mode (Table II, N:o 1) has been determined in the integration stage, as in all following cases unless stated otherwise.

Hornblende occurs as phenocrysts. Primary crystal forms of augite have been observed. The hornblende occurs also as small flakes in the ground-mass. The optical determinations show that the hornblende in the phenocrysts and in the ground-mass are quite similar.

Plagioclase occurs mainly in the fine-grained ground-mass and only some larger crystals are observed which are regarded as small phenocrysts. The maximum extinction angle in the symmetrical zone is 28—31°. The plagioclase is labradorite ($An_{50—55}$). In some individuals a weakly developed zonal texture is observed.

The most remarkable accessory mineral is sphene, which occurs as small rounded grains. Apatite and ilmenite occur in small amount. Epidote is an alteration product of the anorthite. Quartz has certainly increased in secondary processes and it occurs in many cases as a filling of the cracks.

Among the plagioclase porphyrites also different varieties are met with. A transitional type contains also small hornblende phenocrysts. In the porphyrites containing only plagioclase phenocrysts, the amount and composition of plagioclase alternates. The amount of hornblende in the ground-mass diminishes when plagioclase phenocrysts become more albitic. The mode of occurrence of plagioclase porphyrites is similar to

Fig. 3. Fluidal texture in plagioclase porphyrite. Small needles in the ground-mass are hornblende. E. of Lake Aulangonjärvi. 8 x.

that of uralite porphyrites. West of Hämeenlinna plagioclase porphyrites show the character of a basaltic lava. West of Lake Ahvenistonjärvi there occurs a variety which contains large plagioclase phenocrysts measuring 1—3 cm in length and 1—5 mm in thickness. Sometimes they have a parallel arrangement, while in other cases they are interspersed at random. The plagioclase phenocrysts are sometimes bent and broken by movements and the cracks have been filled by secondary quartz.

In the region east of Lake Aulangonjärvi and on the eastern side of Lake Katumajärvi basic porphyrites occur as thin beds among other volcanics and they have commonly a tuffitic mode of occurrence, whereas other occurrences show characteristics of lava beds. East of Lake Aulangonjärvi, for instance, a primary fluidal texture in the plagioclase porphyrite has been observed (Fig. 3).

The blastoporphyritic plagioclase porphyrite analyzed (Table II, N:o 2) occurs in close connection with uralite porphyrites and its mode of occurrence is clearly that of a lava bed. The analysis shows a little more acid composition than that of the uralite porphyrite described before, and at the same time a higher [FeO] : [MgO] ratio, (4 : 3 against 1 : 1).

Plagioclase forms both phenocrysts and minute grains in the fine-grained ground-mass. The greatest part of the plagioclase occurs as phenocrysts. According to the determination in the integration stage the relation between plagioclase in the phenocrysts and plagioclase in the ground-mass is about 5 : 2. Some phenocrysts have a well developed zonal texture. The composition of the phenocrysts is according to the maximum extinction angle in the symmetrical zone An_{38-44}. Some plagioclase phenocrysts are strongly sericitized, especially the kernels of the zoned crystals.

Hornblende occurs mainly as small flakes in the ground-mass. Also small accumulations of the hornblende grains are observed. These are presumably the relics of the original phenocrysts.

Biotite occurs as an alteration product of hornblende. Biotite is the main carrier of K_2O in the rock. The great amount of K_2O in this rock indicates secondary addition of potash during the biotitization.

Sphene and apatite occur as accessory minerals. Iron ore occurs mainly together with biotite. Probably it has mainly a secondary origin. Quartz occurs as a filling between other minerals and it has a secondary mode of occurrence.

The basic porphyrites show in some cases a hypabyssic mode of occurrence. The difference between phenocrysts and ground-mass is not clear and the plagioclase shows a well developed ophitic texture. This rock type is met with in some places as small sills in the rocks showing tuffitic character and it certainly belongs to the same volcanic period as these. In the easternmost part of the studied area east of Ilamo hypabyssic varieties occur to a greater extent.

In the eastern part of the volcanic schist area the intermediate rocks of a tuffitic character are predominant. In the neighbourhood of the tourist hotel of Aulanko, there has for instance been observed a small outcrop, which reveals through microscopical study a breccia texture occurring in the volcanic rocks.

In the region east of Lake Aulangonjärvi the rock is very inhomogeneous, showing in many places bedded texture. More acid, leptitic parts are rare and very small. Basic volcanics of amphibolitic and porphyritic texture are very common. In general, however, the composition of the rock is intermediate. A chemical analysis was carried out of an intermediate type of the volcanic rock (Table II, N:o 3).

The analysis shows a close relationship to a dioritic composition. The amounts of FeO and MgO are, however, lower and the CaO-amount higher than those of a typical diorite. The analyzed rock is inhomogeneous and gives an idea of a rock originated by the accumulation of volcanic ash. The texture of the rock is granoblastic (Fig. 4). Some bigger individuals of plagioclase are to be met with and also some more basic »bombs» of an amphibolitic rock are observed. Only the amounts of the mafic minerals of the mode were determined in the integration stage and the amounts of the other minerals calculated from the chemical analysis.

Plagioclase occurs as small sericitized grains. Some bigger individuals are also observed. By determination in U-stage the composition of the plagioclase is An_{32-34}.

Hornblende and chlorite occur as small flakes and biotite is present in minute amount as an alteration product.

Quartz forms small grains and as accessory minerals iron ore and apatite are found. Epidote is met with as an alteration product.

In the intermediate rock on the eastern side of Lake Aulangonjärvi also some narrow veins of prehnite are observed. Similar veins are present also in the basic volcanic rocks of the Tammela—Kalvola region.

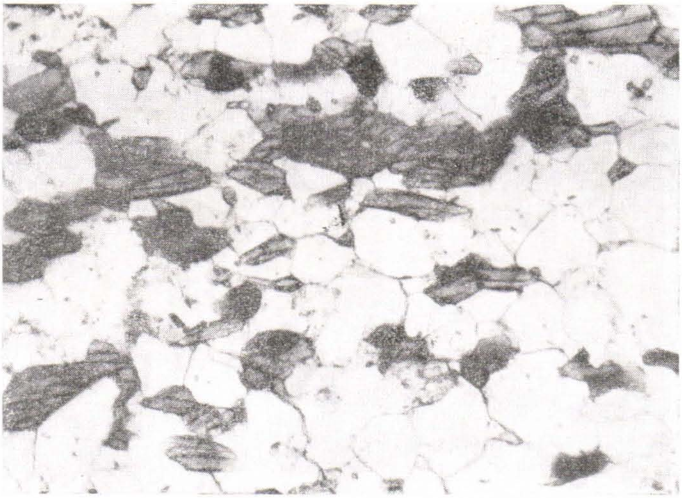

Fig. 4. Granoblastic intermediate volcanic rock showing a pavement texture. E. of Lake Aulangonjärvi. 55 x.

On the eastern side of Lake Katumajärvi the volcanic rock area is very inhomogeneous. There occurs also an acid volcanic rock as a coherent zone. The composition of this rock seems to be nearly liparitic and in some thin sections phenocrysts consisting of plagioclase have been observed. Probably this rock has been originally an acid lava bed. In general, however, the primary textures are not preserved and the rock resembles the leptites and leptite gneisses of other Svecofennidic areas and these have been considered as acid supercrustal rocks of volcanic or sedimentary origin. East of Lake Katumajärvi intermediate and basic volcanic rocks are, however, predominant. Southwest of Lake Nautalampi an intermediate agglomeratic variety associated with a stratified tuffitic rock occurs. Also some beds with amygdaloidal texture are observed, in which the quartz forms the amygdaloids.

In the schist area east of Lake Katumajärvi the primary textures and compositions are in general disturbed by the metasomatic processes characterized especially by increase of FeO and minute amounts of pyrite. In many places the surfaces of the outcrops are quite rusty, so that the textures are only weakly seen in the field. To some characteristics of these rocks we will return later, in connection with the description of the metasomatic processes (p. 38).

Volcanic rocks of tuffitic character are met with also in a small area west of Ilamo. Predominant rocks there are the acid volcanics, but also some basic varieties showing porphyritic texture occur. The volcanic rocks are here in close connection with mica schists of a clayey composition. An acid volcanic rock of this region was analyzed (Table II, N:o 4) and the mode was calculated on the basis of chemical analysis; only the amounts of mafic minerals were determined in the integration stage. The chemical composition shows a close relationship to many leptites of the Svecofennidic territory. Also the granoblastic pavement texture is very characteristic of many Svecofennidic leptites. The term »leptite» includes rocks of very different origin. In Sweden, for instance, the term »leptite» includes both volcanic and sedimentary rocks (Geijer 1944 p. 734). It is very difficult in many cases to decide what is the origin of a leptite. The analyzed rock west of Ilamo probably represents an acid pyroclastic sediment.

Chlorite occurs as mafic mineral of the rock. It has a very low birefringence and the interference colour is indigo.

Plagioclase is weakly sericitized and twinning is not seen. Quartz occurs as rounded grains. Microcline is found only in minute amount. Iron ore and apatite are met with as accessory minerals.

The northern part of the area is largely a region of strongly metamorphic schists, such as hornblende and mica gneisses. The primary textures of these rocks have not been preserved and their primary mode of occurrence is unclear. The amount of outcrops in this region is very small and it is therefore very difficult to follow the different rock varieties exactly in the field. According to the field observations and microscopical data these rocks consist of granoblastic, strongly metamorphozed derivatives of the supercrustal and basic infracrustal rocks met with in the Aulanko area. In the most northern part the rock has the appearance of veined gneisses.

SEDIMENTARY ROCKS.

The new geological mapping of Southwestern Finland shows that weathering sediments of a clayey composition are very common in the Svecofennidic territory. Especially coarse-grained cordierite gneisses, or kinzigites, are widely distributed. In some districts (Kalanti, Western Uusimaa) the sedimentary rocks are predominant among the metamorphic schists, in other regions (Orijärvi, Tammela—Kalvola, Pellinge) again, the volcanic rocks are in excess and sedimentary rocks occur only in small quantity. The Aulanko area belongs to the volcanic schist areas and only some small occurrences of mica schists of clayey composition have been observed. Especially the occurrence of cordierite and andalusite holoblasts shows Al_2O_3-excess of the mica schists.

West of Ilamo a cordierite-bearing mica schist occurs in a small area in close connection with an acid leptite and more basic tuffitic rocks. The mode of occurrence gives the impression that weathering and sedimentation have been only intraformational processes during different kinds of volcanic activity. The primary textures of this mica schist are not preserved but the chemical analysis (Table II, N:o 5) shows clearly the clayey composition.

The chemical composition of the cordierite-bearing mica schist is very similar to many Archaean mica schists and phyllites characterized by a

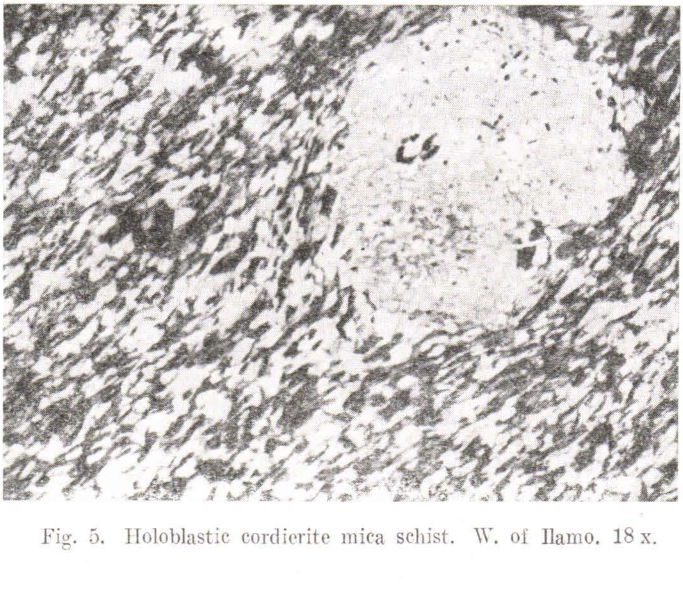

Fig. 5. Holoblastic cordierite mica schist. W. of Ilamo. 18 x.

high content of Al_2O_3, Fe_2O_3, FeO and K_2O, and a low content of CaO. The texture of the analyzed rock is holoblastic (Fig. 5).

Cordierite occurs as big rounded holoblasts, in diameter 1—3 mm, and the greatest part of this is sericitized.

Muscovite, biotite and chlorite occur together as small, well directed flakes. Plagioclase is slightly sericitized. Quartz occurs both in the matrix and as inclusions in cordierite. Iron ore and apatite are observed as accessory minerals.

On the northeastern side of Lake Aulangonjärvi there has been found also a small area of mica schist with andalusite holoblasts and small tourmaline grains.

In the southwestern part of the area, north of Lake Alajärvi, sedimentary mica schists have been met with to a greater extent. There the rock is characterized by pale red andalusite and by dark blue cordierite holoblasts. This mica schist is more coarse-grained than the rock west of Ilamo described above. Especially the andalusite crystals can attain a length of some centimeters. At one place in this area also a relic layer texture characterized by varves has been met with. The thickness of the varves is about 5—10 cm. The coarse-grained parts of the varves, consisting mainly of quartz, plagioclase and biotite, show a gradual transition to a fine-grained part where the big andalusite crystals are concentrated. The bottom of the varves is directed to the southwest. This kind of varved texture has been met with in many Archaean phyllites and mica schists which are supposed to have been originally water-laid sediments, originated under cool or temperate climatic conditions (Eskola 1932 c p. 31).

A chemical analysis of andalusite- and cordierite-bearing mica schist (Table II, N:o 6) shows also a characteristic clayey composition, similar to that of the cordierite mica schist.

Cordierite occurs as rounded holoblasts and contains iron ore as a pigment besides a minute amount of muscovite and quartz inclusions.

Andalusite occurs in minute amount as pale yellow grains.

Biotite with pleochroic haloes is a more abundant component of the matrix. Muscovite occurs mainly as inclusions in the cordierite. Plagioclase and quartz occur as small grains. As accessory minerals apatite, magnetite and zircon are found.

Among the mica schists of the Alajärvi region also some varieties occur which do not contain cordierite or andalusite, but only biotite, quartz and feldspar. These mica schists represent more quartz-rich products of weathering.

West of Tömäjärvi mica schist has been observed as a small area surrounded by the basic porphyrites. This shows that the weathering and sedimentation has taken place between the different volcanic periods and that the mica schists belong to the same formation as the volcanic rocks.

The strongly metamorphic gneisses in the northern part of the area contain rocks of supercrustal origin (p. 18). Among these many mica gneisses have probably originally been sediments. No minerals indicating a great Al_2O_3-excess have, however, been observed: only some coarse-grained varieties containing sericite and some minute grains of garnet are met with.

INFRACRUSTAL ROCKS.

Infracrustal rocks form the greatest part of the rock crust in the Aulanko area. Granodioritic intrusions are predominant and among these both gneissose and massive varieties occur. These rocks are very similar to the synkinematic intrusions of a granodioritic character in the Svecofennidic territory of Southwestern Finland known by the following names: gneissose granites, oligoclase granites, and older granites. The massive granodiorite which forms a coherent area around Aulanko shows an extraordinary character. In the following description it is discussed in a separate paragraph, although its genetical similarity to gneissose varieties of the other synkinematic intrusion is apparent. It is called the Aulanko granodiorite. Microcline-rich granites with a different mode of occurrence form the youngest component of the infracrustal rocks in the Aulanko area.

GNEISSOSE GRANODIORITES.

In the Svecofennidic territory of Southwestern Finland the older intrusives of granodioritic composition are of a very similar nature in different areas. These intrusives represent the synkinematic intrusions during the Svecofennidic orogeny, occurring conformably with the Svecofennidic schists. Gneissose granodiorites in the Aulanko area are in all respects similar to those in other occurrences of Southern Finland. In the following we will present only the main facts and chemical results of the study.

In the northwestern part of the studied area gneissose granodiorite occurs as a long projection. The rock is everywhere distinctly gneissose and in some places it is quite crushed up. Dark, more basic inclusions, predominantly primary inclusions of a gabbroidic character are of common occurrence, but also some inclusions of basic schists are met with here.

The chemical composition of the gneissose granodiorite (Table II, N:o 7) is very similar to that of other synkinematic intrusions in Southwestern Finland. The analysis certainly gives an idea of the primary composition. Probably, however, the content of the alkalies, especially K_2O, has slightly increased secondarily during the advance of the migmatite front. The increase of the alkalies is observed, for instance, in the gneissose variety of the Aulanko granodiorite. This process is discussed more in detail later on (p. 32).

Table II. Chemical and mineralogical composition of the rocks in the Aulanko area. Including their Niggli numbers.

N:o	1	2	3	4	5	6	7	8	9
SiO_2	48.99	55.37	60.07	71.00	61.94	61.37	68.73	59.93	67.47
TiO_2	1.47	1.30	0.84	0.61	1.31	0.68	0.95	1.08	0.52
Al_2O_3	14.26	14.76	16.72	12.45	15.63	13.50	14.42	15.27	14.62
Fe_2O_3	1.56	1.86	1.26	0.83	3.29	4.72	0.36	2.08	0.89
FeO	10.48	9.55	4.57	4.10	5.99	7.14	3.34	6.51	3.67
MnO	0.31	0.14	0.28	0.05	0.10	0.09	0.13	0.19	0.11
MgO	5.77	3.81	1.75	1.68	2.75	3.16	0.75	2.77	1.68
CaO	12.64	6.13	6.71	2.26	1.16	0.91	2.87	5.51	4.01
Na_2O	1.69	2.07	4.75	3.38	1.58	1.43	3.86	3.69	3.48
K_2O	0.41	2.36	0.77	1.34	3.59	3.45	3.45	1.85	2.08
P_2O_5	0.66	0.73	0.29	0.43	0.10	0.19	0.34	0.30	0.13
H_2O+	1.52	1.73	1.42	1.90	2.46	2.71	0.66	0.66	0.61
H_2O-	0.14	0.10	0.41	0.06	0.21	0.29	0.02	0.08	0.58
	99.90	99.91	99.84	100.09	100.11	99.64	99.88	99.92	99.85

1. Uralite porphyrite. 1 km west of the town Hämeenlinna. Anal. A. Simonen.
2. Plagioclase porphyrite. 1 km south of Parola railway station. Anal. P. Ojanperä.
3. Intermediate volcanic rock. E. of Lake Aulangonjärvi. Anal. A. Simonen.
4. Leptite. 1.5 km west of Ilamo. Anal. P. Ojanperä.
5. Cordierite-bearing mica schist. 1.5 km west of Ilamo. Anal. A. Simonen.
6. Cordierite-andalusite mica schist. N. of Lake Alajärvi. Anal. A. Simonen.
7. Gneissose granodiorite. 0.5 km south of Parola railway station. Anal. A. Simonen.
8. Quartz diorite. Tömäjärvi. Anal. A. Simonen.
9. Granodiorite of Aulanko. Myllymäki. Anal. A. Simonen.

N:o	1	2	3	4	5	6	7	8	9
quartz	3.2	12.0	15.4	39.0	31.0	26.8	29.9	14.9	28.6
plagioclase	30.5	35.4	57.0	40.8	16.2	13.4	39.6	49.7	45.2
microcline				4.3			17.0	2.2	9.1
biotite		21.5	1.8			33.5	6.5	13.5	8.3
muscovite					42.0	6.1			
chlorite			12.2	14.1				1.9	1.4
hornblende	61.9	26.9	11.3				3.9	14.5	5.5
cordierite					8.2	14.9			
andalusite						2.5			
epidote	0.2	0.1					0.4		
sphene	2.5	0.1					0.3	0.5	0.2
apatite	1.3	1.4	0.6	0.5	0.2	0.4	0.6	0.5	0.3
iron ore	0.4	2.6	1.7	1.3	2.4	2.4	1.8	2.3	1.4
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

si	115	163	202	345	238	228	314	193	281
ti	2.6	2.9	2.1	2.2	3.8	1.9	3.3	2.6	1.6
al	19.7	25.6	33.1	35.7	35.5	29.6	38.9	29.0	35.9
fm	44.1	44.7	25.6	32.3	45.0	53.4	19.7	36.5	26.5
c	31.8	19.4	24.2	11.8	4.8	3.6	14.1	19.1	18.0
alk	4.4	10.3	17.1	20.2	14.7	13.4	27.3	15.4	19.6
k	0.14	0.43	0.10	0.21	0.60	0.61	0.37	0.25	0.28
mg	0.46	0.37	0.34	0.38	0.35	0.33	0.26	0.37	0.40
c/fm	0.72	0.43	0.95	0.37	0.11	0.07	0.72	0.52	0.68

N:o	10	11	12	13	14	15	16	17	18
SiO_2	52.19	70.67	76.53	72.15	72.21	59.71	69.89	73.74	66.80
TiO_2	1.37	0.31	0.12	0.28	0.35	1.50	0.69	0.13	0.24
Al_2O_3	15.69	13.95	13.19	14.69	14.31	14.28	15.03	14.05	17.28
Fe_2O_3	2.67	1.37	0.10	0.07	0.66	1.08	0.30	0.17	1.83
FeO	9.66	2.24	1.62	1.01	1.21	12.14	2.14	1.24	0.88
MnO	0.31	0.06	0.03	0.03	0.06	0.20	0.08	0.04	0.10
MgO	4.47	1.15	0.47	0.15	0.32	5.79	0.74	0.43	0.86
CaO	4.79	2.89	2.55	0.52	1.63	1.34	3.18	2.28	1.88
Na_2O	3.44	3.84	3.92	4.51	2.83	0.97	4.09	3.66	8.14
K_2O	3.47	2.83	0.87	5.97	5.93	0.19	2.66	3.19	0.88
P_2O_5	0.26	0.12	0.02	0.13	0.30	0.64	0.15	0.01	0.15
H_2O+	1.59	0.62	0.52	0.49	0.45	2.03	0.68	0.59	0.59
H_2O-	0.31	0.06	0.10	0.06	0.06	0.05	0.33	0.31	0.47
	100.22	100.11	100.04	100.06	100.32	99.92	99.96	99.84	100.10

10. Biotite-rich basic inclusion in the Aulanko granodiorite. Myllymäki. Anal. A. Simonen.
11. Gneissose variety of the Aulanko granodiorite. Vanaja. Pappila. Anal. A. Simonen.
12. Rand facies of the Aulanko granodiorite. 1 km north of Äikäälä farm. Anal. A. Simonen.
13. Aplitic microcline granite. Western shore of Lake Katumajärvi. Anal. A. Simonen.
14. Microcline granite. Between Lakes Alajärvi and Hattelmalanjärvi. Anal. A. Simonen.
15. Anthophyllite-cordierite rock. E. of Lake Katumajärvi. Anal. P. Ojanperä.
16. Granitized granodiorite of Aulanko. National park Aulanko. Anal. A. Simonen.
17. Granitized granodiorite of Aulanko. 0.5 km south of Lake Aulangonjärvi. Anal. A. Simonen.
18. Albitic rock of Aulanko. Anal. A. Simonen.

N:o	10	11	12	13	14	15	16	17	18
quartz	8.5	31.3	44.0	22.0	29.6	23.6	28.3	35.5	13.2
plagioclase	39.1	43.4	45.4	39.9	29.9		46.0	41.3	71.3
microcline	0.8	13.9		35.0	30.6		14.2	16.2	
biotite	34.8	5.3	4.2	1.5	5.1		3.1	4.1	5.4
muscovite			2.8		3.3				
chlorite		0.9	3.3		0.6		1.8	2.1	1.1
hornblende	15.2	3.8					4.3	0.4	
anthophyllite						34.1			
cordierite						36.1			
almandite				0.4		2.2			
epidote							0.6		8.0
sphene	0.6						0.2		
apatite	0.4	0.2		0.4	0.4	1.0	0.3	0.1	0.4
iron ore	0.6	1.2	0.3	0.8	0.5		1.2	0.3	0.6
pyrite						3.0			
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

si	141	328	448	388	385	194	330	406	276
ti	2.8	1.1	0.5	1.1	1.4	3.7	2.5	0.5	0.7
al	25.0	38.2	45.6	46.6	45.0	27.4	41.9	45.6	42.2
fm	46.1	21.7	12.7	6.2	10.8	64.5	15.1	10.2	14.4
c	13.9	14.4	16.1	3.0	9.3	4.7	16.2	13.4	8.3
alk	15.0	25.7	25.6	44.2	34.9	3.4	26.8	30.8	35.1
k	0.40	0.33	0.13	0.47	0.58	0.11	0.30	0.36	0.07
mg	0.39	0.37	0.33	0.19	0.23	0.44	0.35	0.35	0.37
c/fm	0.30	0.66	1.27	0.48	0.86	0.07	1.07	1.31	0.58

The texture of the analyzed granodiorite is seen in Fig. 6. Big plagioclase grains are embedded in a granoblastic mass consisting mainly of quartz, biotite, feldspar and hornblende.

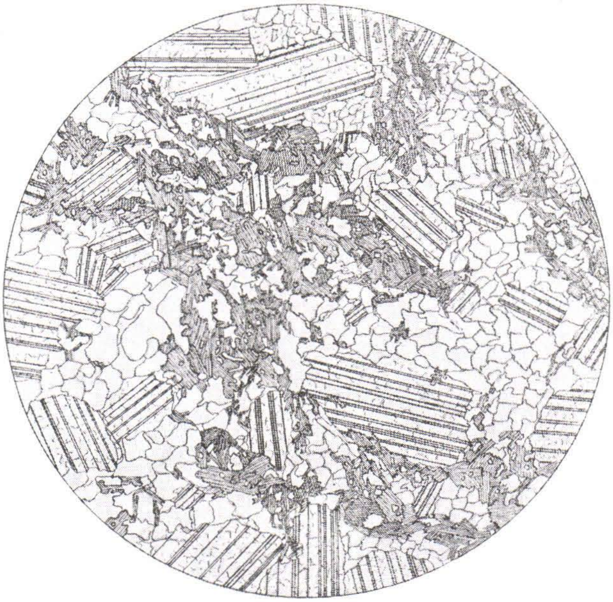

Fig. 6. Gneissose granodiorite. S. of Parola railway station. 7 x.

Plagioclase occurs as crushed up grains. In some cases a zonal texture is observed. According to the optical determination in the U-stage the composition of the plagioclase is An_{26-28}.

Microcline and quartz occur as xenomorphic grains between the big crystals of the plagioclase.

Hornblende occurs as ragged grains. Biotite is dark-coloured.

Accessory minerals are iron ore, apatite and sphene. Sericite occurs as an alteration product of plagioclase and epidote as that of hornblende.

The southeastern part of the Aulanko region is part of a great granodiorite area. The rock is very similar to the gneissose granodiorite described before. Eastwards, outside of the mapped area, the rock changes gradually to more coarse-grained varieties and the schistosity is not so clear. This is also a very common feature of the gneissose granodiorites of Southwestern Finland in general; in the central area the rock is frequently devoid of remarkable schistosity, but at the boundaries it has a well developed linear texture. The chemical composition of the schistose rand zone rock is very similar to that of the massive rock. According to the microscopical study, however, the amount of microcline seems to be lower in the massive variety. The increase of microcline in the schistose type is clearly a secondary process, due to the pushing forward of younger microcline granite along the schistosity planes.

The mineralogical composition of the gneissose granodiorite east of Lake Nautalampi is according to the microscopical study very similar to the above described and analyzed rock south of Parola railway station.

West of Lake Alajärvi, in the western part of the mapped area, there occurs also an intrusive rock showing a quartz dioritic composition (Table II, N:o 8) more basic than that of the gneissose granodiorite. The quartz diorite does not show any distinct schistosity. The texture of the rock is hypidiomorphic.

Plagioclase occurs as big individuals showing a well developed zoning. In a zoned grain the kernel showed the composition An_{45}, a certain zone of the same crystal An_{35} and the rand zone An_{25}. As a whole the composition of the plagioclase varies between An_{35} and An_{36}.

Hornblende and biotite occur as mafic minerals. The hornblende has partly altered into chlorite and contains sphene inclusions. The biotite is dark-coloured and apatite inclusions with pleochroic haloes are common.

Quartz is clearly a last product of crystallization, occurring without idiomorphic shapes between other minerals. Microcline is met with only as small grains in some thin sections, but in general it is lacking.

Accessory minerals are apatite, sphene and magnetite.

It is a common feature among the synkinematic intrusions of Southwestern Finland that there occur sparsely, in close connection with the acid intrusions, small occurrences of gabbros and diorites. In the Aulanko area gabbros also occur as small lenses in close relation to gneissose granodiorites and quartz diorites.

In the quartz diorite area of Tömäjärvi both dioritic and gabbroidic rocks occur. All basic infracrustal rocks are hornblende-bearing and one gabbroidic variety contains, together with common green hornblende, colourless needles of cummingtonite in which the birefringence is higher ($\gamma - \alpha = 0.026$) than that of the hornblende. The plagioclase in the gabbroidic varieties is labradorite.

North and northeast of Hämeenlinna also gabbroidic rocks occur as small lenses. The primary hypidiomorphic texture of these rocks is only weakly preserved. These rocks contain only hornblende and biotite as mafic minerals and in many cases it is observed that the hornblende is lighter-coloured in the kernels of individuals surrounded by green-coloured hornblende. The composition of the plagioclase varies between An_{40} and An_{55}. These gabbroidic rocks in many cases pass gradually into hornblende schists, common in the northeastern part of the area.

THE GRANODIORITE OF AULANKO.

The Aulanko granodiorite occurs as a great *massif* in the middle of the region studied. The outlines of the rock area are not quite similar to the general, elongated shapes of granodiorites and gneissose granites in Southwestern Finland and gneissose texture has been observed only

Fig. 7. Granodiorite of Aulanko with basic inclusions. Myllymäki. 1/10 natural size.

occasionally near the boundaries. The granodiorite occurs most typically in Myllymäki, in the closest vicinity of the town Hämeenlinna, where the rock has been quarried for building material. The rock is grey in colour and contains dark inclusions of rounded forms. It is coarse-grained and lacks all signs of a gneissose texture (Fig. 7). The most characteristic feature of the Aulanko granodiorite is the occurrence of idiomorphic hornblende grains in which the crystal faces of the prismatic zone are usually seen. A typical example crops out at the belvedere in the Aulanko hill.

The chemical composition of the Aulanko granodiorite (Table II, N:o 9) differs most remarkably from the gneissose granodiorite occurring south of Parola railway station (Table II, N:o 7) in the higher amount of CaO;

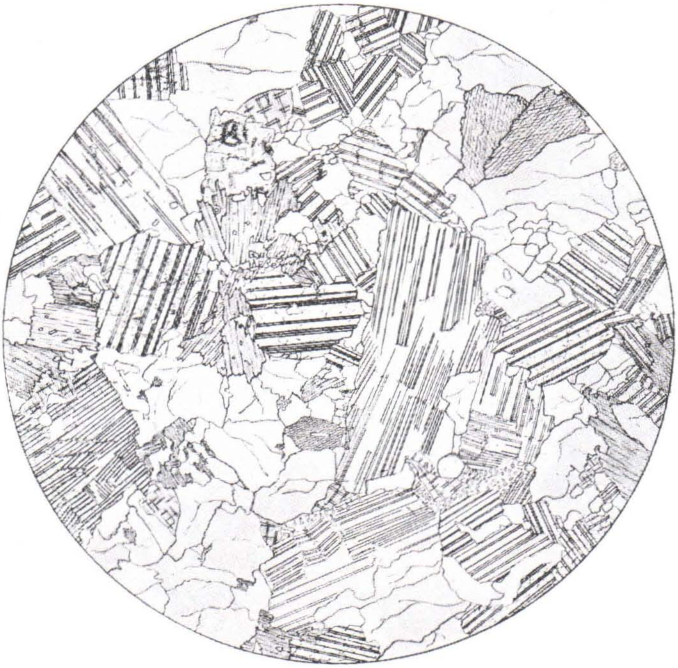

Fig. 8. Texture of the Aulanko granodiorite. Myllymäki. 8 x.

on the other hand the K_2O-content is lower than that of the last-mentioned rock. The [FeO] : [MgO] ratio of the gneissose granodiorite is 2.5 and that of the Aulanko granodiorite is 1. 2. Apparently the Aulanko granodiorite belongs to a calc-alkalic rock series similar to the gneissose granodiorite of the area, but it is more basic in composition.

The texture is hypidiomorphic (Fig. 8) though there sometimes occurs a granoblastic mass between bigger individuals of plagioclase.

Plagioclase is present as zoned crystals. According to the optical determination in the U-stage the composition of the plagioclase is An_{30-34}.

The crystals of plagioclase enclose small microcline individuals and also small grains of calcite (Fig. 9). The origin of the microcline inclusions is due to metasomatic processes and the calcite has received its CaO-amount from the plagioclase. The metasomatism has perhaps taken place in the latest phase of the magmatic crystallization. Later on (p. 31) we will describe some other phenomena which also indicate late-magmatic reactions.

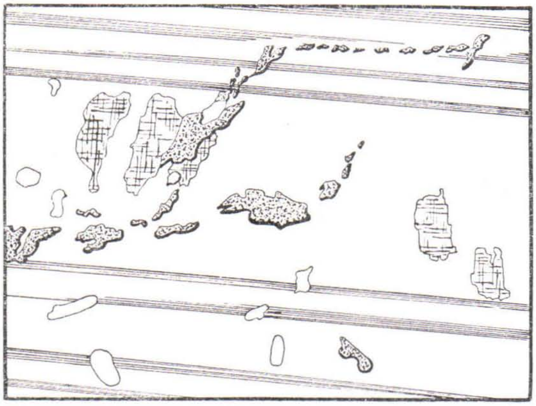

Fig. 9. Microcline and calcite inclusions in the plagioclase of the Aulanko granodiorite. Myllymäki. 50 x.

Quartz is present in abundance as xenomorphic grains.

Microcline was met with only as xenomorphic grains between other minerals. It forms myrmekite in the boundary zone of the plagioclase.

In Fig. 10 is seen a corroded plagioclase grain with myrmekite surrounded by the microcline. In the boundary zone between the plagioclase and the microcline the myrmekite quartz is sometimes observed also as inclusions in the microcline. This gives the impression that myrmekite has been formed by the replacement processes between older plagioclase and younger microcline. The origin of the myrmekite has been discussed in detail by Drescher—Kaden (1940). According to his opinion, the myrmekite has originated by metasomatic replacement in close relation to formation of the microcline. In the Aulanko granodiorite the late liquid magma residue especially rich in K_2O has probably caused the myrmekite formation. In this place the writer will mention that in the granitized

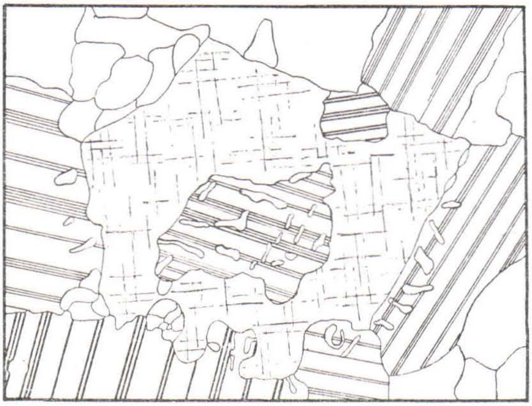

Fig. 10. Corroded plagioclase grain with myrmekite surrounded by microcline in the Aulanko granodiorite. Myllymäki. 30 x.

varieties of the granodiorite the myrmekite formation has not been observed in connection with the secondary increase of the microcline. The present author sets forth the opinion that myrmekite has originated in the Aulanko granodiorite as a replacement product of primary residual magma liquid after the main crystallization of granodiorite.

Hornblende and biotite are found as mafic minerals. The hornblende is the most idiomorphic constituent and has assuredly crystallized earlier than the other minerals. Remains of pyroxene have not been found and probably the hornblende is the most primary crystallization product of the granodioritic magma. In the granodiorites it is observed, however, in many cases that the hornblende has crystallized as a product of replacement by other minerals. In a granodiorite of the Namama area in Transbaikalia, for instance, according to Eskola (1930 p. 126), idiomorphic hornblende has crystallized instead of an earlier clinopyroxene before the crystallization of the salic minerals. In this rock some grains of diopside are observed in the hornblende as relics from an earlier phase of crystallization.

The refractive indices of the hornblende in the Aulanko granodiorite, determined by the immersion method in cleavage splinters are: $\alpha' = 1.662$ and $\gamma' = 1.684$, indicating [FeO] : [MgO] = 1 according to Winchell (1933).

In many cases it is found that individuals showing the hornblende in crystal form have altered into biotite flakes; unaltered hornblende is met with only in the kernels of the crystals. The biotite groups consequently occur as pseudomorphs after hornblende.

Apatite, sphene and zircon are observed as accessory minerals. Sphene occurs mainly together with chlorite.

The hornblende of the Aulanko granodiorite was separated by Clerici solution and the resulting material containing some apatite as inclusions was analyzed (Table III). The composition differs from the average compositions calculated by Tschirwinsky (1928) principally in the ratio [FeO] : [MgO]. According to Tschirwinsky, the MgO-content in the hornblende of granitic rocks is higher than that of FeO, but in the hornblende of the Aulanko granodiorite this relation is the reverse. The composition of the analyzed hornblende is, in the opinion of the present author, more characteristic of the composition of the hornblendes in the granodioritic rocks of Southwestern Finland than the averages presented by Tschirwinsky; this because already the rock analyses of the Svecofennidic hornblende-bearing diorites and granodiorites show that the FeO-content is always remarkably higher than that of MgO.

The dark, rounded inclusions in the Aulanko granodiorite contain more hornblende and biotite than the main rock. Plagioclase occurs as zoned crystals and its composition according to the optical determinations varies greatly (An_{30-40}). Quartz is present only in minute amount. These inclusions have a hypidiomorphic texture and they represent more basic differentiation products of the granodioritic magma. The amounts of hornblende and biotite vary greatly and in some cases the biotite and the zoned plagioclase are the main components. This kind of inclusion was analyzed (Table II, N:o 10).

The analysis does not represent the primary composition of a basic inclusion, but metasomatic processes have occurred. The primary hornblende of basic inclusion has altered into biotite causing the high K_2O-amount. The enrichment of some trace elements (rubidium and caesium, see p. 59), which are typical of the late-magmatic rocks, in the basic inclusion, shows that this alteration has been due to the late-magmatic liquids. The Aulanko granodiorite, in which the analyzed inclusion has its place, is not influenced by secondary metasomatic processes caused by younger microcline granite, but apparently an autometasomatic process has occurred in connection with the magmatic crystallization, so that the magma residue of the granodiorite rich in K_2O and volatile substances has caused the metasomatic alteration of the basic inclusion.

Table III. Chemical analyses of hornblende and biotite in the granodiorite area of Aulanko.

	1	1 a		2	
	%	%	Mol. prop.	%	Mol. prop.
SiO_2	45.18	46.36	.7688	35.75	.5929
TiO_2	1.50	1.54	.0192	2.73	.0341
Al_2O_3	6.30	6.46	.0632	14.08	.1378
Fe_2O_3	3.88	3.98	.0249	3.36	.0210
FeO	15.81	16.22	.2257	20.68	.2878
MnO	0.43	0.44	.0062	0.31	.0044
MgO	9.58	9.84	.2440	8.61	.2135
CaO	11.56	10.53	.1877	0.31	.0055
Na_2O	0.92	0.94	.0152	0.55	.0089
K_2O	0.95	0.97	.0103	9.05	.0961
P_2O_5	0.99	—	—	0.10	.0007
H_2O+	2.17	2.23	.1238	3.94	.2187
H_2O-	0.48	0.49		0.34	
	99.75	100.00		99.81	

1. Chemical composition of the hornblende containing apatite inclusions in the Aulanko granodiorite. Anal. Pentti Ojanperä.
1 a. Calculated from anal. 1 without P_2O_5 and subtracting CaO-amount which goes to form apatite occurring as inclusions in the analyzed hornblende.
2. Chemical composition of the biotite of the dark inclusion in the Aulanko granodiorite. Anal. Pentti Ojanperä.

Plagioclase (An_{34-35}) forms zoned crystals which have altered in minute amounts into sericite and epidote.

According to the optical determinations the hornblende is very similar to that of the granodiorite. It has altered into dark biotite. Only minute amounts of chlorite are observed.

Quartz and microcline are sparsely present and they have probably originated in connection with the late-magmatic processes.

Sphene, iron ore, apatite and zircon occur as accessory minerals.

The biotite in the analyzed basic inclusion of the Aulanko granodiorite was separated by Clerici solution and pure material was analyzed (Table III). The composition of the biotite differs greatly from the averages calculated by Tschirwinsky (1928). The high FeO-content shows a relationship to the biotite occurring in the acid rocks. Probably many biotites of the granitized rocks are of a similar character.

In the southern part of the Aulanko granodiorite area, southeast of Vanaja church, signs of the orogenic movements are observed. In the neighbourhood of Pappila the gradual change into a gneissose type is seen. This change seems to be originally a purely mechanical process, but afterwards the gneissose modification has been most easily attacked by the new microcline granitic material. For illustration of this process the content of alkalies in the gneissose and in the non-gneissose varieties in the neighbourhood of Pappila was determined (Table IV). For comparison also the alkali-content of the granodiorite in Myllymäki is presented.

Table IV. Alkali-content of some varieties of the Aulanko granodiorite.

	Na_2O %	K_2O %
Granodiorite. Myllymäki	3.48	2.08
Granodiorite. Vanaja. Pappila	3.69	2.11
Gneissose variety of granodiorite. Vanaja. Pappila	3.84	2.83

The alkali-content of the different varieties shows clearly that both Na_2O and K_2O have enriched in the gneissose type of granodiorite. Microscopical study shows that fine-grained granitic fabric has been formed secondarily between the crushed crystals of the primary rock.

The composition of the gneissose variety in the Aulanko granodiorite (Table II, N:o 11) is very similar to that of the gneissose granodiorite south of Parola railway station (Table II, N:o 7). The primary composition of the analyzed rock has been changed by the secondary processes to more granitic by the attack of the migmatite front. The anisotropic structure of the rock has made the granitization easier.

Plagioclase occurs both as big crushed crystals and as minute grains in a granitic fabric between bigger mineral grains of the rock. According to the optical determination in the U-stage the composition of it is An_{28}.

Quartz occurs as two generations. It is seen as big primary crystals and as minute grains in the granitic material.

Microcline forms the main component of that secondary material which has increased through the mechanical granitization.

Mafic minerals, hornblende and biotite, occur as groups. Chlorite is met with as an alteration product.

Apatite and iron ore are found as accessory minerals.

East of Lake Katumajärvi, 1 km north of Äikäälä farm, in the boundary zone of the Aulanko granodiorite a marginal variety is observed showing a peculiar chemical composition (Table II, N:o 12). This composition is related to rand facies observed in connection with the urgranites in Sweden. In Finland this kind of rock has been observed earlier only in the Orijärvi region (Eskola 1914). The most remarkable characteristic of these rand facies is the high Na_2O- and low K_2O- content, showing in this relation similarity to the rocks of the trondhjemitic suite.

The rand facies of the Aulanko granodiorite has a granoblastic texture (Fig. 11) and it shows a slightly developed gneissose character.

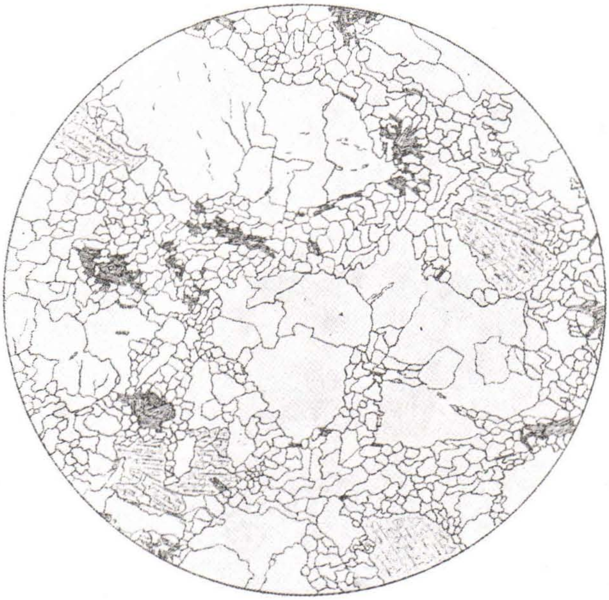

Fig. 11. Rand facies of the Aulanko granodiorite, showing big quartz and plagioclase crystals in the granoblastic matrix. N. of Äikäälä. 7 x.

Plagioclase occurs both as bigger and smaller grains. The big grains are rich in muscovite inclusions. According to the optical determination in the U-stage the composition of the plagioclase is An_{25-27}.

Quartz occurs also as bigger and smaller individuals.

Biotite flakes are present as groups, giving the idea that these are relics of a more basic mineral, probably hornblende.

Muscovite flakes occur in plagioclase as alteration products. Epidote is observed in minute amounts.

Apatite and iron ore are accessory minerals.

Many hypotheses have been presented on the origin of the soda-rich rand facies. Of late years, this problem has been discussed by Backlund (1938 p. 192) and Magnusson (1937 p. 529). Backlund regards the marginal varieties as granitized rocks and Magnusson holds them to be differentiation products of the urgranite. Hjelmqvist (1943) describes a soda-rich rand facies of the urgranite and regards it as an alteration product of soda-rich leptite.

The origin of the marginal variety of the Aulanko granodiorite is difficult to unravel, because the rock crust around this is widely covered by loose soil. Probably the rand facies is a metasomatic product of the Aulanko granodiorite due to the albitization in the later phase of the magmatic crystallization. In harmony with this opinion is the occurrence

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of the biotite groups, probably pseudomorphs, after the primary hornblende and the occurrence of big plagioclase and quartz individuals showing relationship to such in the Aulanko granodiorite. On the other hand, the texture of the marginal variety shows also relationship to the leptite gneisses and north of it are found some outcrops of the coarse-grained leptitic rock containing oligoclase phenocrysts. Probably the marginal variety represents a transitional form between the leptite and the granodiorite. In the rand facies are observed, however, inclusions of the basic volcanics showing that the primary mode of the occurrence has been merely intrusive.

North- and eastward of Hämeenlinna the granodiorite becomes gradually more microcline-rich and the hornblende content decreases. The texture relics of the primary granodiorite are seen also in the microcline-rich varieties in which microcline granitic fabric has found a place between the zoned crystals of plagioclase. These rocks have clearly a granitized character and a detailed description of same is given later in the chapter »Granitization» (p. 44).

MICROCLINE GRANITE.

In Southwestern Finland microcline granites are widely distributed and with older rocks they form different kinds of migmatites. The main part of the microcline granites has clearly a palingenic mode of occurrence. Aplitic, medium-grained and pegmatitic varieties occur, but the general character of all these is the impoverishment in mafic components, whereas the pegmatites are so-called simple pegmatites, without minerals containing rare elements in great amount. In the Aulanko area microcline granites of the same kind as the above-mentioned so-called coast granites occur, but there are also some varieties which have a more juvenile or purely magmatic mode of occurrence.

In the southern part of the area the microcline granite is of great extent. In some places one may observe mica streaks, which are probably relics of granitized schists. Near the contacts of the older rocks aplitic and pegmatitic varieties which penetrate other rocks are generally found. The mineralogical composition of these is very monotonous, consisting mainly of feldspar and quartz. A fine-grained aplitic variety was analyzed (Table II, N:o 13).

The analyzed rock occurs in the boundary zone of the Aulanko granodiorite and granitized inclusions of this are observed in the aplitic microcline granite. The analysis shows the poverty in mafic components. According to the field observation it seems that an aplitic variety of this kind in the first place has caused the granitization phenomena discussed later (p. 45). The Aulanko granodiorite, which appears as inclusions in the analyzed rock, causes the high amount of Na_2O in the analysis.

Plagioclase, microcline and quartz are the main components. The composition of the plagioclase is — according to the optical determination — An_{6-7}.

As mafic component biotite occurs sparsely. The biotite shows a green colour under the microscope. This kind of biotite is probably a first stage in the alteration into chlorite.

Apatite and iron ore are present in very minute amounts. Some grains of garnet are also observed.

In the heart of the microcline granite area of a palingenic mode of occurrence also a muscovite-bearing medium-grained variety is met with between Lakes Alajärvi and Hattelmalanjärvi. In this rock the biotite-rich schliers common in other varieties are not seen, while the presence of muscovite is characteristic of this variety. Probably this muscovite-bearing granite is a more active palingenic magma which does not represent a rock originated by the replacement processes of older rocks, but has to a greater extent formed a magma. The relation of this rock to the palingenic varieties is not observed in the field, because the rock crust is largely covered by the Quaternary deposits.

The composition of the muscovite-bearing microcline granite (Table II, N:o 14) is very similar to that of the coast granites in Southern Finland. It differs most remarkably from the aplitic variety presented before in the great excess of K_2O over Na_2O.

The texture is hypidiomorphic. Most remarkable is the occurrence of zoned crystals of idiomorphic plagioclase (Fig. 12); this indicates that

Fig. 12. Microcline granite with zoned plagioclase. Between Lakes Alajärvi and Hattelmalanjärvi. 7 x.

this rock has crystallized from a coherent magma without replacement processes. In general zoned plagioclase has not been observed in the late-kinematic granites of the Svecofennidic orogeny, which have usually a palingenic and granitized mode of occurrence.

Plagioclase is the most idiomorphic component of the rock and zoned crystals are somewhat sericitized. The composition of the plagioclase is, according to the optical determination in the U-stage, An $_{20-21}$.

Microcline is present as minute and big grains. Quartz occurs without idiomorphic forms between feldspar grains.

Biotite is met with as tattered flakes showing a strong pleochroism. Chlorite occurs as alteration product of biotite. Muscovite is present in more minute amount than biotite.

Apatite and magnetite are observed as accessory minerals.

In the northern part of the area there occur pegmatites containing mainly microcline, quartz and muscovite. These pegmatites belong genetically to the microcline granites. The pegmatites in the northern part of the Aulanko area have a typical character of the so-called complex pegmatites. They contain dark tourmaline, and also crystals of beryl are observed. Probably these pegmatites belong genetically closely to hose of Tammela thoroughly described by Mäkinen (1913).

CONTACTS OF THE INFRACRUSTAL ROCKS.

Contact relations of the infracrustal rocks are most decisive as regards the stratigraphical classification of the Pre-Cambrian rocks. In the following the author will describe some contacts in the Aulanko area and discuss the significance of these.

Gneissose granodiorite penetrates the volcanic and iron- and magnesia-metasomatic rocks southwest of Lake Nautalampi. Gneissose granodiorite does not sharply cut the schists; it occurs only as a long projection pointing to an intrusive dike pressed forward along the plane of schistosity. This mode of occurrence shows that the deformation of the volcanic rocks had begun already before the intrusion of the granodiorite took place. On the other hand, however, the deformation continued also after the intrusion which gave the gneissose texture to the granodioritic rocks. The relation between the schist and gneissose granodiorite shows that the schists are older than the intrusives.

Earlier, in the description of the supercrustal rocks, the author has pointed out, based on the facts revealed by the field observations, that all supercrustal rocks belong to the same formation. According to the stratigraphical classification of Sederholm the uralite porphyrites in the Tammela region are younger than the gneissose granite. He considers the uralite porphyrite to belong to a special, so-called Bothnian formation. The field observations in the Aulanko area show, however, that there is no reason to distinguish a special Bothnian formation, but that all schists are older than the gneissose granodiorite. This is the case also in the Tammela—Kalvola area, where the gneissose granite, according to the new field observations (Eskola 1936 a), penetrates the uralite porphyrite and other supercrustal rocks. Furthermore, the petrographical and tectonical similarity of the rock crust of the Tammela—Kalvola and Aulanko areas to the Svecofennidic formations is so clear that the assumption of their belonging to the same orogenic formation is well founded.

Southwest of Lake Nautalampi the gneissose granodiorite penetrates also the metasomatic altered rock characterized by increase of FeO. This shows that the Fe-metasomatism is older than or contemporaneous with the intrusion of the gneissose granodiorite.

In Metsänkylä the gneissose granodiorite penetrates the hornblende gneiss, which is originally a more basic infracrustal rock. The basic infracrustal rocks are consequently older than the acid ones.

The Aulanko granodiorite penetrates also the schist formation. On the southern side of Lake Matkalampi is observed a contact between the granitized granodiorite and the intermediate tuffitic rock (Fig. 13). The granodiorite cuts the strike of the schists and fragments of the latter are

Fig. 13. The contact between the Aulanko granodiorite and the intermediate volcanic rock. S. of Matkalampi. 1/10 natural size.

observed as inclusions in the granodiorite. Some of the fragments occur only as altered shapes. The granitized granodiorite further contains crystals of hornblende and in the contact it is slightly gneissose, but at a distance of some meters from the contact gneissose texture is not observed. From the granodiorite a vein runs into the tuffitic rock; this cutting vein becomes gradually more microcline-rich and the vein gradually receives the character of microcline granite.

On the eastern side of Lake Katumajärvi, northwest of Äikäälä farm, a tuffitic volcanic rock is also observed as fragments in the Aulanko granodiorite and in the marginal variety of this rock. Also iron- and magnesia-metasomatic rocks with pyrite occur as inclusions.

It has already earlier been pointed out that the Aulanko granodiorite is closely related to the same group of intrusions as the gneissose granodiorites. In this case the above-mentioned facts only strengthen the opinions set forth in connection with contacts of the gneissose granodiorite.

Microcline granite is the youngest infracrustal rock. Microcline granite of aplitic and pegmatitic character is frequently found penetrating the schists and other infracrustal rocks. At many places it is possible to establish that these veins occur in the fissure directions of the older rocks.

METASOMATIC ROCKS.

MAGNESIA METASOMATISM.

In the schist zone on the eastern side of Lake Katumajärvi rocks characterized by the following minerals commonly occur: almandite, anthophyllite, cordierite and cummingtonite. Already Tigerstedt (1888) mentions in his explanation to the map sheet of Hämeenlinna that in the neighbourhood of Kappola farm some outcrops have been found of a rock »in which shiny, needle-formed crystals occur abundantly in an amphibolitic ground-mass». Furthermore, Tigerstedt observed that these rocks contain pyrite in small quantities. The present author discovered that the rocks containing the above-mentioned minerals extend as a coherent zone from Lake Matkalampi into the southern part of Lake Katumajärvi. The length of this zone is about 4 kilometers.

The petrographical characteristics of the rocks met with in the above-mentioned zone vary greatly. Most predominant are amphibolitic rocks containing basic plagioclase, almandite, anthophyllite and cummingtonite. In some varieties also cordierite occurs. The amount of the above-mentioned minerals varies greatly. For example the amount of almandite, which is easily observed in the field, varies so that in some types it is entirely lacking, while the almandite-richest parts again consist of about 30—50 per cent of the said mineral. Furthermore, the size of the mineral grains varies greatly.

All rocks containing basic plagioclase are called amphibolites, because according to the field observations, they stand in close relationship to the basic and intermediate schists. The classification of the different amphibolites has been based on the mineral parageneses met with.

Cummingtonite amphibolite. — Cummingtonite occurs as needles which traverse other minerals and it is generally colourless, but a pale green colour without pleochroism is sometimes found under the microscope. Cummingtonite needles form accumulations which are probably relics of earlier uralite phenocrysts. In some cases minute spots of green hornblende are observed. In general, however, the rocks contain mainly cummingtonite and labradoritic plagioclase. Fine-grained matrix between cummingtonite needles shows granoblastic texture. Apatite, iron oxide and sulphide ores occur only sparsely.

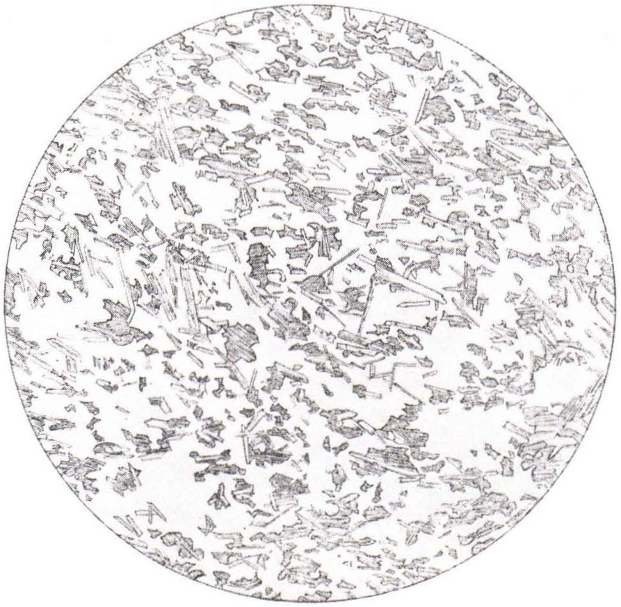

Fig. 14. Cummingtonite amphibolite rich in biotite. E. of Lake Katumajärvi. Colourless needles = cummingtonite; grey = biotite and white = granoblastic matrix. 7 x.

In one variety pale biotite occurs abundantly (Fig. 14). Cummingtonite needles run generally through the biotite, but sometimes the ends of the needles consist of biotite, suggesting the idea that the cummingtonite has originated at the expense of biotite. This variety contains also plagioclase in abundance (An_{40}—$_{50}$). The refractive indices of the cummingtonite were found to be $\alpha' = 1.649$ and $\gamma' = 1.666$.

C u m m i n g t o n i t e - a l m a n d i t e a m p h i b o l i t e. — This type is very similar to the cummingtonite amphibolite described above. Cummingtonite does not form accumulations, but it occurs as idioblastic needles, showing a clear linear arrangement. Only in the neighbourhood of the garnet crystals do the cummingtonite needles show deviations from the direction of the well developed lineation. The colour of the cummingtonite under the microscope is pale green and it shows very weak pleochroism. The refractive indices of the cummingtonite determined by the immersion method in the cleavage splinters are: $\alpha' = 1.658$, $\gamma' = 1.679$. The optical character is positive, $c \wedge \gamma = 18°$ and $2\ V = 76°$ determined in the U-stage. According to the refractive indices this cummingtonite is very similar to the analyzed cummingtonite in the gedrite-cummingtonite-almandite amphibolite of Isopää, Kalvola, described by Eskola (1936 b p. 482).

Almandite occurs as well developed crystals showing ideal faces (110). The refractive index of the almandite, determined in a polished prism, was found to be $N_D = 1.808$. The almandite contains abundant quartz inclusions and is surrounded by an aureole of quartz.

The composition of the plagioclase varies from An_{50} to An_{40}. In some cases small cordierite grains occur in this type. Apatite, iron oxide and sulphide ores occur as accessory minerals.

Almandite-anthophyllite amphibolite. — This type is very similar to the almandite-cummingtonite amphibolite; anthophyllite occurs instead of cummingtonite. In this type sometimes also cummingtonite occurs in minute amount together with anthophyllite. Only in very few cases anthophyllite and cummingtonite are observed in a homoaxial intergrowth, so that anthophyllite is found in the kernel of a needle.

The almandite is very similar to that occurring in the cummingtonite-almandite amphibolite. Plagioclase is very rich in anorthite (An_{40-45}). Cordierite occurs sometimes in minute amount. Quartz, biotite, apatite, iron oxide and sulphide ores occur in minor amounts.

Anthophyllite-cordierite amphibolite. — This type arises from the almandite-anthophyllite amphibolite when the cordierite amount increases. In connection with the increase of cordierite the amount of plagioclase decreases. Many transitional types between the abovementioned types are to be found.

Anthophyllite occurs often as idioblastic needles showing radial arrangement. In some cases also cummingtonite occurs in minute amount.

Cordierite appears as poikiloblastic grains, but develops in connection with the decrease of plagioclase into big porphyroblastic individuals containing abundant inclusions of quartz, anthophyllite, biotite, iron oxide and sulphide ores. In the boundary zone between quartz inclusions and cordierite sericite often occurs.

In many cases also almandite is found. The plagioclase amount varies greatly, depending on the amount of cordierite. It is rich in anorthite (An_{40}).

Anthophyllite-cordierite rock. — The anthophyllite-cordierite amphibolite grades into anthophyllite-cordierite rock when all plagioclase disappears. The almandite amount varies greatly in this type. Cummingtonite is not observed. Other minerals occurring are quartz (quantity varies greatly), small ragged flakes of biotite and of chlorite, apatite, iron oxide and sulphide ores.

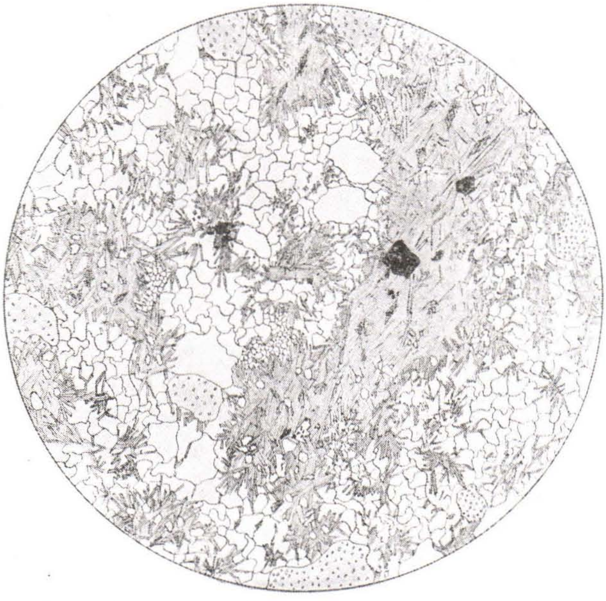

Fig. 15. Anthophyllite-cordierite rock. E. of Katumajärvi. Grey needles = anthophyllite; grey porphyroblasts with inclusions = cordierite; white = granoblastic matrix. 7 x.

Anthophyllite occurs as idioblastic needles showing radial arrangement (Fig. 15). The anthophyllite needles have grown through other minerals. The anthophyllite is pale green and shows very weak pleochroism. It shows the ordinary optical orientation with $a = \alpha$, $b = \beta$, $c = \gamma$. The refractive indices determined by the immersion method are $\alpha' = 1.666$ and $\gamma = 1.683$. The optical character is positive and $2\ V = 76°$ determined in the U-stage. The high values of the refractive indices show that this anthophyllite is very rich in FeO.

Cordierite occurs as big porphyroblasts containing mainly inclusions of anthophyllite, quartz, biotite and iron ore. The optical orientation is $a = \beta$, $b = \gamma$, $c = \alpha$. The optical character is negative and $2\ V = 74°$ determined in the U-stage.

The composition of the anthophyllite-cordierite rock (Table II, N:o 15) does not seem to be that usual in sedimentary and igneous rocks. The analyzed rock does not represent the more basic types of the anthophyllite-cordierite rocks in the Aulanko area. According to the determinations in the integration stage we can establish that some varieties contain about 40 per cent of anthophyllite.

Due to the great inhomogeneity of the rock it was not possible to determine exactly in the integration stage the mode of the analyzed rock. Three determinations in different thin sections were carried out, showing mineral compositions as follows:

	%	%	%
Cordierite	32.1	37.4	38.8
Anthophyllite	38.5	23.6	40.1
Quartz	24.4	29.6	16.9
Almandite	0.0	5.2	1.2
Iron oxide and sulphide ore	3.9	2.6	2.6
Apatite	1.1	1.6	0.4

Table II, N:o 15 gives the average of these determinations, showing the approximate mode of the analyzed rock.

C o r d i e r i t e g n e i s s. — In the schist zone east of Lake Katumajärvi cordierite-bearing varieties occur in close connection with the leptites. In these rocks light eyes are observed, consisting mainly of cordierite grains. These eyes are surrounded by the granoblastic leptitic material containing biotite, feldspar and quartz. Some almandite crystals are met with also in this rock variety.

The rocks described above are very similar to the rocks occurring in the Orijärvi region of Southwestern Finland and in many parts of Central Sweden. Eskola (1914) has described these rocks as magnesia-metasomatic alteration products of the supercrustal rocks, especially of leptites. The same opinion has been put forward by Geijer (1916) in his study of similar rocks in Sweden.

The above-mentioned opinions hold that the magnesia has been carried by the ichors from places outside the rock complex. According to the studies made in Finland and Sweden the magnesia metasomatism stands in close connection with the synkinematic intrusions of the Svecofennidic orogeny. Some authors (Wegmann and Kranck 1931, Magnusson 1936 b, S. Gavelin 1939) have pointed out that during the migmatitization the magnesia is very mobile. Recently J. Bugge (1943) in Norway assumes that the anthophyllite-cordierite-bearing rocks in the Kongsberg-Bamble formation have originated during the period of migmatitization through leached material originated from gabbros and amphibolites containing magnesia. A lively discussion on the iron-magnesia metasomatism is going on in England (Doris Reynolds 1947 and Tilley 1947) caused by Doris Reynolds having published a reinterpretation of the iron-magnesia metasomatic rocks in Cornwall, pointing out that their origin is due to widespread basification and solid diffusion »in a frontal zone in advance of the main theatre of granitization».

The cummingtonite-, anthophyllite-, almandite- and cordierite-bearing rocks occur in the Aulanko area in a schist zone containing different kinds of volcanic rocks. Predominant among the volcanics are basic and intermediate types. Anthophyllite-cordierite rock in the Aulanko area shows a chemical composition (Table II, N:o 15) which is not usual among the igneous and sedimentary rocks. The composition is characterized by the low content of CaO, Na_2O and K_2O and high content of FeO and MgO. The high content of SiO_2 in the analyzed rock, together with certain unusual other components, shows the abnormal character of the rock. It seems evident that the decrease of CaO, Na_2O and K_2O has occurred in the primary rock. On the other hand the FeO- and MgO-amounts of the analyzed rock are but little higher than those of the most basic volcanics (see Table II). The composition does not, however, represent the most mafic types of the anthophyllite-cordierite rocks and the content of FeO and MgO is lower in the common types of the volcanics. Therefore, it seems evident that the FeO- and MgO-content has increased in the primary rock and that the rocks discussed have originated by magnesia metasomatism.

A very characteristic feature among the magnesia-metasomatic rocks in general is that they are closely connected with sulphide ores. Also in the Aulanko area a small pyrite impregnation in the magnesia-metasomatic rocks is commonly met with. In some cases also minute grains of chalcopyrite occur. Arsenopyrite—mentioned by Tigerstedt (1888) — has not been observed by the present author. Tourmaline, mentioned also by Tigerstedt in the rocks of the neighbourhood of Kappola farm, is met with only in minute part in connection with the small quartz veins. South of Lake Matkalampi in a small outcrop one quartz-rich variety similar to the metasomatic sericite schists occurs containing a minute pyrite impregnation. This rock type represents a metasomatic rock originated in the PT-conditions of the low-temperature facies.

The basic volcanics in the Aulanko area have altered in connection with magnesia metasomatism into cummingtonite amphibolites. In this process the composition of the primary rock has not been greatly altered. Only primary hornblende has altered into cummingtonite, but the plagioclase has not been attacked. The magnesia metasomatism, being more effective in the basic rock, produces cummingtonite-almandite amphibolites. In some cases also almandite-anthophyllite amphibolites occur. In the Aulanko area pure anthophyllite amphibolites have not been found, but anthophyllite always occurs together with almandite or cordierite. Cummingtonite-almandite amphibolites and almandite-anthophyllite amphibolites are very similar to the almandite-gedrite-cummingtonite amphibolites met with in Kalvola and described by Eskola (1936 b). In the Aulanko area, however, monoclinic and rhombic amphibole do not in general occur together, only in one cordierite- and plagioclase-bearing rock are anthophyllite and cummingtonite found together and form a homoaxial intergrowth. The origin of the almandite-bearing cummingtonite and anthophyllite amphibolites is similar to that of the Kalvola rocks. According to Eskola, the gedrite-cummingtonite-almandite amphibolite in Kalvola has originated by iron-magnesia-metasomatic processes taking place in basic volcanics. In the Kalvola region also a rock is found consisting of labradoritic·plagioclase and cummingtonite. This rock is very similar to the cummingtonite amphibolite in the Aulanko area.

The basic plagioclase is generally very able to withstand the magnesia-metasomatic processes. The appearance of cordierite in the amphibolitic rocks shows, however, both that the plagioclase amount decreases and that the gradual decrease of plagioclase through the crystallization of cordierite finally causes the origin of the anthophyllite-cordierite rocks without plagioclase. The anthophyllite-cordierite rock in the Aulanko area is the final product of the magnesia metasomatism.

In the leptitic rocks of the Aulanko area cordierite has originated in the first phase of metasomatism. Other types of magnesia-metasomatic rocks of the acid volcanics have not been met with in the area. According to the studies of other writers, especially by Eskola (1914), it is evident that anthophyllite-cordierite rocks can originate also through magnesia metasomatism of the leptites. The studies carried out by Tilley (1937) and J. Bugge (1943) show that anthophyllite-cordierite rocks are the final products of the magnesia metasomatism of different rock types.

Field observations concerning the contacts of the infracrustal rocks made in the Aulanko area and described before (p. 37) show that magnesia metasomatism is older than the crystallization of the synkinematic intrusions. On the other hand, magnesia-metasomatic rocks occur in a schist zone which is surrounded by synkinematic intrusions. It does not seem evident that the mobilization of magnesia has happened in connection with migmatitization caused by the younger granite. To the present writer it appears that the mobilization of magnesia has been caused by the intrusion of the synkinematic rocks, so that it is older than the crystallization of the synkinematic granodiorites. It is very difficult to decide whether the material added in metasomatism has been a primary component of the synkinematic granodiorite or whether it has leached from the basic rocks. It seems, however, credible that the magnesia metasomatism and the intrusion of the synkinematic rocks stand in close connection with each other.

GRANITIZATION.

In the Aulanko area granitization is not so common as in Southern Finland in general. In the Aulanko granodiorite, however, a gradual passing into microcline-rich varieties is observed. The field observations and the microscopical data described below show that this gradual change is due to the granitization caused by secondary increase of alkalies, especially of K_2O. It is most remarkable that some features of the primary texture of the granodiorite are seen in the granitized rock.

This gives a possibility of following the different degrees in the process of granitization.

The granitization of the Aulanko granodiorite is best seen northeast of Hämeenlinna. The first sign of the granitization is the occurrence of a thin red-coloured tissue containing microcline, plagioclase and quartz between the coarse-grained crystals of the granodiorite. With increase of a granitic fabric the amount of the primary hornblende decreases and alters into biotite. In the most granitized types the hornblende is lacking, but groups of biotite, which are probably relics of the primary hornblende, have been met with. During granitization the biotite-amount has also decreased. The rock has become poorer in its mafic components. The primary zoned plagioclase becomes more albitic during the granitization, but the primary appearance has been preserved and it is observed also in the varieties which do not contain hornblende.

In the granitized rocks thin, fine-grained, aplitic veins which show indistinct boundaries against the granitized rock are observed. Probably these veins represent the concentrated supplies of the ichor causing the granitization. According to the microscopical data, the petrographical properties characteristic of these veins are very similar to those of the aplitic variety of the microcline granite (p. 34). In the Aulanko granodiorite also pegmatitic veins rich in microcline occur. These have always sharp contacts and they penetrate the granitized granodiorite. The pegmatitic veins have not caused the granitization and they are younger than the aplitic veins which stand in close connection with the granitization.

The effect of the granitization is also observed in the dark, more basic inclusions characteristic of the Aulanko granodiorite. With increase of alkalies in the granodiorite the porphyroblasts of microcline in the basic inclusions appear and so-called mortar texture is observed. In connection with the granitization the amount of the basic inclusions decreases and the boundaries between the inclusions and the granitized granodiorite become unclear. Basic inclusions have not been observed in the granitized varieties in which all hornblende of the granodiorite has disappeared.

N:o 16 in Table II shows an analysis of a slightly granitized granodiorite. Already megascopically it is observed that the textural relations between coarse-grained crystals of the plagioclase, hornblende and quartz are quite similar to those in the Aulanko granodiorite. The rock has, however, a red-coloured fine-grained fabric between the primary coarse-grained individuals (Fig. 16). The mineralogical composition is very similar to that of the Aulanko granodiorite.

N:o 17 in Table II gives the composition of a specimen taken south of Lake Aulangonjärvi. In this rock the amount of the hornblende is very small and the zoned plagioclase individuals are surrounded by the secondary fine-grained microcline-granitic fabric (Fig. 17).

Fig. 16. Slightly granitized granodiorite of Aulanko showing the fine-grained fabric between the primary coarse-grained individuals of granodiorite. National park Aulanko. 7 x.

Fig. 17. Granitized granodiorite of Aulanko. Big zoned crystals are regarded as texture relics from the primary mode of occurrence. S. of Lake Aulangonjärvi. 7 x.

Plagioclase occurs as big zoned crystals which are relics of the primary granodiorite. Plagioclase occurs also in the fine-grained fabric. The composition of plagioclase is, according to the determination in U-stage, An_{23-25}.

Quartz occurs as big and as minute grains. The big grains are probably relics of the primary rock.

Microcline is met with only in the fine-grained mass.

Biotite is very ragged. It contains pleochroic haloes and it has altered into chlorite. In connection with mafic minerals sphene occurs.

As alteration products of plagioclase epidote and sericite are met with.

Apatite and iron ore occur as accessory minerals.

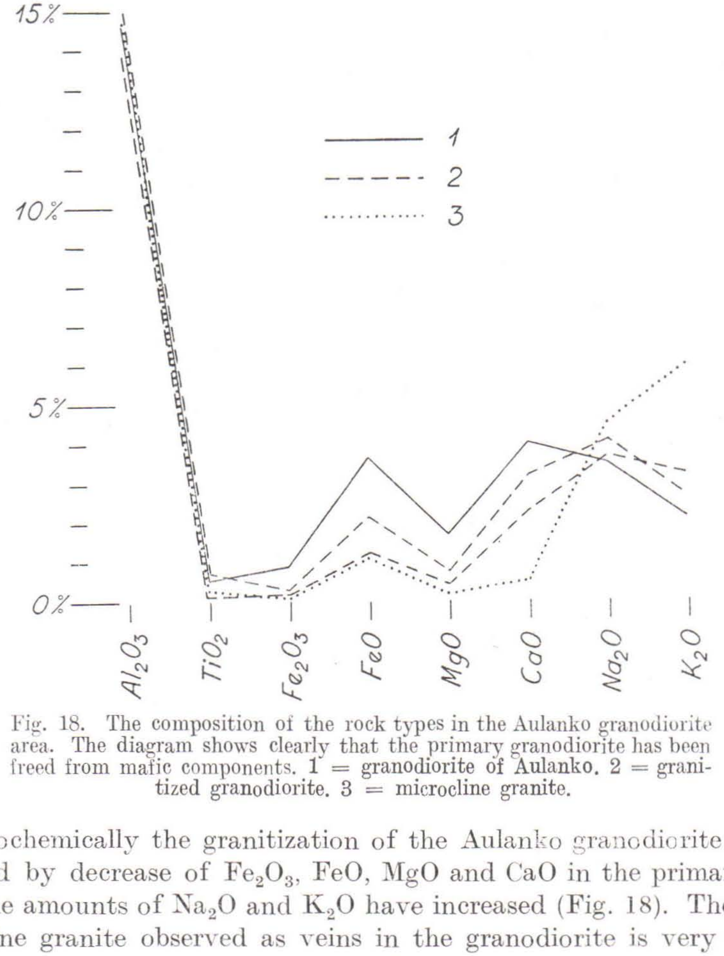

Fig. 18. The composition of the rock types in the Aulanko granodiorite area. The diagram shows clearly that the primary granodiorite has been freed from mafic components. 1 = granodiorite of Aulanko. 2 = granitized granodiorite. 3 = microcline granite.

Petrochemically the granitization of the Aulanko granodiorite is characterized by decrease of Fe_2O_3, FeO, MgO and CaO in the primary rock, while the amounts of Na_2O and K_2O have increased (Fig. 18). The aplitic microcline granite observed as veins in the granodiorite is very poor in mafic components and rich in alkalies. Therefore it seems credible that granitization has taken place by means of this kind of »emanation», having the character of a granitic pore magma.

To illustrate the regional granitization in the Aulanko granodiorite area the writer has carried out a group of alkali determinations presented in Figs. 19 and 20. In the granitization of the granodiorite especially the

K_2O-amount increases and the content of this gives an idea of the degree of granitization. Fig. 19 shows that the granitization is most predominant in the region of Lake Aulangonjärvi. Probably the ichor causing the granitization has pushed forward most easily in the boundary zone of two rock types, which has assuredly been a weak point in the rock crust. Fig. 20 shows that the granitization is always marked by increase of both Na_2O

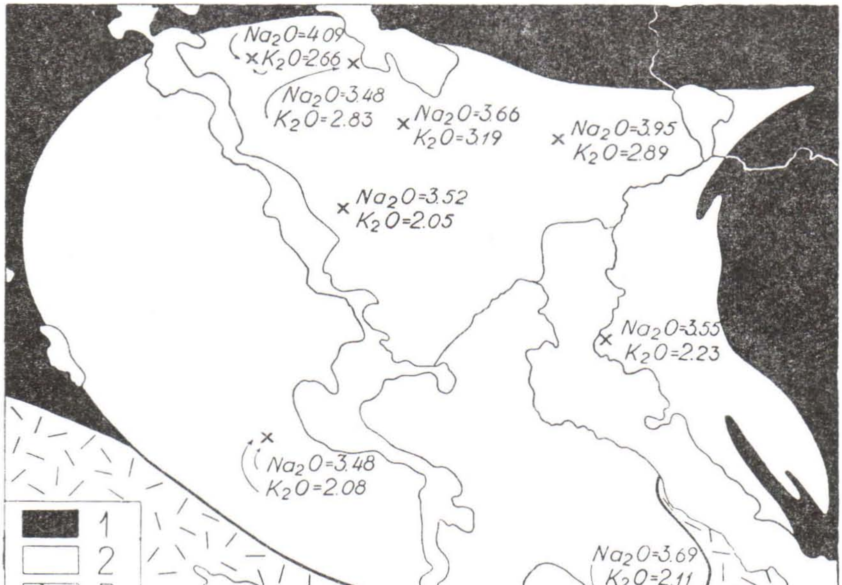

Fig. 19. Alkali determinations in the granodiorite area of Aulanko. 1 = supercrustal rock. 2 = granodiorite of Aulanko. 3 = microcline granite.

and K_2O and makes clear that the granitization has happened inhomogeneously, showing that the relation between increase of Na_2O and K_2O is variable. In some cases the granitization is characterized mainly by the increase of K_2O; in other cases again the Na_2O-amount has increased remarkably also in the primary rock.

The observations described before show that during the granitization migration of material has taken place. Especially the amount of microcline has increased secondarily. The process of granitization has happened metasomatically, so that primary components of the rock have gradually given place to new minerals. Apparently the reactions have happened in the intergranular film of the mineral grains, in accordance with the ideas presented by Wegmann (1935).

The increase of alkalies in the primary rock shows that the ichor causing the granitization has been rich in components usual in typical granites. Some aplitic microcline granite veins occurring in the granitized granodiorite give the idea that just this kind of granite has caused the granitization. Of the physico-chemical conditions during the granitization it is very difficult to speak. It seems to the author that the granitic material causing the granitization has been granitic pore magma originated by differential anatexis (Eskola 1933). This kind of granitic magma, especially

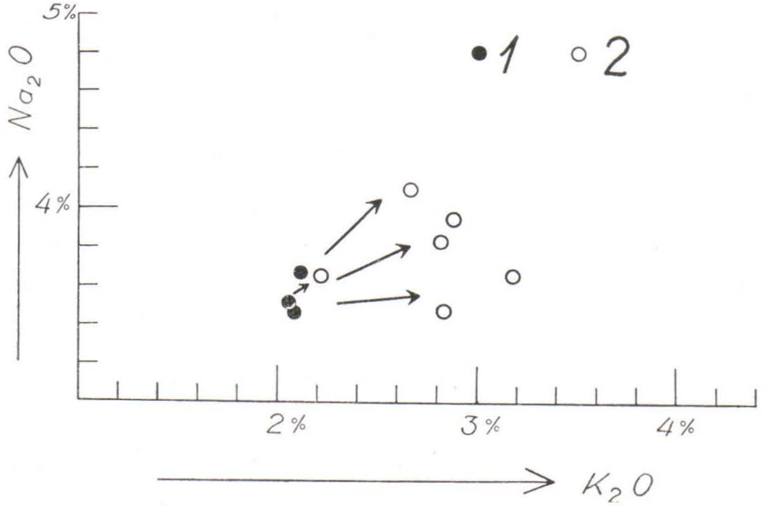

Fig. 20. Diagram showing the alkali-ratio in the rocks representing the various stages of the granitization. 1 = granodiorite of Aulanko. 2 = granitized granodiorite.

rich in alkalies, has penetrated metasomatically the primary rock which has been in the solid state.

Many studies carried out in the migmatitic rocks of Southern Finland indicate that the palingenic microcline granitic magma has played a significant rôle in the granitization process. Palingenic pore magma has originated in the depths of the earth especially from the primary rocks containing abundance of the same components as microcline granites. In some cases this magma shows a purely magmatic mode of occurrence, penetrating older rocks as sharp-boundaried veins and does not show replacement processes causing granitization. On the other hand, again, it metasomatically penetrates older rocks and causes granitization. This kind of granitic pore magma is certainly very mobile and forms thin tissues helping the replacement in the older rocks. The texture relics (well preserved drawings of the primary texture) of many granitized rocks give the idea that the amount of the granitic pore magma has not been great and that the rock under granitization has been in the solid state. Especially in the granitized basic rocks is it seen that new material from outside has come into the primary rock. This is seen also in the granitization of the Aulanko granodiorite.

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ALBITIZATION.

In the region of Lake Aulangonjärvi the metasomatic change has in some cases been connected with epidotization, so that the anorthite component of the plagioclase forms epidote. It is remarkable that the metasomatic process has exclusively the character of albitization. Already Väyrynen (1919) in his investigation on the rocks of the Aulangonjärvi region mentions that in connection with the origin of klinozoisite the amount of microcline decreases, and that at last all microcline has disappeared and the rock is characterized by the mineral paragenesis albite-epidote-chlorite.

The present author has discovered an extremely soda-rich rock on the slope of the hill by Aulanko belvedere. There an albite-rich rock of a thickness of some meters occurs as a lens in the granitized granodiorite of Aulanko and the boundaries against the later-mentioned rock are not sharp. The mode of occurrence shows clearly that there the albitic rock is younger than the granitization, because the albitization has taken place in the granitized rock. In the albitic rock there may be observed also some texture relics which show some properties typical of the Aulanko granodiorite. In some cases there are relics of the idiomorphic hornblende which have, however, altered mainly into epidote, biotite and chlorite.

Fig. 21. The albitic rock of the slope on the hill beside the Aulanko belvedere. 8 x.

Also shapes of the coarse-grained primary plagioclase are marked by groups of secondary epidote.

An analysis of the albitic rock near the Aulanko belvedere was carried out, representing the soda-extreme type (Table II, N:o 18). The micro-texture is seen in Fig. 21, showing the occurrence of albite as bunches of radial arrangement between the relics of the primary epidotized plagioclase grains.

The plagioclase is pure albite of the composition An_{2-3} according to the optical determination in the U-stage. It occurs as two different modes; the one together with epidote as a relic of the primary plagioclase and the other as radial bunches which have crystallized from new material added during the metasomatism. The albite contains hematite pigment giving the rock a red colour.

Quartz occurs sparsely, forming also two kinds of grains. Some bigger quartz grains seem to be relics from the primary rock and some minute individuals with well developed crystal faces have crystallized in connection with the soda metasomatism.

Epidote occurs as alteration products of the primary minerals in the rock. The anorthite component of the primary plagioclase forms epidote. Some mineral groups containing chiefly epidote and biotite without albite are also to be seen. Probably these are pseudomorphs after the primary hornblende.

Biotite is dark and very ragged.

Chlorite occurs only in minute amount.

Apatite is present as an accessory mineral and hematite occurs as pigment.

In the region of Lake Aulangonjärvi some types of albitic rocks are observed in which the albitization has not gone so far as in the above-mentioned rock. The main petrographical points concerning these rocks are given already in the investigation of Väyrynen (1919) and the present author will give only the main facts of observations.

Albitic rocks in which the albitization has taken place without addition of soda in the primary rock occur for instance on the cape at the southern end of Lake Aulangonjärvi. The primary textural features of the Aulanko granodiorite are clearly seen (Fig. 22) and only big grains of primary plagioclase have altered into epidote and albite. This variety contains also abundance of microcline added during granitization and occurring between the altered grains of plagioclase.

Northeast of Lake Aulangonjärvi there are epidote-bearing rocks in which albitization has not occurred in connection with the origin of epidote. Gneissose granodiorite has been brecciated and epidote occurs as filling between unaltered plagioclase (An_{26}). This mode of occurrence of epidote gives the impression that epidote material has come secondarily into the rock.

Soda-extreme albitic rock shows both chemical and mineralogical similarities to albite-epidote rocks, so-called helsinkites (Laitakari 1918). New opinions on the helsinkite problem have been presented by Mellis (1932). According to his investigation the helsinkites are not magmatic crystallization products, but hydrothermal processes have played a predominant rôle in their origin. In the soda-extreme rock of Aulanko the metasomatic origin by hydrothermal and replacement processes through secondary addition of soda is quite clear, because there are to be seen the relics of the primary granodiorite in which the metasomatism has taken place. The present author considers the granitization and albitization in the Aulanko area to be closely related processes. The granitization has

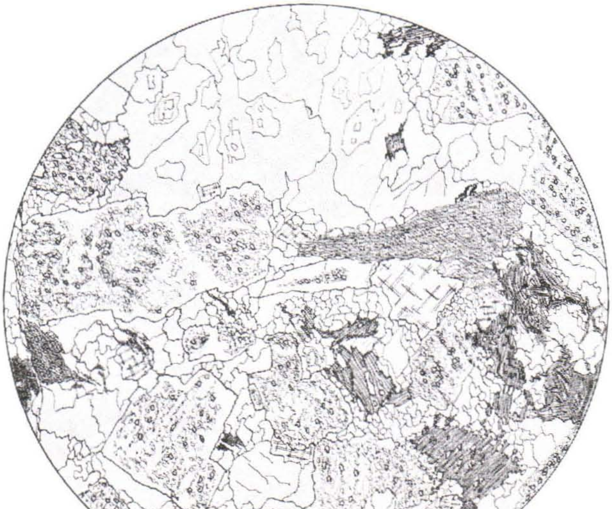

Fig. 22. Epidote-albite rock showing texture relics of the Aulanko granodiorite. Primary plagioclase has altered into epidote and albite. Between bigger plagioclase grains a granitic fabric occurs. The cape at the southern end of Lake Aulangonjärvi. 7 x.

taken place by granitic pore magma rich in alkalies and albitization has been caused by soda-rich hydrothermal solutions of the same magma. The relation between magma and water-rich solution is very close and the line between magmatic and pneumatolytic or hydrothermal processes or the processes taking place in the solid state (intergranular film) cannot always be drawn in practice.

In his investigation concerning the coast region of Southern Finland Kranck (1931) has pointed out the close relationship between the pegmatites of coast granites and helsinkites. According to Kranck the hydrothermal solutions have been carriers of epidote material and these solutions have altered the plagioclase of the pegmatites into albite. In the soda-extreme albite-epidote rock of Aulanko the CaO-amount has in connection with metasomatic processes become lower than in the primary granodioritic rock. Apparently the hydrothermal solution causing the metasomatism has not in this case been the carrier of epidote material, but the latter has originated only from the anorthite component of the primary plagioclase, as is clearly seen also from the mode of occurrence of the epidote.

Albitization does not necessarily play a rôle in the origin of all helsinkites, as is pointed out by Kranck (1931) and Mellis (1932). The above-mentioned authors have drawn attention to the micro-breccia texture of helsinkites and have shown that epidote has crystallized in the cracks without metasomatic processes and that it can also take place in the rocks containing predominantly potash feldspar. In cases of this kind the hydrothermal solutions have apparently been the carriers of epidote material. Epidote can be present also in some hydrothermal pegmatites (Fersman 1931 p. 70). In the Aulanko area the epidote-bearing rocks northeast of Lake Aulangonjärvi, showing breccia texture and lacking the signs of metasomatic changes, have originated through crystallization of epidote from hydrothermal solutions.

The origin of the helsinkites can take place also by autohydrothermal metasomatism through residual liquids of magmatic differentiation, as described by Eskola (1934 p. 126). In the Aulanko area we find some albite-epidote rocks in which the bulk composition of the primary rock has not changed during the helsinkitization; only autometamorphic processes have taken place, causing the alteration of plagioclase into epidote and albite. This change has occurred by means of secondary water-rich solution circulating in the solid rock.

It is apparent that helsinkites originate by hydrothermal solutions, but that there occur differences caused by the intensity of albitization. To illustrate the chemical side of the helsinkite problem, the present author has plotted the normative relations of the analyzed Fennoscandian helsinkites (unakites) in the Ab : Or : An diagram (Fig. 23). The points plotted cover a wide field, showing the inhomogeneity of the chemical composition of helsinkites. The points (1—3 and 12) near the albite corner represent the varieties in which the helsinkitization has been connected with metasomatic addition of soda. In other instances again the increase of Na_2O has not played a predominant rôle. The helsinkite of Aspetorp shows different varieties, so that more albitic rock occurs as streaks in the microcline-rich helsinkite. Probably the albitic rock represents those parts of the helsinkite in which the metasomatic addition of soda has been more effective. In the porphyries of the Baltic the helsinkitization has consisted of autohydrothermal alteration (Eskola 1934) without addition of soda from outside. The analyzed albitic rock of Aulanko clearly shows the great increase of soda in the primary rock.

It seems probable that granitization and albitization in the Aulanko area have been caused by the origination of microcline granite, however, so that granitization is older than albitization. Perhaps the fractionization of alkalies into different kinds of solutions has occurred. According to the observations of Wegmann and Kranck (1931) the granitization has taken place also before the helsinkitization, but both stand in close relationship to the microcline granite of coast type. The fractionization of alkalies has been discussed by Magnusson (1937 p. 544) concerning

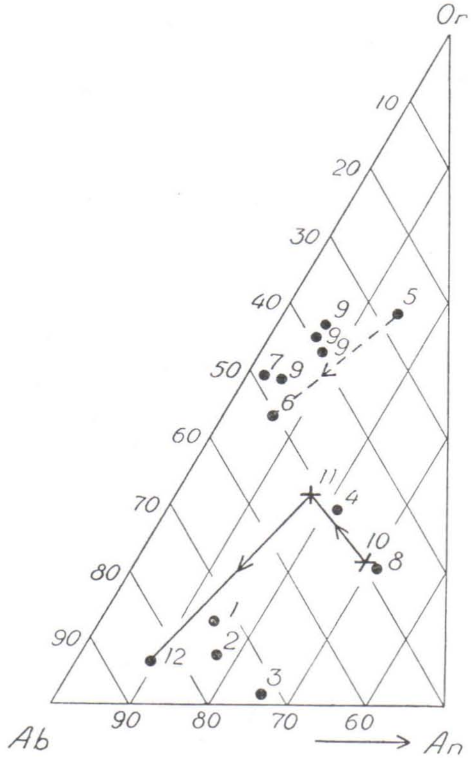

Fig. 23. The normative relations of Ab : Or An in the Fennoscandian helsinkites. The numbers plotted represent the following rocks:
1. Soda syenite. Räsy. Oulainen. Mäkinen (1916 p. 73).
2. Soda syenite. Räsy. Oulainen. Mäkinen (1916 p. 74).
3. Helsinkite. Suursaari. Laitakari (1918 p. 6).
4. Helsinkite. Alfta. Eckermann (1925 p. 508).
5. Microcline-rich helsinkite. S. of Aspetorp. Asklund (1925 p. 41).
6. Fine-grained helsinkite forming small streaks in the microcline-rich helsinkite. S. of Aspetorp. Asklund (1925 p. 42).
7. Unakite. Ollikkaanvuori. Haapavesi. Wilkman (1928 p. 11).
8. Epidote-rich unakite. Naistenkallio. Haapavesi. Wilkman (1928 p. 13).
9. Porphyries of the Baltic. Glacial boulders. Eskola (1934 p. 114).
10. Granodiorite of Aulanko. Myllymäki. Table II, N:o 9.
11. Granitized granodiorite of Aulanko. Table II, N:o 17.
12. Albitic rock of Aulanko. Table II, N:o 18.

the palingenic granites of Central Sweden and he mentions a contradictory behaviour, so that soda precedes potash in the metasomatic processes. The studies of the orbicular rocks (Eskola 1938 b; Simonen 1940) show that during the metasomatic replacement processes the potash and soda metasomatism often alternate with each other. Usually, however, the replacement has begun as soda metasomatism producing an esboitic rock.

SOME TRACE ELEMENT DETERMINATIONS.

In order to complete the results arrived at by the petrographical study, the author has carried out some trace element determinations of the rocks in the Aulanko area. The most typical and chemically studied representatives of the different rock groups have been selected for this. The material employed is seen in Table V and rock analyses of these specimens are presented in Table II.

In the material studied (Table V) numbers 1—5 represent the rocks of synkinematic intrusions in the Svecofennidic orogeny. 6—7 are slightly granitized varieties of the Aulanko granodiorite. 8—9 belong to the younger, late-kinematic intrusions. 10—12 represent volcanic schists and 13—14 sedimentary rocks having a clayey composition. 15—16 are metasomatically altered rocks.

CHLORINE AND FLUORINE.

The chlorine was determined gravimetrically as silver chloride according to the method given in the hand-book of Groves (1937). Besides the gravimetrical method, the observation of that turbidity which appears when silver nitrate is added to solution has been used as a control. This turbidimetric method is very serviceable if the content of chlorine is lower than 0.03 per cent. Fluorine was determined colorimetrically by standard titanium solution according to the method developed by Merwin (see Groves 1937). The results of these determinations are seen in Table V.

Table V. Chlorine, fluorine and rubidium content in the rocks of the Aulanko area.

		Number of rock analysis in Table II	Cl %	F %	Rb_2O %
1	Diorite	8	0.07	0.03	0.03
2	Gneissose granodiorite	7	0.04	0.06	0.04
3	Dark basic inclusion in the Aulanko granodiorite	10	0.10	0.02	0.10
4	Granodiorite of Aulanko	9	0.08	0.02	0.04
5	Rand facies of granodiorite	12	0.03	0.02	<0.01
6	Granitized granodiorite of Aulanko	16	0.04	0.01	0.04
7	Granitized granodiorite of Aulanko	17	0.03	0.01	0.05
8	Aplitic microcline granite	13	0.02	<0.01	0.14
9	Muscovite-bearing microcline granite	14	0.04	0.03	0.19
10	Uralite porphyrite	1	0.03	<0.01	<0.01
11	Plagioclase porphyrite	2	0.03	0.02	0.02
12	Intermediate tuffitic rock	3	0.02	0.02	0.02
13	Cordierite mica schist	5	0.01	0.07	0.06
14	Cordierite-andalusite mica schist	6	0.02	0.06	0.07
15	Albitic rock	18	0.01	0.01	<0.01
16	Anthophyllite-cordierite rock	15	0.01	<0.01	0.00

In the synkinematic intrusions the amount of chlorine is greatest in the more basic members. The average chlorine content of all the granodiorites and granites in the Aulanko area is about 0.04 per cent.

In the volcanics the amount of chlorine is lower than in the infracrustal rocks showing a similar bulk composition. The reason of this is either the exhalation of chlorine during volcanic processes or metamorphism owing to the driving out of the most volatile substances.

Very remarkable is the low chlorine content (0.01—0.02 per cent) in the mica schists representing the originally clayey sediments. This shows that in the weathering process the greatest part of chlorine of the rocks has been dissolved and carried into sea water.

In the metasomatic processes (granitization, albitization and magnesia metasomatism) the chlorine content of the primary rocks has decreased.

As regards its geochemical nature, the behaviour of fluorine is very different to that of chlorine. In the diorite the amount of fluorine is lower than in the gneissose granodiorite. The average fluorine content of all granodioritic and granitic rocks in the Aulanko area is about 0.02 per cent.

No great deviations in the fluorine content have been observed in the different varieties of the rocks in the Aulanko granodiorite. This content is very similar, both in the dark inclusion and in the granodiorite. The writer has put forward the opinion (p. 31) that the basic inclusions have been altered by the metasomatic processes caused by the residual liquids of the granodiorite. Fluorine has probably enriched in the residual liquid, and in connection with late-magmatic metasomatic processes the primary fluorine content of the basic inclusion has become higher and the difference in this relation between the inclusion and the matrix has disappeared.

The fluorine content of the younger microcline granites differs greatly. Muscovite-bearing granite naturally contains fluorine in the mica lattice, but the aplitic type of microcline granite is free from it.

The basic volcanics have a very low content of fluorine, but in the mica schists it has clearly been concentrated. The enrichment of fluorine in the original clay sediments is to be understood so that it has on the one hand an inclination to take place in the lattices of the different clay minerals, and on the other hand mica minerals containing fluorine are able to migrate unweathered into the clayey sediments.

The fluorine content of the primary rock has decreased by the granitization. This is well explained by the fact that the granitization has occurred by means of aplitic microcline granite free from fluorine. Also in the other metasomatic processes the amount of fluorine has decreased, showing behaviour similar to that of chlorine.

The quantities of chlorine and fluorine in the silicate rocks are insufficiently known. For comparison of own results with earlier determinations the writer has selected all chlorine and fluorine determinations, made in the calc-alkalic eruptive rocks, from the following tables of analyses: Washington 1917; Larsson 1933; Lokka 1934; Munck and Noe-Nygaard 1942. The results are presented in Figs. 24 and 25, showing the dependence of chlorine and fluorine content on the SiO_2-amount in the calc-alkalic rocks. The above-mentioned tables of analyses do not, however, contain any chlorine and fluorine determinations giving an idea as to the distribution of these elements in the different sedimentary rocks.

Figs. 24 and 25 show that the content of chlorine is greatest in the more basic members of the calc-alkalic rocks and that fluorine has strongly concentrated in the granitic rocks. These conclusions harmonise very well with the results presented by the writer. In the effusive rocks the

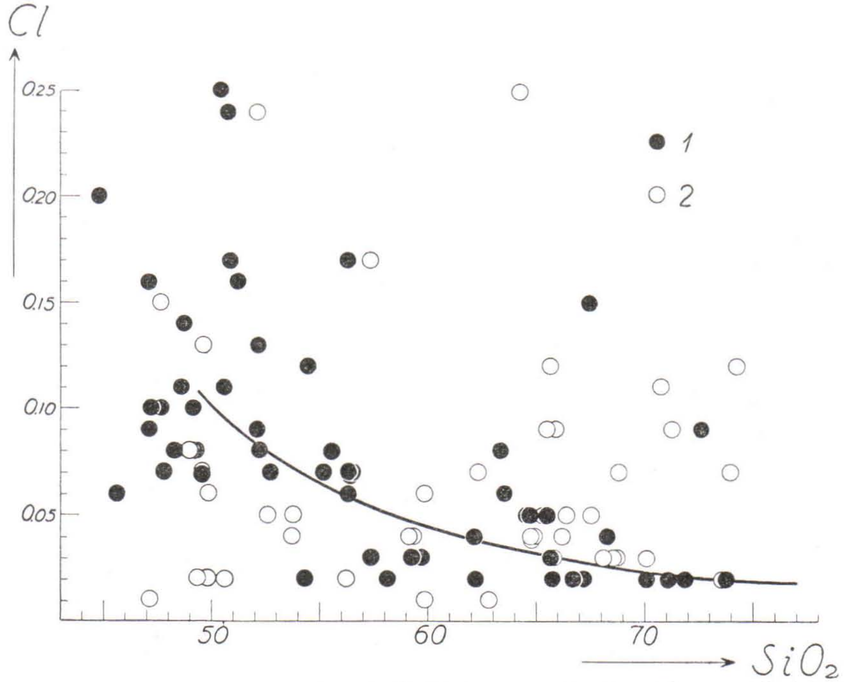

Fig. 24. Chlorine content in the calc-alkalic igneous rocks. 1 = Cl-amount in infracrustal rocks. 2 = Cl-amount in volcanic rocks.

content of chlorine and fluorine is not so regular as in infracrustal rocks, this depending on the great variations of the volatile substances. According to the fluorine determinations presented by Shepherd (1940 p. 128) the obsidians have a tendency towards a fluorine concentration of 0.10 per cent, while the lavas tend towards 0.01 per cent.

To obtain an idea as to the chlorine and fluorine content in the rock crust of the Aulanko area the author has calculated averages by means of all determinations carried out. These values are presented in Table VI and for comparison is given also the average content of the elements discussed, as determined by Clarke and Washington (1924). The average content of chlorine and fluorine in the Aulanko area shows values little lower than the averages presented by Clarke and Washington. The ratio between the elements is, however, very similar in both determinations. The averages presented by the chlorine and fluorine determinations made from the rocks in the Aulanko area do not give a sure value for the averages in the earth crust in general, because many samples examined are not typical of the rock crust as a whole. The values obtained illustrate only the regional distribution.

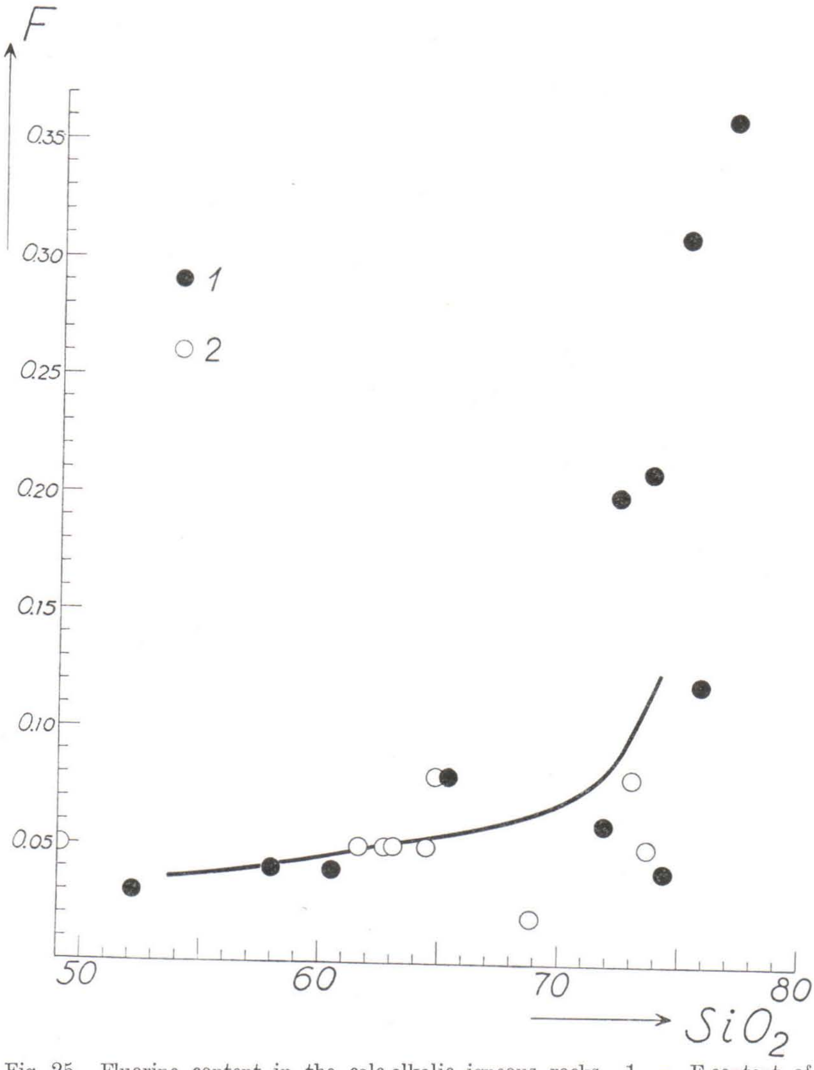

Fig. 25. Fluorine content in the calc-alkalic igneous rocks. 1 = F-content of infracrustal rocks. 2 = F-content of volcanic rocks. All determinations of rapakivi granites are not presented, but only the average content of EastFenno-scandian rapakivis (Sahama 1945 b).

Table VI. The average content of chlorine and fluorine in the Aulanko area and in the igneous rocks in general.

	Cl %	F %
Aulanko area	0.035	0.024
Igneous rocks (Clarke and Washington)	0.048	0.03

Apatite is the most remarkable carrier of chlorine in the igneous rocks. According to Kind (1939) chlorine has concentrated especially in the apatites of the basic rocks; fluorine again has enriched in the apatites of the acid members of magmatic crystallization. These results are in very good harmony with the geochemical distribution of the discussed elements in the magmatic rocks.

Fluorine occurs mainly in the igneous rocks in the minerals containing water in their lattices, as in micas and amphiboles. In some cases fluorine occurs in the granitic rocks also in the form of fluorite, and the fluorine content is then usually very high. This is the case *e. g.* in the rapakivi granites, which contain fluorite as a typical accessory mineral. The average fluorine content of rapakivi granites is 0.36 per cent (Sahama 1945 b); this is certainly greater than is usual in the granitic rocks.

RUBIDIUM AND CAESIUM.

The rubidium and caesium content was determined spectrographically by a method used earlier in the Geochemical Laboratory of the Helsinki University (Erämetsä, Sahama and Kanula 1943). The photometric determination of rubidium was made by help of the lines Rb 7800.30 and Ba 7780.50. Caesium was determined only visually from the line Cs 8521.15. The results of the determinations are presented in Table V.

The geochemistry of rubidium and caesium, made clear by Goldschmidt and collaborators (1933 and 1934), shows that these elements are typical representatives of the late-magmatic crystallization. This fact is only incompletely revealed in the rubidium determinations of the magmatic rocks in the Aulanko area. The caesium content in the rocks examined is generally lower than 0.001 per cent of Cs_2O.

The rock types of the Aulanko granodiorite area show at first sight a behaviour contradictory to the general geochemical laws of the elements discussed. The dark basic inclusion contains 0.10 per cent of Rb_2O and the line of caesium is very clear. The petrographical study of the basic inclusion given earlier (p. 31) shows, however, that this rock has altered metasomatically, forming biotite. According to the author, biotitization has been caused by late-magmatic material of the granodioritic magma. The K_2O-amount has greatly increased and in connection with this rubidium and caesium have found a place in the lattice of biotite, which is a remarkable carrier of these elements.

The rubidium content of the younger microcline granites is higher than that of the synkinematic intrusions. The average rubidium content of the microcline granites in the Aulanko area is 0.16 per cent of Rb_2O. This is similar to that of the Hangö granite (0.16 per cent of Rb_2O determined by Erämetsä, Sahama and Kanula 1943) which is a typical representative of the late-kinematic intrusions of the Svecofennidic orogeny.

In the Aulanko granodiorite the rubidium content is 0.04 per cent of Rb_2O. This is very similar to the rubidium content of the oligoclase granite of Orijärvi (0.03 per cent of Rb_2O according to Erämetsä, Sahama and Kanula 1943) which is the most typical representative of the synkinematic intrusions in Southwestern Finland.

From the above-mentioned studies of Goldschmidt and his collaborators it is known that the discussed elements are indicators of adsorption by the sedimentary processes in sea water. The two determinations of the mica schists give as results 0.06 and 0.07 per cent of Rb_2O. These values are very similar to the content in the Al-rich schists of Southern Lapland discussed by Sahama (1945 a) and show that rubidium has adsorbed in hydrolysatic sediments.

The rubidium determinations of the granitized granodiorite of Aulanko show only a slight enrichment in rubidium in connection with potash metasomatism. In the albite-rich rock the rubidium line is very weak and in the rock developed by the magnesia metasomatism rubidium is entirely lacking.

VISUAL DETERMINATIONS BY THE SPECTROGRAPH Qu_{24}.

By the spectrograph Qu_{24} the content of the following elements was visually determined: nickel, cobalt, germanium, lead, gallium and beryllium.

Nickel and cobalt. In the synkinematic intrusions the CoO-amount is about 0.001 per cent and the NiO-content is a little lower. The microcline granites are quite devoid of Ni and Co. Uralite porphyrite shows the highest content (NiO = 0.002 per cent and CoO = 0.003 per cent). In the hydrolysatic sediments the content of NiO and CoO is about 0.001 per cent.

The germanium content of all specimens is lover than 0,001 per cent of GeO_2

Lead. The amount of PbO is usually lower than 0.001 per cent. In the muscovite-bearing microcline granite the PbO-content is 0.003 and in the aplitic microcline granite as high as 0.01 per cent.

Gallium is present in all specimens. The content of Ga_2O_3 varies between 0.001—0.003 per cent.

The beryllium content (>0.003 per cent of BeO) has been observed only in muscovite-bearing microcline granite and in the hydrolysatic sediments.

EVOLUTION OF THE ROCK CRUST IN THE AULANKO AREA.

According to the contact studies discussed before (p. 36) supercrustal rocks are the oldest formation in the Aulanko area. All supercrustal rocks belong to the same formation, but it has not been possible to make the intraformational stratigraphy clear by observations. The volcanic activity during the origin of supercrustal rocks has varied greatly. Especially in the eastern part of the area are textures of different kinds observed and lava beds occur intraformationally in the tuffitic rocks. During the volcanic period chemical weathering has taken place only in minute amount. This is shown by an intraformational kind of occurrence of cordierite mica schist west of Ilamo. The relation of the mica schist region in Alajärvi to the volcanic series is not quite clear, but the author considers that also this belongs to the same period as the above-mentioned rocks. Quartzites and limestones are lacking entirely in the Aulanko area.

The deformation of the supercrustal rocks has begun already before the intrusion of the synkinematic rocks (p. 36). The magnesia metasomatism in basic and intermediate volcanics has probably taken place in close connection with the first folding.

Among the synkinematic intrusions the basic rocks are oldest. By field observations it is not possible to make clear in what degree the folding has taken place between intrusions of different synkinematic rocks. According to the results given above, the folding has continued also between and during the different kinds of intrusions. The folding has continued also after the intrusions of synkinematic rocks, and has given to these rocks a gneissose texture.

From the magmatectonical point of view the relation of the Aulanko granodiorite to the gneissose granodiorites is difficult to decide. According to the field observations presented before it seems that the Aulanko granodiorite belongs to the synkinematic intrusions, but the mode of the occurrence and the fact of the gneissose texture being found only in the boundaries points to an intrusion later than that of strongly gneissose granodiorite.

The folding has occurred in close connection with the intrusions of gneissose granodiorites. The folding and intrusions of synkinematic rocks occurred contemporaneously and geochronological classification of these processes is very difficult. The mountain-folding is a slow process which continues during periods in the history of the earth.

Every mountain-folding process is followed by late-kinematic intrusions. In the Aulanko area these have been represented by microcline granites, among which also different modes of occurrences are met with and these show that the evolution after deformation has been very complex. There occur two kinds of late-kinematic intrusions; one of migmatitic character, whereas the other has features indicating a rock crystallized from a coherent magma. Among pegmatites belonging to the late-kinematic intrusions also two kinds are observed: simple and complex pegmatites.

The most remarkable process connected with late-kinematic intrusions is the granitization, which has occurred mainly mechanically by the pushing forward of granitic material along planes of foliation, though sometimes again the granitization has taken place chemically by metasomatic processes between an older rock and granitic ichor. Albitization stands in close connection with granitization. These different metasomatic processes (granitization and albitization) show that the fractionization of alkalies has occurred during metasomatism.

The opinions given above on the evolution in the Aulanko area can be summarized in the following table:

	Intrusion of muscovite-bearing microcline granite and complex pegmatites Intrusion of migmatite granite, simple pegmatites and aplites	Albitization Granitization
Folding	Intrusion of the Aulanko granodiorite Intrusion of gneissose granodiorite Intrusion of gabbro	Magnesia metasomatism
	Supercrustal formation	

The results presented above have been obtained in a small area and these opinions do not generalize on the problems concerning all Svecofennidic formations. In the evolution of the rock crust in the Aulanko area have been observed, however, in rough outline similarities to the features in the coast region east of Helsinki described in detail by Wegmann and Kranck (1931). The most remarkable differences are the lack of greenstone dikes in the Aulanko area and the fact that the magmatic evolution in the synkinematic and late-kinematic intrusions is represented by more different types. In their main points the opinions on the evolution of Svecofennides in Finland and Sweden are very similar (Magnusson 1936 a) and naturally there occur also differences in different areas of Svecofennidic territory. Only by the help of detailed studies of Svecofennides carried out in many places can we obtain the material on which generalized conclusions must always be based.

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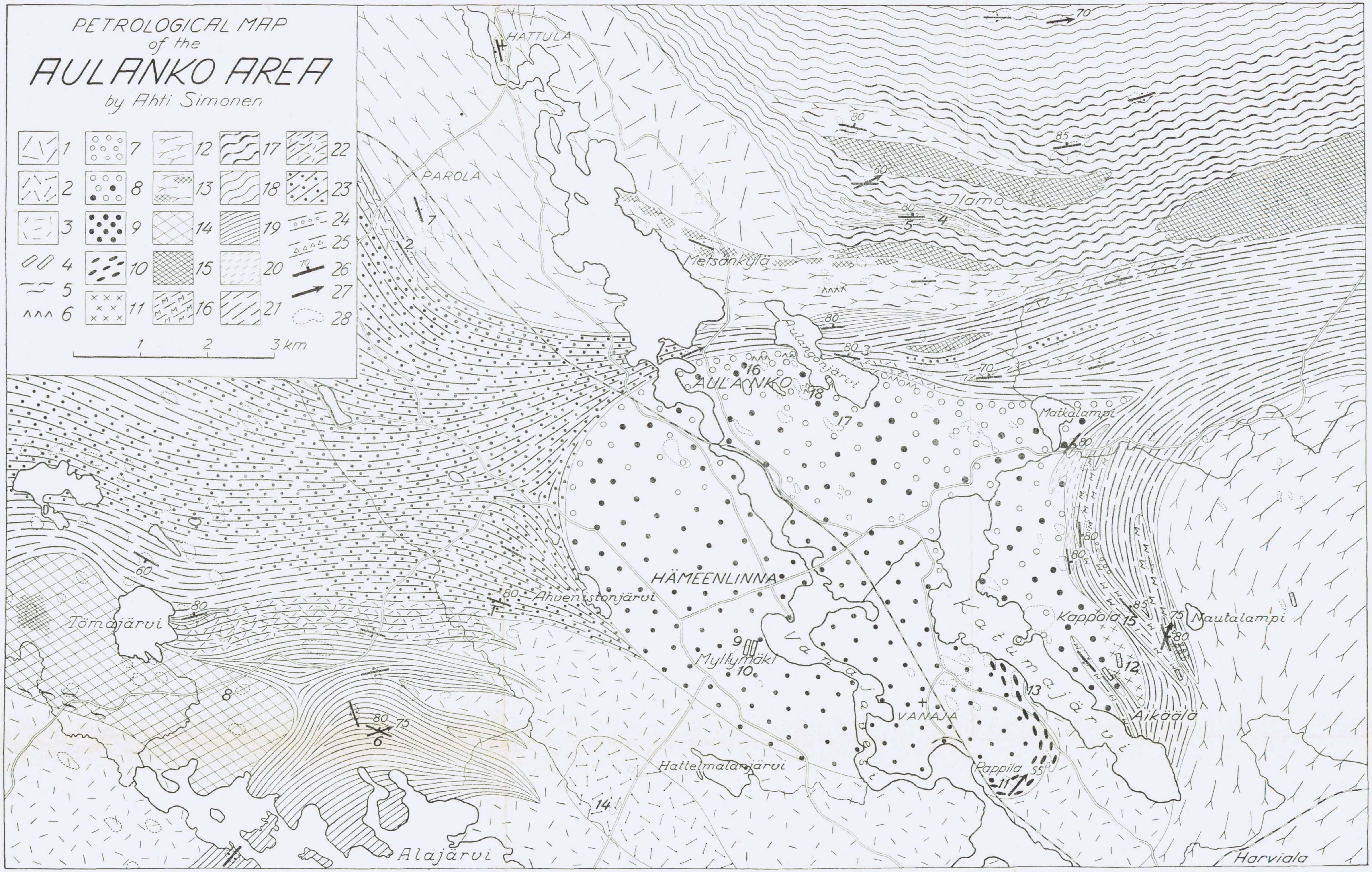

1 pegmatite
2 muscovite-bearing microcline granite
3 microcline granite
4 veins of microcline granite
5 migmatite
6 albite-epidote rocks
7 granitized granodiorite of Aulanko without hornblende
8 granitized granodiorite of Aulanko containing hornblende
9 granodiorite of Aulanko
10 gneissose variety of the Aulanko granodiorite
11 rand facies of the Aulanko granodiorite
12 gneissose granodiorite
13 gneissose granodiorite with gabbro inclusions
14 quartz diorite
15 gabbro
16 magnesia-metasomatic rocks
17 hornblende gneiss
18 mica gneiss
19 mica schist
20 leptite
21 intermediate and basic volcanics
22 plagioclase porphyrite
23 uralite porphyrite
24 amygdaloidal texture
25 agglomeratic texture
26 strike and dip
27 lineation
28 outcrop

The numbers (1—18) in the map refer to the analyses in Table II.