SUOMEN GEOLOGINEN TOIMIKUNTA | GEOLOGISKA KOMMISSIONEN I FINLAND

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N:o 107

ON MIGMATITES AND ASSOCIATED PRE-CAMBRIAN ROCKS OF SOUTHWESTERN FINLAND

PART III. THE ÅLAND ISLANDS

BY
J. J. SEDERHOLM †

WITH TWO MAPS AND 43 FIGURES IN THE TEXT

HELSINKI - HELSINGFORS
DECEMBER 1934

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PREFACE.

This paper is one of the last works of the late Professor J. J. Sederholm, who died on 26th of June 1934. The manuscript left for the paper had no title, and therefore we do not exactly know, whether it was intended to be published as an additional number in the series of the author's studies on migmatites, or as a more condensed description. It is, as compared with the two previous parts of the series, those dealing with the Pellinge and Barösundsfjärd regions, fairly short and concise, but the maps had obviously been prepared for a larger memoir. However, it seems to us most in accordance with the intentions of the late author to issue this paper as Part III of his series »On Migmatites and Associated Pre-Cambrian Rocks of Southwestern Finland».

The late Professor Sederholm also had material collected and plans ready for a fourth number of this series, in which he would have dealt with the Hangö area anew, in a more wide and general way. Apparently this was his thought when he wrote, in the preface to the second part: »We are therefore now able to give, at least preliminarily, some of the general theoretical conclusions to which our study has led, retaining their further elucidation and definite formation for later memoirs».

The task of bringing Professor Sederholm's manuscript in its final condition for printing was entrusted to the undersigned, because he, as Professor Sederholm's collaborator during the field work in Enklinge, was the geologist best acquainted with that particular area. The analyses, the figures, for most of which the author himself already had the plates made, and some of the local names have been inserted during this final editorial work. The undersigned also prepared the explanations to the figures. A chapter of »Concluding Remarks» would probably have completed this memoir, as in the case of the previous ones, had the authors work not been so prematurely interrupted.

The author himself had also compiled the accompanying maps, and they were already printed when preparations for printing of the manuscript were begun. Some small errors which had crept into these

could therefore not be corrected. In preparing coloured geological maps of migmatitic areas one is confronted with many difficulties of a technical nature, especially in an area like the one under consideration, with its extremely complicated and varied mixtures of rocks and kinds of metamorphism. As a matter of fact, the scale of the map of the Enklinge area is still much too small to show many of its characteristic features and details. The part of the mapping in the field, carried out by the undersigned, is also far from sufficient to do justice to the extremely complicated geology of that particular area — Enklinge — which is probably not surpassed by any other pre-Cambrian area of corresponding size in the world for beauty and variety of rocks and the astonishing complexity of structure.

E. Mikkola.

INTRODUCTION.

The archipelago of the Åland Islands, as well as the adjacent archipelago of Åbo in Finland, consists of a very great number of islands of varying sizes. Both archipelagoes together contain about 10 000 islands. Those that lie next to the open sea are almost entirely bare, while others are covered with vegetation. All the larger islands are forested, except those of the parish of Kökar next to the Baltic Sea. Even on the larger islands, bare rocks are common. Next to the sea, even lichens and mosses are scanty or absent. This area therefore offers excellent facilities for the study of its rocks, but its geology presents riddles which at the beginning seemed to the writer almost impossible to solve. He has, however, after studying this area for a great part of seven summers, arrived at a conception of its geological structure which he thinks will in essence stand the test of future criticism. Some features are so enigmatic that opinions as to their explanation will probably differ even in the future.

Most of the rocks of the region have in the main a granitic composition. The largest granitic areas are formed of so-called rapakivi granites, but other granites are also prevalent. Among the supracrustal rocks, both sediments and volcanics occur. Both are highly metamorphic and very much mixed with granitic veins.

Most of the geological problems of this region are also connected with the petrology and tectonics of granitic masses and associated rocks. Occasionally, however, rocks occur that clearly show their characteristics of sediments and effusive rocks and which are of unusual interest. This is especially the case with the schists of the Enklinge area which the writer has studied very thoroughly. In the summer of 1928, Dr. E. Mikkola acted as his assistant, mapping the Enklinge area in still greater detail than had been done before. The writer desires to thank him cordially for this valuable aid. The opportunity for a dialectic treatment of the problems has been of great use especially in the study of the most difficult outcrops of the area.

The writer also had the advantage of visiting the Enklinge area in the company of several foreign geologists, like Professor Barbour from Peiping, Doctor Magnusson from Stockholm, Professor Bruce from Kingston, Doctor Wegmann from Schaffhausen, as well as Professor Eskola from Helsingfors. Dr. Wegmann has given him valuable information as to the tectonics of the region. Other parts of the region, viz. the neighbourhood of Mariehamn, Lemland, Kökar, Sottunga and Brändö, have been visited by a still larger number of foreign geologists who in 1924 took part in an excursion organized by the writer. He cordially thanks his colleagues and friends for their visits and for the suggestions received from many of them. Unfortunately the Enklinge area had not yet been re-studied in detail at the time of this international excursion.

THE OLDEST SUPRACRUSTAL ROCKS (SVIONIAN).

The oldest of the rocks of the region are those highly metamorphic schists belonging to the so-called Svionian series, in Sweden usually called the Leptite Formation. Most of them are here so highly metamorphic and so much mixed with granitic veins that it is difficult to determine what has been their primary composition and texture. Better preserved portions, however, sometimes occur, especially near the contacts with the schists of the so-called Enklinge formation which the writer regards as an unconformably overlying formation younger than the leptites. In the Enklinge area, the older schists have been designated Kumlinge schists, because they occur in Kumlinge Island and the adjacent smaller islands N. of it. They also appear in the southernmost part of Enklinge Island. There we find some varieties of these oldest schists which may be termed typical fine-grained mica-schists. They still show a distinct bedding, and are intercalated with thin layers of quartzitic schists that have certainly originally consisted of quartz sand, while the darker, phyllitic portions rich in mica, have originally had a more pelitic composition. Thin layers of crystalline limestone also occur intercalated with these mica-schists (Fig. 1).

Analysis No. 1, Table I shows the composition of a mica-schist. There is very little left of the primary mineral constituents. The rock is now composed mainly of flakes of biotite and angular or lenticular grains of quartz, with some feldspar. The composition of a quartzitic intercalation is shown by analysis No. 2 in the same table.

Fig. 1. Thin layers of limestone intercalated with pelitic and quartzitic schists. Pilot Station of Enklinge, Kumlinge.

Table I.

1. Mica-schist (Kumlinge schist). Pilot Station of Enklinge, Kumlinge, Åland.
2. Quartzitic schist (Kumlinge series). Pilot Station of Enklinge, Kumlinge, Åland.

Analyzed by Lauri Lokka.

	1		2	
	%	Mol. prop.	%	Mol. prop.
SiO_2	75.06	1 251	81.10	1 352
TiO_2	0.56	7	Traces	—
Al_2O_3	11.28	111	10.44	102
Fe_2O_3	0.48	3	0.12	1
FeO	3.32	46	0.50	7
MnO	0.06	1	Traces	—
MgO	1.45	36	0.17	4
CaO	2.48	44	1.71	31
Na_2O	2.71	44	1.21	20
K_2O	1.75	19	3.93	42
P_2O_5	0.28	2	0.14	1
H_2O+	0.69	—	0.57	—
H_2O-	0.14	—	0.04	—
	100.26		99.93	

The intercalations of limestone stretch from Esplund in the southernmost part of the Enklinge Island beyond the Pilot Station

of Enklinge, and continue further to the S. E. In the islands of Kråkskär and Stenskär the mica-schists are intercalated with layers of limestone, quartzite and greenstones which seem to be partly effusive basaltic rocks, but are now so highly metamorphic that it is difficult to determine their primary texture.

This zone of schists intercalated with limestone is certainly continuous, and it seems probable that they all belong to the oldest schists of the region and not to the Enklinge series, although their original character is sometimes almost as well preserved as that of the rocks of the younger formation.

On the northern shore of the island of Bärö, the mica-schist also contains an intercalated layer of crystalline limestone which probably belongs to the same formation as the rocks of the Esplund-Enklinge belt. N. W. of Esplund in the island of Enklinge there appears, at the edge of the shore, a thin layer of white marble which is possibly a continuation of the Bärö belt.

N. E. of the limestone of Bärö there is a broad intercalation of a basic rock which has the character of a pillow lava, showing rather large rounded pillows surrounded by dark rims. This pillow lava is in contact at both sides with schists that are more highly metamorphic than those outcropping at the Pilot Station of Enklinge. They show no bedding or other positively primary features. More to the S.E., from this place, the schists have also been highly disturbed. Where the layers of different composition originally existed, they are no longer easy to recognize. At the northern side of the islands of Stora Varpskär and Lilla Varpskär there are highly compressed basic rocks which obviously form the continuation of the Bärö belt of pillow lava, or a parallel zone lying to the N.E. of it.

In the southernmost parts of these islands there is another, much broader belt of pillow lava which has a continuation in the island of Torsholmsören and further to the S.E., in the peninsula Torsholmsudden and Stolpören. In Stora Varpskär, it shows in one outcrop the character of a typical pillow lava (Fig. 2) limited by a sharp contact with the schist outcropping N. of it. It has been in parts strongly sheared. (Fig. 3). The pillows have been drawn out and the rock changed into a schist, showing alternating darker and lighter bands. In the south-western part of Lilla Varpskär, the same pillow lava outcrops but it is here more highly metamorphic. Traces of the pillows are, however, still clearly recognizable. In the northern part of Torsholmsudden, again, the same rock has been more completely changed, so that it now presents the appearance of a fine-grained

Fig. 2. Pillow lava, a belt in the Kumlinge schist. S. shore of the island of Stora Varpskär, Kumlinge.

Fig. 3. Pillow lava, partly sheared, belonging to the same layer as that shown on Fig. 2. S. shore of the island of Stora Varpskär, Kumlinge.

schist with alternating dark and white layers. The dark bands are rich in hornblende and the light ones composed mainly of quartz and feldspar. The rock might be called a leptite, according to Swedish nomenclature. The alternation of layers reminds one of bedding (Fig. 4), but there is no doubt that the rock originated by the mechanical squeezing of a pillow lava accompanied by the crystallization of dark and light minerals alternately, during a kind of selective metamorphism.

As there are also pillow lavas in the Enklinge series, the simplest conception would be to regard the Bärö rocks as belonging to the

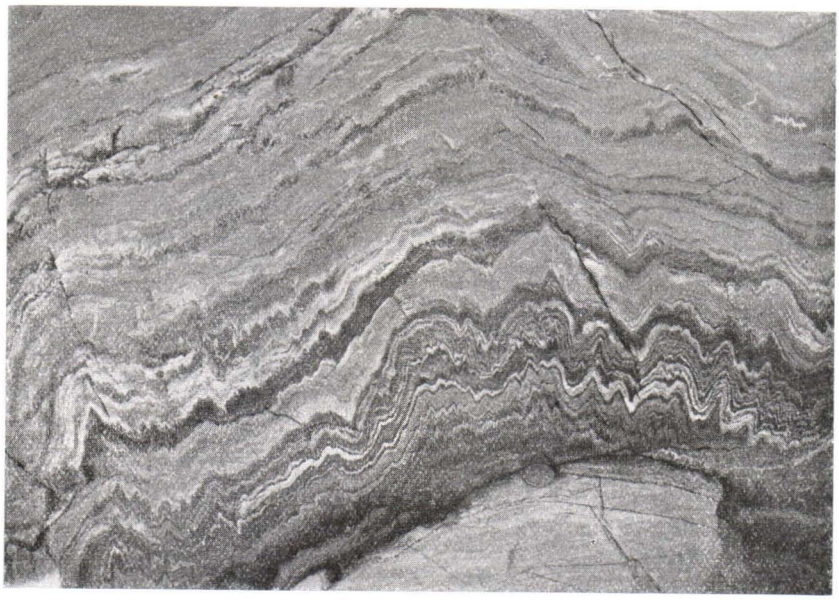

Fig. 4. Banded rock, resembling a »leptite», formed out of a pillow lava by strong shearing movements and a simultaneous segregation of the light and dark components into different bands. N. shore of Torsholmsudden, Kumlinge.

same formation. But the latter are no doubt older than the gneissose granite of the region, while the lavas of the Enklinge series are younger.

There are also other intrusive rocks that penetrate the pillow lavas in the islands of Varpskär and Bärö which seem to be older than the Enklinge series. In the southernmost part of Stora Varpskär, a gabbroid rock outcrops as a pipe-like mass with rounded outlines, penetrating the pillow lava and also forming dykes in it. Similar dykes occur at several places on the northern shore of the

island of Bärö. They are penetrated by a younger dyke of metabasalt which seems to belong to the basic lava formation of the Enklinge series. For all these reasons it seems probable that the pillow lavas in question belong to the Kumlinge series, which is older than the gneissose granite of the region and cannot be connected with the lavas of the Enklinge series.

In the region N.E. of the island of Enklinge, and at the northeastern shore of that island, there are also mica-schists which are penetrated not only by the younger granite but also by the gneissose granite. Here and there they show the character of a mica-schist not much different from that outcropping near the Pilot Station of Enklinge. In most cases, however, this older schist has been much changed by the action of the older granite. It often contains feldspar and shows gradation into rocks with a more gneissic composition.

Other crystalline limestones occur in many parts of the areas where the older granite predominates. Thus there are layers of limestone, very much crumpled and contorted, in Illisholm and at several other places in the archipelago of Jurmo in northern Brändö and in the island of Bergskär in Kökar.

Typical leptites of the character so common in parts of middle Sweden have not been found here. In spite of diligent search it has not been possible to discover here any of the characteristic leptites, rich in potash, which occur in the archipelago E. of Stockholm. More typical mica-schists associated with quartzites, and rocks of an andesitic or basaltic composition seem to be prevalent among the oldest supracrustal rocks of the Åland Islands.

GNEISSOSE GRANITE.

Among the oldest rocks of the region, a gneissose granite has a large distribution, especially in the southernmost parts, next to the Baltic Sea. Here it occurs almost unmixed here and there containing fragments of the oldest schists which it penetrates everywhere at the contacts. It has the same character as the gneissose granites outcropping at the southern shore of Finland, but in that region they are more mixed with younger granite and do not form such large areas as in the archipelago now under discussion. The latter obviously form a direct continuation of the great areas of gneissose granites in the region N. of Stockholm (the Uppsala granite etc.).

Where this gneissose granite is well preserved, it is a very typical granite, rich in plagioclase, as is usually the case with the granites of the oldest group in southern Finland. It always shows gneissic texture, although it is only slightly recognizable in the best preserved varieties. This granite everywhere contains small fragments of a dark rock which is similar in composition to a mica-schist. Where the granite is more schistose than usual, these fragments are drawn out along the direction of schistosity. There are, however, granites of this group containing innumerable small fragments of schist which are not drawn out at all, but show the original angular forms

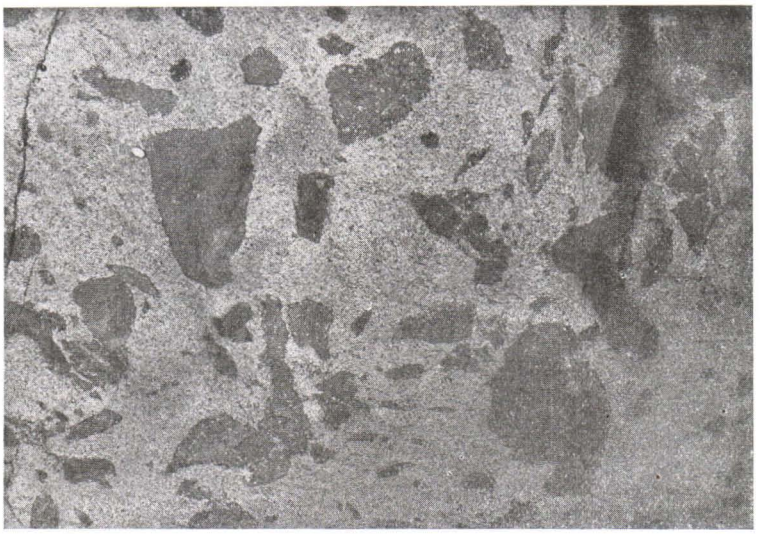

Fig. 5. Gneissose granite with fragments of schists. Islands of Småholmarna, N. of Enklinge, Kumlinge.

entirely preserved (Fig. 5). This fact proves that there are portions of the oldest granite which have not been changed mechanically to any high degree. In any case, these rocks always show a granulation of the quartz, faulted twinning lamellation of the plagioclase, and other signs of tectonic movements.

This granite is usually equigranular, but often the feldspars tend to be a little bigger than the other mineral constituents. In the island of Ljusskär in Kökar and at some other places porphyritic varieties of the older granites occur. These granites also contain fine-grained rocks, closely associated with the main mass, which are aplitic in character, and occasionally darker varieties. When these

rocks, showing an alternation of varieties with different colours, have been drawn out through mechanical action, they have a certain resemblance to leptites, but there is no doubt that they are associated with the older granites.

That the dark fragments usually found in these granites are in many cases fragments of mica-schists, is clearly shown in the north-eastern part of the island of Enklinge and the islands of Småholmarna N. of it. At the north-eastern shore of the larger island, the schists

Fig. 6. Gneissose granite with innumerable fragments of leptitic schists. Islands of Småholmarna, N. of Enklinge, Kumlinge.

are in contact with gneissose granite which clearly penetrates them, forming dykes parallel with the schistosity of the rock. When we follow this belt of granite-invaded schist further to the N.N.W., it becomes more and more mingled with gneissose granite, and in the island of Granskär the schist becomes gradually more and more split up into large and small fragments, between which the granite has penetrated. There are continuous gradations between this mixed rock and the rock of Småholmarna (Vindarskär) which is formed by plagioclase-granite containing millions of fragments of mica-schist more or less changed and penetrated by the granitic magma, so that they gradually become lighter in colour and mixed with feldspar and other granitic minerals (Fig. 6). In one of these fragments we

can follow the continued splitting up of the schists. Radiating fissures into which the granite has penetrated have been formed at the periphery of the fragment (Fig. 7).

Rocks also occur which have been formed by the intrusion of the oldest granite into amphibolitic schists that seem to have been originally either andesitic effusive rocks or tuffs associated with them. In the island of Redarskär in Brändö, 5 km. N.E. of Enklinge, such a schist has been intruded by gneissose granite which has brecciated the older rock so that a hybrid

Fig. 7. Fragment of schist being assimilated by the gneissose granite which penetrates into the fragment along fissures from the periphery.

rock has originated, consisting mostly of angular fragments of basic schist cemented by granite. This kind of migmatite is characteristic of the oldest granite. The migmatites showing ptygmatic folding, which are so common when the veins consist of granite of the second group, are rather rare among the oldest migmatites. Only occasionally are varieties with folded veins observed among them.

It is, however, not certain that all the dark fragments in these granites have the same character. In some cases they seem to have been formed through the splitting up of portions

of more basic rocks which are genetically associated with the granite.

All over these areas of gneissose granite there are basic dykes which are genetically associated with the granite and also show gradations into more acid dyke rocks approaching an aplite in composition. These dykes may be designated l a m p r o p h y r i c, although it must be admitted that this term is not entirely adequate. It means rocks which are glistening and porphyritic, while these rocks now in question are equigranular and have a dark, rather dull colour. Moreover the name »lamphrophyric» has been used for rocks of such varying character that it has not a very precise meaning. The writer has sometimes used the name »epibasites» for these rocks. This name indicates that they were formed later than the main mass of surrounding granite and that they have a preponderantly basic character. Törnebohm, who was annoyed at the inconsistent behaviour of the basic dykes so common in middle Sweden and southern Finland, called them »the rogues of the Pre-Cambrian». In accordance with this, the basic rocks of lamprophyric character might be called k l e p t o l i t h s, alluding both to the nickname given them by Törnebohm and the fact that they have »stolen» their material from the intrusive granites in which they occur. This is only meant as a suggestion that ought to be discussed before it is possible to make a more formal proposal of such a term.

These lamprophyric dykes have been formed in fissures cutting the gneissose granite. They usually have a breadth varying between a couple of metres and a few centimeters. Unlike the metabasaltic dykes in the same region they do not show a different composition or texture in the narrower from that in the broader veins, nor do the broader dykes, in most cases, show any aphanitic contact zone, as is often the case with the metabasaltic dykes. Moreover, the lamprophyric vein rocks are often closely associated with more acid rocks. The most typical lamprophyres have, however, a chemical composition which is very near to that of a metabasalt, only with the difference that they show a higher content of potash (cf. analyses pp. 20—21). They are often homogeneous in composition. In other cases, they show alternate darker and lighter stripes parallel to the walls of the dyke. The lighter portions are richer in feldspar and sometimes also contain some epidote.

These lamprophyric or »kleptolithic» dykes are very common in the archipelago of Föglö and Kökar in the Baltic Sea and are especially common in the island of Kökarsörn. Most of these dykes

consist of a very dark rock; others are striped (Fig. 8). Spotted rocks are also common which seem to have been formed by the brecciation of lamprophyric zones and cementation of the fragments by a more acidic magma.

In the island of Följskär in Kökar, lamprophyric rocks are also common and are associated with aplitic rocks, pegmatites and intrusive breccias. The phenomena in this island are rather enigmatic, some of the dykes are somewhat similar to metabasaltic dykes, and are penetrated by granitic veins that may belong to the granites of the second group.

Fig. 8. Dyke of lamprophyre with banded structure, cutting the gneissose granite. Island of Kökarsörn, Kökar.

Here a number of dark basic dykes occur, sometimes intersecting each other, and also penetrated by veins of light red pegmatite and aplite. In other cases, again, aplite and dark lamprophyre occur in the same veins, alternating with each other, but rather well separated. It is obvious that they are genetically connected, but the basic and the acid rock seem in a way antagonistic to each other, so that gradations between them do not occur.

In Table II three analyses are given to show the chemical composition of some lamprophyric rocks in the island of Följskär.

In the eastern part of the island of Följskär, there is a composite dyke (Figg. 9, 10) where the contact zone (Anal. 2, Table II) consists of dark hornblende mixed with small patches of quartz, while the middle of the dyke consists of a rather light rock of dioritic composition (Anal. 3, Table II) containing angular fragments of the basic contact rock. This composite dyke, which strikes in a W.—E. direction, is cut by a broad belt of breccia striking at the contacts mostly in a N.—S. direction (Fig. 11). It consists of fragments of a basic schist-like rock and a cementing mass of aplitic composition, although rather rich in plagioclase. This cementing mass is also non-homogeneous, and we get the impression that the brecciation of the darker rock and the penetration of the lighter magma has been accompanied by a process of differentiation, causing the former to be more and more basic and the other to vary in the direction of an aplitic magma.

In the island of Långskär, N.E. of the Kumlinge Island, there are a great number of narrow lamprophyric dykes some of which have the composition of a minette-like basic rock, while others are rich in epidote so that they grade

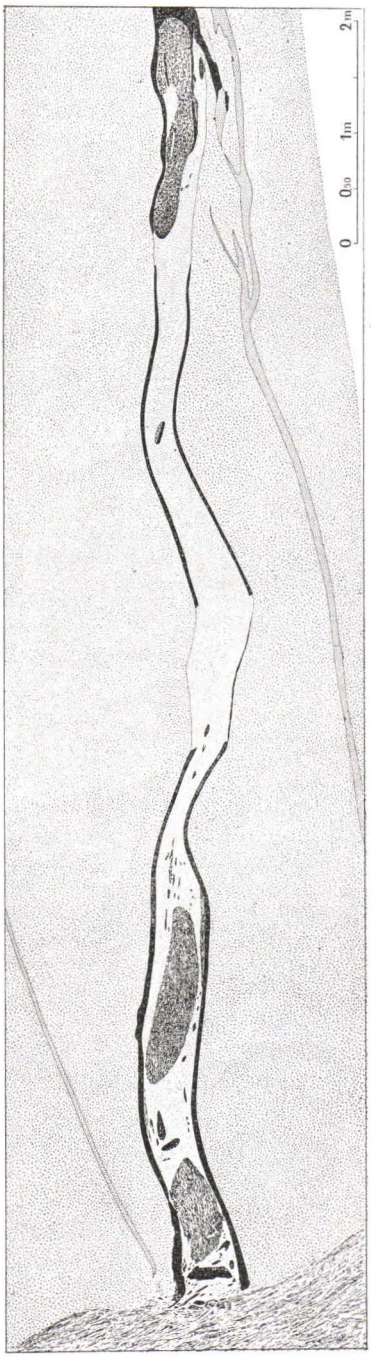

Fig. 9. Composite dyke in the island of Följskär, Kökar. The dark contact zone is indicated with black, the granodioritic middle with fine dots. The country rock is granodiorite, which is also cut by dykes of pegmatite. The breccia mentioned in the description on the left.

Fig. 10. The western end portion of the composite dyke in Följskär, Kökar. 1 : 11.

Table II.

1. Dark lamprophyre. Följskär, Kökar, Åland.
   Analyzed by Lauri Lokka.
2. Dark contact zone of the composite dyke in the island of Följskär, Kökar, Åland.
   Analyzed by Elsa Ståhlberg.
3. Dioritic rock from the middle of the composite dyke. Följskär, Kökar, Åland.
   Analyzed by Elsa Ståhlberg.

	1		2		3	
	%	Mol. prop.	%	Mol. prop.	%	Mol. prop.
SiO_2	47.69	795	52.45	874	67.38	1 123
TiO_2	1.18	15	0.19	2	0.37	5
Al_2O_3	14.21	139	8.92	87	15.30	150
Fe_2O_3	4.14	26	2.32	15	0.64	4
FeO	8.69	121	9.05	126	3.38	47
MnO	0.11	2	0.09	1	0.07	1
MgO	8.06	202	11.57	289	1.43	36
CaO	9.01	161	11.65	208	3.85	69
Na_2O	2.68	43	1.25	20	2.13	34
K_2O	1.96	21	0.66	7	4.30	46
P_2O_5	0.30	2	—	—	—	—
S	—	—	0.19	—	0.32	—
H_2O+	1.75	—	1.48	—	0.68	—
H_2O-	0.12	—		—		—
	99.90		99.82		99.85	

into a mass consisting mainly of that mineral. The chemical composition of such a rock was determined, and the result is shown by analysis No. 1 in Table III.

Fig. 11. Breccia of a schist-like basic rock and a cement of non-homogeneous aplitic rock rich in plagioclase, cutting the composite dyke in Följskär, Kökar. 1: 13.

Table III.

1. Lamprophyre very rich in epidote. Långskär, Kumlinge, Åland.
2. Amphibolitic lamprophyre. Trutklobb, Skeppsvik, Eckerö, Åland.
3. Gneissose granite. Skeppsvik, Eckerö, Åland.

Analyzed by Lauri Lokka.

	1		2		3	
	%	Mol. prop.	%	Mol. prop.	%	Mol. prop.
SiO_2	39.79	663	44.74	746	74.17	1 236
TiO_2	0.23	3	0.78	10	0.26	3
Al_2O_3	24.35	239	11.43	112	12.78	125
Fe_2O_3	7.56	47	3.39	21	1.80	11
FeO	2.98	41	8.51	118	0.59	8
MnO	0.11	2	0.36	5	0.03	—
MgO	3.13	78	14.40	360	0.29	7
CaO	19.68	351	12.90	230	0.74	13
Na_2O	0.26	4	1.17	19	3.38	55
K_2O	0.50	5	1.08	11	5.14	55
P_2O_5	0.15	1	0.27	2	0.19	1
H_2O+	1.12	—	0.72	—	0.63	—
H_2O-	0.10	—	0.23	—	0.16	—
	99.96		99.98		100.16	

In some of those dykes a brecciation took place after the consolidation of the basic dyke rock, portions of which now form angular

fragments. Others have a composite character, the rock next to the contact being very dark and rich in biotite, while the middle part consists of an aplite rather rich in potash. There are also broader dykes of aplite in which the lamprophyric variety only forms a narrow zone next to the contact.

At the N.E. shore of the Enklinge Island, N.E. of Enklubb, very interesting basic dyke rocks, associated with a gneissose granite, occur. The granite has here been brecciated over a rather large area, and the fragments cemented by more basic rocks. Some of them are very dark, consisting mainly of biotite, but they pass by gradation into lighter, dioritic rocks, and aplitic and pegmatitic veins, obviously belonging to the same magma, are also associated with them. While in most cases the more basic rocks cut the acid ones, here and there may also be observed inclusions of very basic rocks, obviously possessing the same character as the others, and entirely surrounded by granite.

Lastly the interesting basic dyke rocks of the island of Svartgrund in the archipelago of the Gulf of Bothnia, N.W. of Jurmo in Brändö may be mentioned. The prevalent rock in that little island is a diorite which often shows a distinct parallel texture, caused by darker stripes of biotite and hornblende. This diorite is cut by numerous dykes of lamprophyric character. Some of them have the composition of a minette and are rather rich in biotite. In others small crystals of plagioclase occur as a kind of porphyritic constituent. Several of the dykes are very rich in garnet, a constituent which seems to have been formed as early as during the crystallization of the dykes. The composition of the different dykes is rather varied; aplitic and pegmatitic veins are associated with some of them; on the other hand, there are narrow veins consisting almost exclusively of biotite that cut the other rock varieties. There is no doubt that all these dykes of varied composition and texture were formed at the final stage of the crystallization of the dioritic magma which, again, is certainly consanguineous with the old gneissose granite.

Finally a very peculiar dyke rock has been observed in the little island of Trutklobben at Skeppsvik in Eckerö, next to the Åland Sea (Fig. 12). The prevalent rock here is a gneissose granite, but in it occurs a basic rock consisting mainly of hornblende (Anal. 2, Table III). Its contacts cut the schistosity of the gneissose granite, and the basic rock has clearly an intrusive character. It includes fragments of the granite which have been more or less changed by the basic magma. Associated with those portions, which consist mainly of amphibole are others in which epidote becomes more and

more prevalent. S. of the main mass of the amphibolitic lamprophyre, narrower dykes of another lamprophyric rock occur which are similar to the common metabasalt-like variety of these rocks, but they

Fig. 12. Dark dyke-like rock masses in the gneissose granite in the island of Trutklobben, Eckerö. The black portions consist mainly of hornblende, the dotted ones of epidote.

are here to a great extent transformed into a rock consisting mainly of green epidote. This mineral occurs also in the gneissose granite between these peculiar dyke rocks.

The origin of all these basic dyke rocks of a lamprophyric or »kleptolithic» character as segregation products of the granitic magma is obvious. They have »stolen» their magma from the last residuum of that magma. In these remnants of magma, a continuous differentiation by fractionation has taken place. The most basic minerals crystallized at an early date, leaving a mother liquid of more acid magma which was probably diluted with water. This acid portion crystallized later than the basic one. The last remains of the epimagmatic solutions were rich in CaO and CO_2, effecting the partial transformation of the basic rocks into a mass rich in epidote. This mineral has obviously crystallized at a much lower temperature than the biotite and feldspar. In many rocks of the region an epidote crystallized in narrow fissures in the granitic masses during the last epoch of rock formation.

Most of the gneissose granites are rich in plagioclase, but there is one variety undoubtedly belonging genetically to the same group of granites, which has a composition more resembling that of the granites of the second group, especially of the typical Hangö granite. This gneissose granite, reddish in colour, occurs in Skeppsvik in Eckerö, the westernmost part of the Åland islands. The analysis No. 3, Table III shows its composition.

BOTHNIAN SCHISTS.

ENKLINGE SERIES.

METAMORPHIC SEDIMENTS.

Only in a small area, that of Enklinge in the parish of Kumlinge, do supracrustal schists occur which quite clearly show their primary character. They belong, as already mentioned, to a series that is younger than the Svionian schists and the gneissose granite which penetrates them. These younger schists may be designated the Enklinge series. As will be shown later, they probably belong to the same cycle as the Bothnian schists of the Tampere (Tammerfors) region and the uralite-porphyrites of the Tammela—Kalvola and the Pellinge areas in southern Finland. The Enklinge schists form a small area, irregular in form, stretching from the region N. of the village of Enklinge over the middle and the south-eastern part of this island to some smaller islands S.E. of it. It is surrounded on most sides by gneissose granites, but in the S. it is in contact with the older schists. Both of those rock formations are, in the opinion of the author, older than the Enklinge series.

Next to the gneissose granites which form the substructure of the schists, occurs in most places a fine-grained mica-schist. This consists mainly of quartz and biotite, with which minerals sometimes are found also feldspars and crystals of ore. The schist does not show a distinct bedding, nor, on the whole, other primary features indicating its sedimentary character. This character is, however, quite obvious from its chemical composition which is entirely that

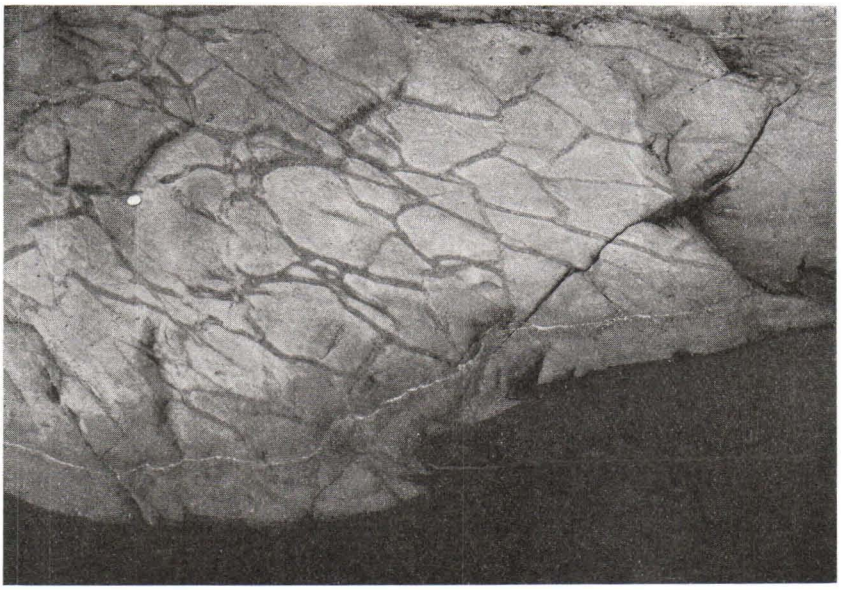

Fig. 13. Metamorphic alteration of the mica-schist, whereby the rock is divided into parallelipipedic portions separated from each other by dark stripes rich in mica. Bockholm, Kumlinge.

of a pelitic sediment, a common clay. The strike of the schists is usually parallel to their contacts with the adjacent granite, and only in the western part of the area is it more irregular.

While the absence of such primary features as bedding etc. and the crystalline character of the rock show that it is highly metamorphic, changes have in many cases taken place which go beyond the realm of metamorphism and may be designated ultra-metamorphic. In the island of Bockholm, the schist often shows a peculiar brecciation (Fig. 13), being divided into parallelipipedic portions whose outlines are marked by black stripes richer in biotite than the rest of the schist. At other places, again, the schist, which

has obviously been soaked with granitic magma or ichor, has become rich in feldspar and gradually changed into a fine-grained gneissic rock which in some parts has even a granitic composition. The analyses No. 1 and 2 in Table VI, p. 43, give examples of composition of schists produced by such changes. These gneissose, or »felsitic» rocks show no marked difference from similar rocks which must simply be regarded as aplitic portions of the granite. These are more massive, while the felsitic schists are schistose and show no sharp boundaries towards the mica-schist. We shall return to the question of their origin later. In the middle part of the area of schists, and

Fig. 14. Pillow lava, Enklinge, Kumlinge.

also W. of it, varieties occur which are also feldspathiferous and seem to be ultra-metamorphic parts of the same formation, but do not contain any remains of the better preserved, typical mica-schist.

There are, however, also feldspathiferous schists which seem to have a different origin. They are found especially in the middle part of the area, in the island of Enklinge, as layers with a maximum breadth of some twenty to thirty metres, and consist of a rock that reminds one of a gneissose granite, but is more fine-grained, richer in biotite, and contains rounded grains of glassy quartz. They show some similarity to porphyritic quartz crystals, and the rock is therefore somewhat like a quartz-porphyry. Some of the rounded accumulations of quartz, however, are too big to be porphyritic crystals,

and their forms too are different and seem to indicate that they are small pebbles of quartzite. The rock has the same character as the sathrolithic schist in the Tampere (Tammerfors) region, which has been described by the writer. These latter rocks, again, are metamorphic sediments formed by the weathering of the underlying diorite.

At some places lighter varieties of the schists occur which are richer in quartz and feldspar than the other parts, and probably have originally contained less completely assorted material.

METAMORPHIC VOLCANIC ROCKS.

S. of this irregular belt of mica-schist are supracrustal rocks which, where they are well preserved, show clearly the character of metamorphic lavas and associated volcanic rocks. Especially on the promontories S.W. of Bovik, on the south-eastern shore of the Enklinge Island, do rocks occur which, in the well-exposed outcrops at the shore, show the character of pillow lavas so clearly that one is astonished to find them among so highly metamorphic rocks (Fig. 14). Other structures, which do not show such typical pillows, have obviously also been formed by the accumulation of loose volcanic materials (Fig. 15) or by the bursting of the lavas during

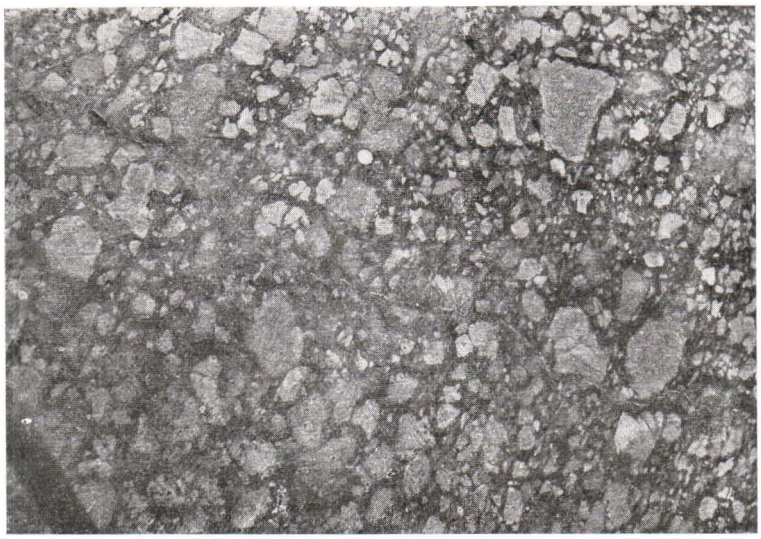

Fig. 15. Volcanic agglomerate. Near Bovik, Enklinge, Kumlinge.

Fig. 16. Bursting of the surface lava flows. Near Bovik, Enklinge, Kumlinge.

their downward movement (Fig. 16). The analysis of a pillow lava (Anal. No. 1, Table IV) shows a composition which is nearer to that of an andesite than a basalt, but it is not quite clear whether this composition is primary, as there are, among the more highly metamorphic varieties of the same rock, some in which a change into more acid rocks has clearly taken place. The pillow lavas are also cut by basic dykes (Fig. 17). The rock of one of these has been analyzed (Anal. No. 2, Table IV), and reveals a wholly basaltic composition, and it is so closely associated with the lavas that it seems

Fig. 17. Pillow lava cut by a basaltic dyke. Near Bovik, Enklinge, Kumlinge.

probable that the original composition was the same in both, although the dyke rock has been more resistant to metamorphic changes. Around the northern shore of the bay which lies N.E. of the localities mentioned, there are, in the lavas, big fragment-like portions of mica-schist, similar to that which outcrops in greater masses a little more to the N. This mica-schist is cut by numerous metabasaltic dykes which end abruptly at faults that limit the fragments. Fig. 18 shows such a fragment at the eastern shore of the

Fig. 18. Big fragment of mica-schist cut by basaltic dykes, which in turn are broken and limited by an agglomeratic lava. E. shore of the bay at the Likholm pier, S. shore of Enklinge, Kumlinge.

deepest bay on the S. shore of Enklinge. A big fragment of mica-schist is here cut by several dykes of metabasalt which end abruptly at the northern contact. The first impression which one receives, is that of a fragment which has been faulted after the penetration of the dykes and the deposition of the lava which outcrops N. of the mica-schist. But when we follow the same lava bed to the S.E., we find that it continues farther in that direction and that it must have originated later than the movements which caused the abrupt ending of the metabasaltic dykes. They were not cut by a fault later than the deposition of the whole series, but disturbances took place already at the time of the volcanic activity. These volcanic earthquakes have brought about the relations between the fragment

and the overlying lava beds. These facts are of great importance, because they clearly prove that the basaltic dykes belong to the same volcanic series as the lavas, and not to any later formation.

Table IV.

1. Andesitic pillow lava, Enklinge, Kumlinge, Åland.
2. Metabasalt, from a dyke cutting the pillow lava. Enklinge, Kumlinge, Åland.
3. Metabasalt, from a dyke cutting the mica-schist. The small island of Smörklippan, between Enklinge and Bockholm, Kumlinge, Åland.
4. Granite (Kumlinge granite). W. of the church, Kumlinge, Åland. Analyzed by Lauri Lokka.

	1		2		3		4	
	%	Mol. prop.	%	Mol. prop.	%	Mol. prop.	%	Mol. prop.
SiO_2	70.75	1 179	49.89	832	54.09	902	74.30	1 238
TiO_2	1.02	13	0.74	9	2.37	30	0.19	2
Al_2O_3	10.75	105	22.07	216	13.15	129	13.85	136
Fe_2O_3	1.44	9	1.44	9	4.00	25	0.32	2
FeO	5.33	74	7.70	107	10.66	148	1.44	20
MnO	0.11	2	0.07	1	0.18	3	0.02	—
MgO	2.27	57	4.92	123	3.52	88	0.09	2
CaO	4.08	73	7.36	131	6.84	122	1.24	22
Na_2O	2.50	40	3.75	60	2.44	39	3.42	55
K_2O	1.07	11	0.75	8	1.50	16	4.66	50
P_2O_5	0.20	1	0.13	1	0.41	3	0.14	1
H_2O+	0.72	—	1.35	—	1.11	—	0.47	—
H_2O-	0.13	—	0.15	—	0.11	—	0.10	—
	100.37		100.32		100.38		100.24	

These metabasaltic dykes are quite like the basic dykes which occur in the neighbourhood, cutting the gneissose granite, and which are not to be confounded with the lamprophyric dykes. They are found in great numbers e. g. in the northern part of the island of Ängholm. Several broad dykes also occur in Småholmarna, cutting the gneissose granite which contains numerous fragments of mica-schist.

The same dykes have on the whole a wide distribution all over the area of gneissose granite. Where the younger granite has injected it, the fragments of gneissose granite, surrounded by the younger one, often contain dykes of that dark basic rock. In the island of Öster Florskär in Föglö, this metabasaltic rock occurs in greater masses, which seem to lie flatter, but from which vertical dykes branch, cutting the surrounding gneissose granite.

Although, as already remarked, the lamprophyric rocks may show a certain similarity to the metabasaltic dykes, it is in most cases possible to distinguish them. The metabasaltic dykes are also common in the eastern part of the archipelago skirting the southern shore of Finland, in which lamprophyric dykes are rare or absent and where

better preserved portions of the rock masses often show basic dykes with the most indubitable basaltic textures. In the Pellinge area E. of Helsingfors, we also find dykes associated with larger masses of lavas that are younger than the gneissose granite.

Towards the W., the lavas of the Enklinge Island gradually pass into schistose rocks with a more acid composition and with only rare traces of the pillow lava structure. These are no doubt ultra-metamorphic portions of the same lavas. In the westernmost parts of the area of schists, near the western shore of the Enklinge Island, basic rocks are rather common near the contacts of the schist. In some parts they are dykes, in other parts they may be surface flows. In the southernmost part of the Enklinge Island, and in the adjacent part of the island of Bärö, similar basic dykes occur cutting both the schists and those older porphyritic basic rocks mentioned above that have a certain resemblance to basic portions of the gneissose granite. But, as already stated, still older basic rocks also occur in the same islands intercalated with the older schists, and it may in some cases be difficult to distinguish the different groups of basic dykes.

CONGLOMERATE OF BOCKHOLM.

In the island of Bockholm there is a rock which is of great importance, because it gives evidence which proves conclusively that the schist of Enklinge is younger than the gneissose granite. It is a conglomerate intercalated with the mica-schist and lying near the contact of the gneissose granite. The map in Fig. 20 gives an idea

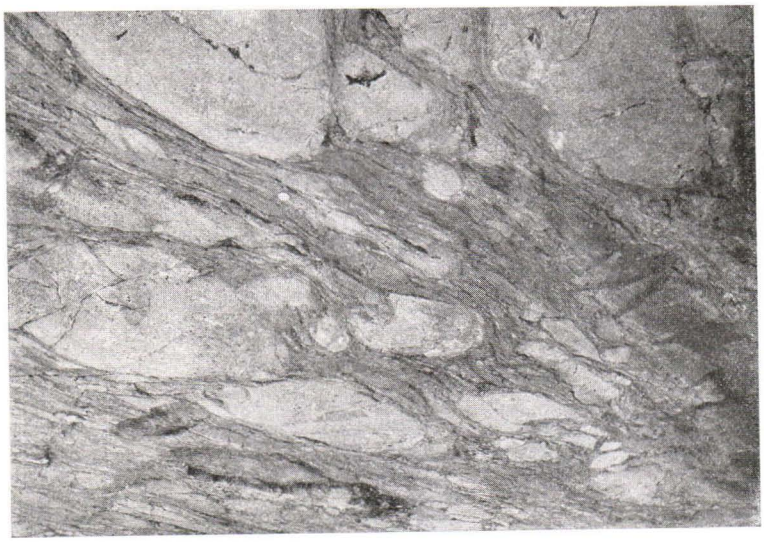

Fig. 19. Conglomerate containing pebbles of the gneissose granite which outcrops near to the conglomerate. Bockholm, Kumlinge.

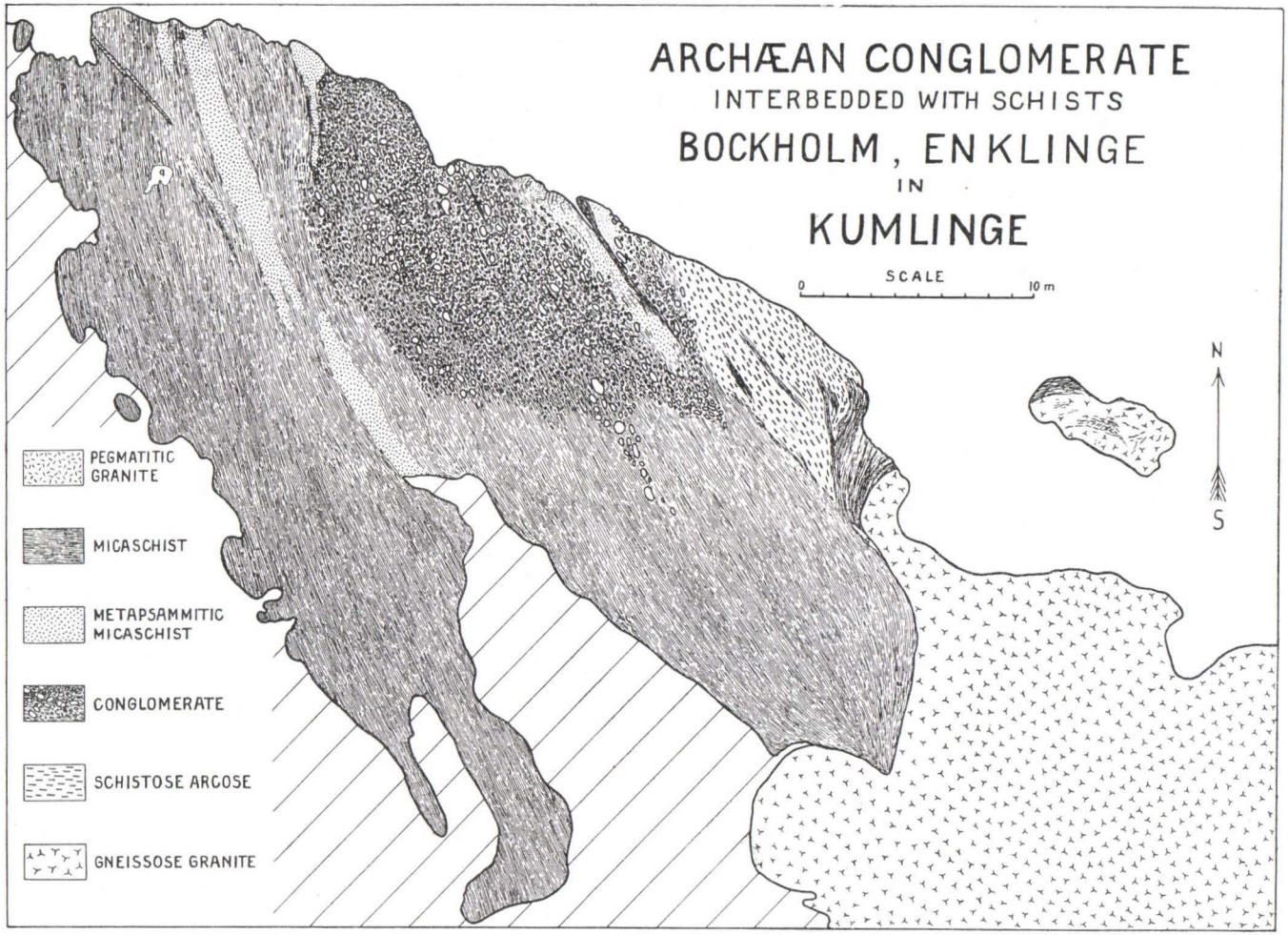

Fig. 20. Map of the outcrop of conglomerate, showing its relations to the schist and the gneissose granite. N. E. shore of Bockholm, Kumlinge.

of the occurrence of this conglomerate and its relation to the surrounding rocks. It consists of a great number of pebbles of gneissose granite (Fig. 20). With them are found a few consisting of mica-schist or a basic rock. The granitic pebbles are often well rounded, while those consisting of schist have originally been flatter and are usually smaller. The largest of the granite pebbles measure nearly one metre in length, but most of them vary between the size of a head and that of a fist. Gradually the conglomerate passes into a rock in which the fragments are very small, down to the size of a pea and even less. It thus passes by gradation into a rock that may be termed a metamorphic arkose, and further into the mica-schist. The cementing mass between the larger pebbles has also in some parts the character of an arkose, in others of a mica-schist. In the adjacent schist isolated pebbles of granite also occur. In the conglomerate, there are intercalated beds of a fine-grained light rock which has obviously been a feldspathiferous sand, and next to the contact with the adjacent gneissose granite a rock is found which consists of a coarser-grained mixture of granite and small fragments of schist. It may be termed an arkose, or perhaps better a s a t h r o l i t h formed out of weathered granitic material. In a little island near the conglomerate rock, the gneissose granite is highly brecciated, and the fragments are cemented by a dark material rich in biotite which in parts is very similar to the mica-schist or to the arkosic parts of the conglomerate (Fig. 21). This breccia has no doubt been formed by weathering processes, through the action of which the superficial parts of the granite have been fissured and mixed with sedimentary material.

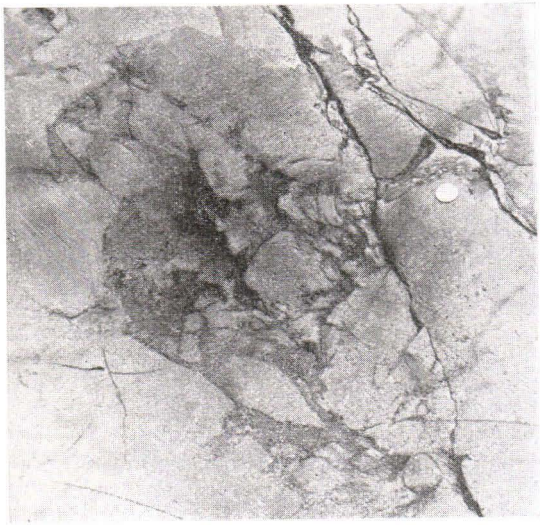

Fig. 21. Sedimentary breccia, consisting of blocks of the gneissose granite which are cemented by an arkose- or schist-like mass. The small island E. of the conglomerate outcrop of Bockholm, Kumlinge.

Table V.

1. Gneissose granite. Bockholm, Kumlinge, Åland.
2. Gneissose granite from a pebble of conglomerate. Bockholm, Kumlinge, Åland.

Analyzed by Lauri Lokka.

	1		2	
	%	Mol. prop.	%	Mol. prop.
SiO_2	74.54	1 242	75.46	1 258
TiO_2	0.58	7	0.63	8
Al_2O_3	12.48	122	12.40	122
Fe_2O_3	0.39	2	0.57	4
FeO	1.54	21	1.66	23
MnO	0.02	—	0.02	—
MgO	0.32	8	0.70	18
CaO	3.08	55	3.10	55
Na_2O	4.16	67	3.58	58
K_2O	1.06	11	0.82	9
P_2O_5	0.70	5	0.17	1
H_2O+	0.75	—	0.40	—
H_2O-	0.16	—	0.10	—
	99.78		99.61	

The granite of the pebbles is exactly like that of the gneissose granite outcropping next to the schist, as appears from the analyses in Table V. Even the small dark fragments which are so characteristic of this granite occur in the pebbles. The rock must thus be regarded as a basal conglomerate of the material of the gneissose granite that has formed the substructure of the sedimentary formation. The mica-schist which is so closely connected with the conglomerate must obviously also be younger than the granite. This is a typical deep-seated rock which must have been eroded to a great depth before the deposition of the sediment.

We are able to follow the contact between the mica-schist and the gneissose granite all over the island in a N.—S. direction. The boundary in the north has a zigzag direction because folding has taken place, but the greater part of the contact between the schist and the granite is straight, and it is everywhere quite sharp. Nowhere are any dykes or veins of gneissose granite intruded into the schist. Narrow veins of granite occur both in the conglomerate rock and at some places near the contact between schist and granite, but they do not cut the contact, and are even found cutting the gneissose granite outside of it. They belong to the younger granite, that of the second group.

It is difficult to say to what extent the present contact of the rocks is the original one. The contact surface which was originally flat-lying is now vertical, and great disturbances must therefore have

taken place. That is proved also by the occurrence of a big fragment of schist in the gneissose granite which has, however, not at all the character of fragments lying in an intruding granite of a younger age, but has obviously arrived at its present position through faulting movements. In other parts of Bockholm, the mica-schist is extremely contorted and has been mixed with younger granite, as will be described in detail later on. Along the northern shore, again, one observes portions of gneissose granite which have a breadth of only a few metres and one of which ends abruptly. The end is rounded, and next to it a fault has divided a lens of granite into two portions. The fissure has been partly filled with quartz, but folds of schists have also penetrated the fissure at both sides. These lenses or sheets of gneissose granite have obviously been pushed into the schist in a solid state during overthrust movements. A continuation of the same lens of gneissose granite is found in a promontory of the Enklinge Island where it penetrates the lava, but not in the way of a younger intrusive rock. It forms a highly mylonitized mass in which the granitic character is fairly well preserved only in some places, while most of the rock is almost schist-like.

OTHER CONTACT RELATIONS OF THE ENKLINGE SERIES.

As the occurrence of a conglomerate containing pebbles of gneissose granite is evidence of age that cannot be gainsaid, the relations of the Enklinge schist and the adjacent gneissose granite at other contacts in the same region must be explained by taking into account the results obtained on the island of Bockholm. A detailed study of the other contacts has shown that there are no facts which do not agree with the conclusions now drawn. In the island of Ängholm, the contact between schist and gneissose granite is at some places rather sharp, but there are dykes of a pegmatite belonging to the younger granite which have in parts been intruded near the contact, obliterating the primary features. At the contacts in the nearest parts of the island of Enklinge, N. of Enklubb, there occurs, near the contact and at some places even next to it, a schist which has obviously been soaked with aplitic ichor belonging to the younger granite. That complicates the contact relations. More to the N. W., again, there are, along many hundreds of metres, contacts where schist and gneissose granite may be seen next to each other and where there is no penetration by the gneissose granite, although in some places folding movements have deformed the contact line. At one place, farther N. of Enklubb, a number of dykes of gray granite were found which at one

time were regarded as belonging to the gneissose granite, because they in parts show a well developed parallel texture. Some of them, however, showed more similarity to the younger, Kumlinge granite. By a closer study of the relations of different rocks it was found, however, that the real contact between schist and gneissose granite lies to the north of the place where the dykes occur and here a sharp contact of the usual character was found. The dykes have nothing to do with the gneissose granite, but certainly belong to the younger granite in which varieties are common having quite the same character as the dyke rocks.

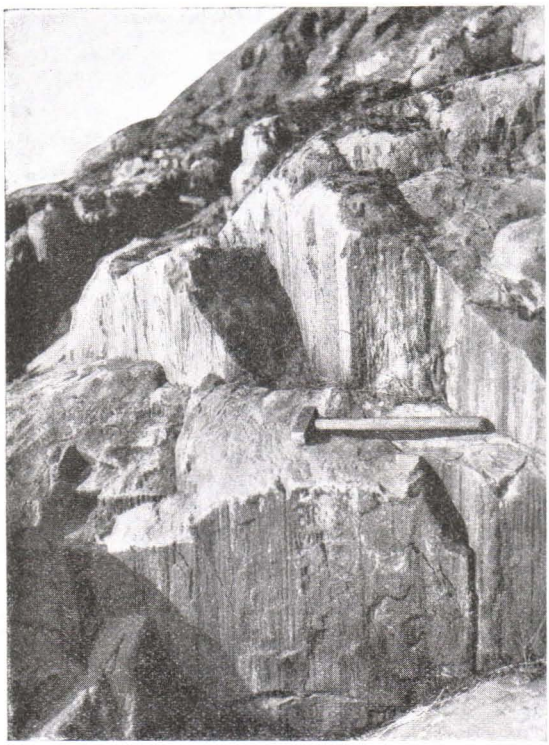

Fig. 22. Slickensides and a very pronounced vertical »rodding structure» in the schist in a zone of strong disturbances of a late date. W. shore of the S. part of the Enklinge Island, Kumlinge.

In the narrow portion of schists which forms the northernmost part of the area, felsitic varieties of schist are rather common, which are certainly to be interpreted as sedimentary rocks that have been soaked with magma, or ichor, emanating from the magma of the younger granite.

In the region near the western boundary of the schist, strong disturbances have obviously taken place at an epoch which seems to be much later than the folding of the schist, and is also later than the intrusion of pegmatitic dykes associated with the younger granite. Shearing movements have caused a strongly developed »rodding» structure in the schist, the position of which, in general, is nearly vertical (Figg. 22, 23). This zone of disturbances stretches along the shore of the Enklinge Island and continues to the island of Bärö.

There is indisputable evidence in favour of the older age of the limestone-bearing mica-schists of the Kumlinge series, which occur as big fragments in the gneissose granite; therefore, a contact line must separate those older schists and the schists of the Enklinge series, in such a way as is shown on the map of the Enklinge area. The contacts are probably, at most places, mechanical. Both rocks have been mylonitized and mixed with each other. In the southern-

Fig. 23. Rocky shore portion on the W. side of the S. part of Enklinge, in the region of the intricate welding together of the older and younger schists. The rocks show a strongly-developed stretching or rodding structure in a highly inclined position.

most part of the Enklinge Island, in a zone of strong disturbances, wedge-like portions of the older schist seem to protrude into the schist of the Enklinge series.

POST-BOTHNIAN GRANITES.

(GRANITES OF THE SECOND GROUP).

All over the region which lies E. of the rapakivi granite, and also in the south-eastern part of the area mapped, a granite is widely distributed which is younger than the schists of the Enklinge series and the basic dyke rocks associated with it and so common all over

the area of oldest schists and granites. The younger granite, which is widely distributed all over south-western Finland, everywhere penetrates the schists which have been referred to the Bothnian series and can therefore be termed post-Bothnian granite. It belongs to the second group, according to the classification of the granites of Fennoscandia proposed by the author. It has a regional extension, but seldom forms well-individualized areas; usually it is mixed with older rocks which it penetrates in the most intimate fashion. At a few places in the present area, it occurs in purer and more characteristic form and shows no migmatitic structure. The area of granite of the island of Storklyndan in the northernmost part of the region may be regarded as a typical area. Here the granite is quite homophanous, or massive, and is in some parts light gray, in others reddish. The grain varies in size. Middle-grained rocks are prevalent. It is a potash granite, very rich in microcline. A rather regular, almost horizontal jointing occurs in this granite, while more usually in these granites it is almost vertical. This granite contains dykes of a fine-to middle-grained dark rock which is richer in biotite, but has also a granitic composition. It is graded, especially nearer to the contacts, into more dioritic varieties, with a contact seam of a dark lamprophyric rock. The granite contains very large fragments of a migmatite, consisting of a schistose component and parallel dykes and veins of a granite rather similar to that which predominates in the island and which surrounds the fragment. Both granites probably belong to the same group of rocks, although the migmatite was formed at an earlier epoch of intrusion than the prevalent granite. In this migmatite, rounded nodules of quartz and sillimanite occur, both in the granitic portions, which may then be termed a nodular granite, and in the schistose components. At their contacts, too, nodules occur. These facts show that the nodules have been formed through the action of the surrounding granite and later than the migmatite. They can therefore, as has been shown in greater detail in a former paper by the writer, not be explained, according to the earlier theory, as drop-like structures due to liquation.

The granite of Storklyndan shows some similarity to granites of the second group occurring in the region around Uusikaupunki (Nystad). Such granites are, however, not very common in the region where granites of the second group predominate, because these are on the whole more migmatitic.

A more common type of these post-Bothnian granites is the granite in the north-western part of the archipelago of Kumlinge. Analysis No. 4 in Table IV, p. 30, shows its chemical composition.

It is visible N.W. of the church in promontories of the island of Kumlinge and in smaller islands more to the N.W. This Kumlinge granite is a middle-grained gray granite very like some of those varieties from the region of Uusikaupunki (Nystad) which have been exported in large quantities (so called Birkhall gray), and also the Stockholm granite, the granite of Kuru N. of Tampere (Tammerfors) and granites in the Lake Saimaa region. All these granites belong to the second group. The Kumlinge granite is quite uniform in the middle of the area, but at its margins it penetrates the surrounding schists of the island of Bärö and adjacent islands as numerous dykes, and contains a great number of fragments of the schists, forming with them intrusive breccias.

Such breccias or agmatites form the island of Skaftö which is a promontory projecting to the south from the island of Bärö, and connected with it by only a quite low isthmus. The breccia consists of an immense number of fragments of schistose rocks of varying sizes and forms which are more or less intimately penetrated by veins of granite which also form a cementing mass between the fragments. A great part of this granite has the character of a typical Kumlinge granite; aplitic and migmatitic varieties also occur. Very often the granitic veins have a distinct parallel texture along the contacts of the surrounding rock. This gneissose structure is certainly primary and not to be regarded as a mylonitic structure which has originated in a solid rock. Some gneissose veins cut others in which the granite is entirely massive, and there is no doubt that it belongs to the granite of the second group that cements the breccias. As an area of gneissose granite lies immediately W. of this island it seems rather probable that granite of the first group also occurs among the fragments. As the Kumlinge granite also shows gneissose varieties, it is rather difficult to determine whether pre-Bothnian gneissose granite also occurs as fragments in the breccia of Skaftö.

Besides the schists of the Kumlinge series, basic rocks of the same age as the porphyritic dyke rocks at the northern shore of the island of Bärö, occur as components of this migmatitic rock. Many such dykes have been extremely folded and broken into pieces while affected by the movements of the rock masses at the time the agmatite was formed. At some places migmatitic rocks with bands rich in calcite have been observed. It is difficult to describe this breccia in words so as to do full justice to its peculiar character. There is hardly any hybrid rock, consisting of more or less angular fragments and granitic veins, which is more characteristic than this. It shows almost every imaginable variety of such mixtures.

Towards the S.W. too, the Kumlinge granite has no quite definite boundaries. In the migmatite, which is here predominant, smaller areas of purer granite occasionally occur. While the Kumlinge granite has a clear gray colour, reddish varieties are more common here. On the hill S. of the village of Kumlinge where there is a monument of the war of 1808—1809, the granite consists partly of a gray and partly of a reddish variety; the two grade into each other.

At some places, as e. g. in the island of Seglinge, several varieties of granite occur of which none resembles the oldest granite. Among the granites of the second group there seem to be varieties of somewhat different ages. The pegmatites especially are often younger than the main mass of the granite. They are in any case closely associated with some variety.

In the north-easternmost part of the mapped area, granites occur which are in parts, e. g. in the islands of the north-western part of the parish of Iniö, almost as pure as the rock of the Kumlinge area. They contain, however, usually vaguely defined remnants of almost completely assimilated fragments of older rocks, and grade towards the south into migmatites.

Only in the localities mentioned do the granites of the second group show such a character that a stone mason would without any hesitation call the rock a real granite. At most other places where the younger granite occurs it has a more or less migmatitic character.

MIGMATITES.

AGMATITIC MIGMATITES CONSISTING OF GNEISSOSE GRANITE AND GRANITE OF THE SECOND GROUP.

There is a rather decided difference between the migmatites in which the older component is a granite of the first group and those in which it is a schist. The gneissose granite was split, at the time of the intrusion of the younger granite, into innumerable angular fragments. They became more or less intimately penetrated by the granite, and the quantities of both components vary. The hybrid rock, however, always retains the character of a breccia, which has on the whole an unvarying character. Only the most gneissose older granites have more easily been split along the schistosity. Then the migmatites became more similar to those veined gneisses or arterites that consist of a mixture of schists and younger granites. Even at a distance, it is often possible to discern the migmatites of the character now described from those in which the older component is schist. The latter are usually more variegated and spotted.

MIGMATITES CONSISTING OF OLDER SCHISTS AND GRANITES OF THE SECOND GROUP.

Those migmatites too, in which the older component is a schist, often show the character of breccias, containing fragments of schists, surrounded by a granitic mass. The fissures into which the granite has penetrated have, however, here more often followed the schistosity of the rock, and the penetration has often been more intimate. Where the veins lie near each other, the older rocks are entirely soaked with

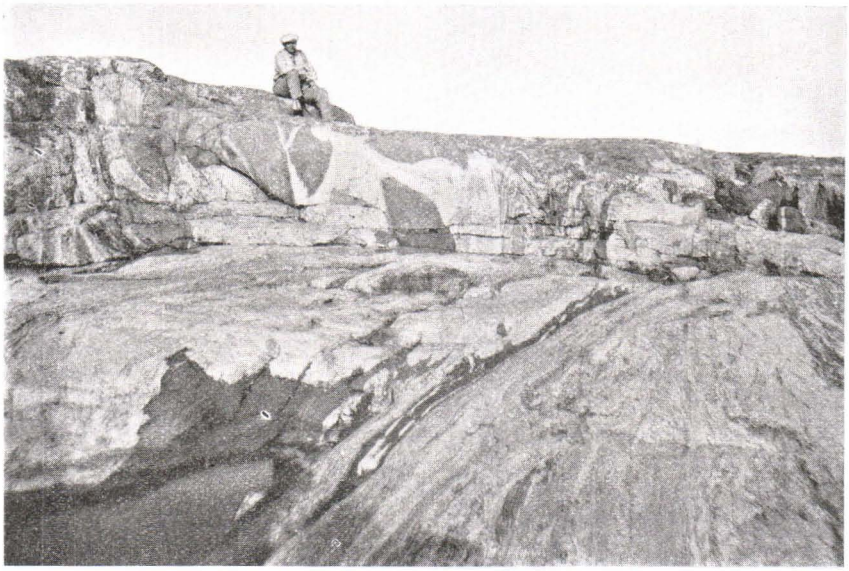

Fig. 24. Migmatite, partly agmatitic, showing different stages of the granitization of the schistose portions. Island of Norra Gåsören, N.W. of Jurmo, Brändö.

granitic magma, or ichor. These portions have often been more strongly folded, obviously while they were in a plastic state. Cases have even been observed where a migmatite, consisting of alternating stripes of schist and granitic veins, has become so plastic that it has penetrated other portions of the migmatite as if it were an igneous rock. In the most plastic portions of the migmatites, the components have been drawn out into narrow veins. In rocky islands lying next to the open sea or to some larger surface of water, these structures may be specially well studied. Such an island is Norra Gåsören, in the Hulberga Archipelago in the N.W. part of the parish of Brändö. Here we observe near to each other portions of the migmatite in which the fragments are angular — those especially have a more basic composition — and other portions which have been changed so that only indistinct light gray stripes indicate the existence of the schistose portions (Fig. 24).

Sometimes certain portions consist of a well-preserved dark schist like a mica-schist in composition and are almost free from granitic veins, while other portions in which a greater number of granitic veins occur have become enriched with feldspar and are lighter in colour.

A very interesting migmatite is seen in the islands of Bogskären N. of Kökar and E. of Sottunga. The older components consist mainly of rather basic schist, but layers of limestone also occur which lie in a direction intersecting the present strike of the migmatite at an angle of 30 degrees. In basic rocks, which have obviously originally been dykes of metabasalt that cut the schists, some granitic veins are observed arranged along the contacts of the basic dyke, while other veins, injected later, lie vertically against the contacts. The opening of the latter fissures is due to a tension in a direction different from that of the movement which caused the folding. This took place at the end of the injection of the granite.

MIGMATITES OF BOTHNIAN SCHISTS AND GRANITES OF THE SECOND GROUP.

In the island of Ängholm there are, as has already been mentioned, migmatites consisting of a mica-schist of the younger group and veins of granite. These veins often show the characteristic ptygmatic folding (Fig. 25). Besides these veins, which are intimately mixed with the schist, there are also better delimited dykes of granite in the region N. of Enklubb (cf. p. 35) in which the granite has in some places the character of the typical Kumlinge granite. Dykes of pegmatites also occur in the same region cutting the schist and sometimes the contact between schist and gneissose granite. There are further fine-grained felsitic va-

Fig. 25. Veins belonging to the Kumlinge granite and showing ptygmatic folding, cutting the Enklinge schist. Island of Ängholm, E. of Enklinge, Kumlinge.

rieties of red granite which belong to the same group and which have intimately penetrated the schist so that they often seem geologically to have more connection with it than with the granite occurring in greater quantity.

Very intimate is the penetration of granite in the western part of the island of Bockholm and S. of it. On its south-western shore occur dyke-like masses of a rock with granitic composition (cf. the analyses No. 1 and 2 in Table VI). They often show a sharp contact at one side while the rock passes by gradation into the schist at the other side. Numerous veins of quartz and hornblende, well separated from each other, also occur in the same island.

Table VI.

Analyses of the metamorphic and ultra-metamorphic rocks of Bockholm and S. of that island, Kumlinge, Åland.

Analyzed by Lauri Lokka.

1. Aplitic (»felsitic») schist, Bockholm.
2. Arkose-like schist, formed by the intimate penetration of granitic magma into mica-schist, Bockholm.
3. Schistose rock, originally a mica-schist which has become semi-eruptive in character. The small island of Bockholmsgrund, S. of Bockholm.
4. Garnet-biotite rock, formed by the enrichment of femic constituents during ultra-metamorphic processes. Bockholmsgrund, S. of Bockholm.
5. Lamprophyric rock, occurring as a dyke-like mass in ultra-metamorphic rock which looks like granite, but where traces of an original schistose composition are preserved. Hundskär, 1.5 km. S.S.E. of Bockholm.

	1		2		3		4		5	
	%	Mol. prop.	%	Mol. prop.	%	Mol. prop.	%	Mol. prop.	%	Mol. prop.
SiO_2	72.57	1 210	72.16	1 203	70.71	1 179	37.58	626	57.50	958
TiO_2	0.42	5	0.37	5	0.35	4	0.93	12	1.25	16
Al_2O_3	12.55	123	13.36	131	15.26	150	19.14	188	16.62	163
Fe_2O_3	1.41	9	0.48	3	0.40	3	3.32	21	1.67	10
FeO	3.74	52	2.95	41	3.46	48	23.11	321	7.53	105
MnO	0.03	—	Traces	—	0.01	—	0.85	12	0.16	2
MgO	0.86	22	1.79	45	1.49	37	7.45	186	2.84	71
CaO	1.09	19	3.17	57	4.24	76	0.65	12	7.39	132
Na_2O	5.84	94	2.68	43	3.04	49	0.52	8	3.74	60
K_2O	1.32	14	2.31	25	0.50	5	2.60	28	0.36	4
P_2O_5	0.09	1	0.12	1	0.12	1	0.32	2	0.08	1
H_2O+	0.41	—	0.47	—	0.55	—	3.25	—	0.63	—
H_2O-	0.11	—	0.07	—	0.15	—	0.16	—	0.13	—
	100.44		99.93		100.28		99.88		99.90	

The small island of Bockholmsgrund S. of Bockholm consists partly of a typical mica-schist, partly of a schistose rock containing much feldspar (Anal. No. 3, Table VI), and it is obvious that this rock, having here and there a semi-eruptive character, has originated by the intimate penetration of granitic magma into the schist. Some portions of the schist have become enriched with femic constituents, resulting in the composition shown by analysis No. 4 in Table VI, which rock is composed almost exclusively of biotite and garnet, while other portions of this migmatitic rock more and more approach the composition of an aplite which sometimes forms distinct dykes and veins in the darker rock. On the other hand the darker, more basic portions of the mixture also occur as dyke-like masses. There is thus no definite order of crystallization of the acid and more basic portions of this migmatite.

The same phenomena occur in still more varied forms in the island of Hundskär. Some parts of the rock masses are similar to a gneissose granite and one would be inclined to regard them as belonging to the gneissose granite outcropping N.E. of this island, but with these granitic components there are also schistose rocks, which gradually become more and more rich in biotite and approach a typical mica-schist. There are dark basic rocks of a lamprophyric character which penetrate the migmatitic rocks as distinct dykes, but, on the other hand, aplitic dykes are also common. At the southern shore of the island a curious dyke-like rock mass occurs. It has a breadth of 70 cm., but gradually narrows towards both ends, and continues as a very narrow vein consisting almost exclusively of biotite and penetrating the surrounding more gneissic rock. By movements of the rock masses this dyke has been cut by numerous faults, whereby pure quartz has crystallized along the fissures. This dyke rock has the chemical composition shown by analysis No. 5 in Table VI.

From a microscopic study of the rocks it is obvious that different minerals have alternately crystallized. So we find kerb-like aggregates of amphibole in which flakes of biotite have crystallized obliquely across streaks of amphibole displacing them and forming a kind of pseudomorphs. Obviously the crystallization of the minerals of these curious migmatites has taken place in the mass where the crystals of different minerals have formed a kind of paste with some fluid magma that was rich in ichors. Many minerals, e. g. the garnet, have replaced minerals that had crystallized earlier.

The differentiation into rocks of basic and acid composition, which has taken place here in connection with the granitization, is

in more typical forms than at any other places. This process is probably rather general although its results may in many cases have again been obliterated during the later facies of anatexis.

GRANITES OF THE THIRD GROUP.

Younger than all the migmatites that have a regional distribution, and the granites of the second group, are certain porphyritic granites which occur in the region in three different areas. The largest of them is situated immediately S.W. of the rapakivi area in the parish of Lemland. A small area of similar porphyritic granite, which was earlier probably continuous with the former area, forms, with gneissose granite, a window-like area surrounded on all sides by the rapakivi. Another smaller area of a similar porphyritic granite lies on the island of Mosshaga and adjacent islands N.W. of the island of Sottunga. A third area is that of Åva N. of Brändö.

In all these areas a porphyritic granite is the most common rock. It is in some places rather similar to the rapakivi granite and earlier has even partly been included in the same group. Rims of plagioclase surrounding the orthoclase or microcline are, however, rare. Gradations into more quartz-porphyritic rocks with micropegmatitic texture occur. Most of those granites have a red colour which is often rather dark. The quartz is often blue. A difference from the rapakivi is that these granites are always more or less sheared, in most cases, however, not in a high degree. The quartz is always crushed. The plagioclase has crystallized earlier than the potash feldspar and the biotite is a late constituent which often has a xenomorphic limit. Equigranular granites also occur, mainly as dykes or at places where this granite has penetrated older rocks.

In the Lemland area basic fragments are very common, so that in some cases they form the greatest part of the rock-mass, but they are always mixed with granitic constituents. In some cases the basic rocks show microscopically an ophitic texture, although not very clearly. They sometimes show angular fragments of a better preserved rock which then has the same character as the basic rocks associated with the oldest schists. There are also gradations between eruptive breccias consisting of angular fragments with narrow veins of granite

Fig. 26. Eruptive breccia consisting of fragments of a basic rock and a granite porphyry belonging to the Lemland granite. The most northerly of the islands of Pungö skären, Lemland.

with straight contacts (Fig. 26) and such migmatitic rocks in which the basic rock has been more or less assimilated by the granite. In some cases the granite has corroded the fragments which show forms similar to those of corroded crystals in porphyritic rocks (Fig. 27). The granitic veins may have repeatedly penetrated the fragment; sometimes again both components have been intimately mixed so that one is inclined to think that the basic rock originated by the differentiation out of the same magma.

The granite of the Lemland area clearly penetrates the adjacent gneissose granite, but is as clearly older than the rapakivi granite (Fig. 28).

The typical Lemland granite has the chemical composition shown by analysis No. 1 in Table VII.

In the Sottunga area the porphyritic granite is more sheared than in the Lemland area. It has also sometimes a coarser grain. It contains in many places great fragments of an amphibolitized basic rock which it penetrates in numerous sharply delimited dykes and veins. In some cases, as in the island of Österkobben, the granite occasionally

fills rounded cavities in the basic rock which have probably originated by the corroding action of the magma (Fig. 29, 30). The granite also contains different sized fragments of gneissose granite and of migmatite. Such a big fragment of migmatite occurs in Lamskär S. of the island of Mosshaga. The gneiss has been cut by a vein of metabasalt which is again penetrated by veins of aplites belonging to the Mosshaga granite. A little older than these veins is a dyke of reddish gray darker rock which also penetrates the main

Fig. 27. Fragments of a fine-grained basic rock in an eruptive breccia, partly corroded by the cementing porphyritic Lemland granite. The most northerly of the islands of Pungö skären, Lemland.

Fig. 28. Dyke of a fine-grained rapakivi granite cutting the Lemland granite. E. shore of the island of Pörkö, Lemland.

Fig. 29. Mosshaga granite, filling rounded cavities in a basic rock, formed by the corroding action of the granite. Island of Österkobben, Sottunga.

mass of Mosshaga granite and belongs to the suite of dyke rocks associated with it and with a composition varying between a lamprophyre and an aplite.

The most interesting of these areas of granite of the third group is that of Åva. It is circular in form with a diameter of about 7 km. It has a crater-like morphology, the greater part of this area forming a circular surface of water with only a few small islands. The strike of the surrounding older rocks follows very much the contacts of the rounded area. The predominant rock here is also a porphyritic granite (Anal. No. 2, Table VII), but this is very much mixed with other rocks. These consist partly of gneissose rocks, mainly migmatites

Fig. 30. Mosshaga granite, occurring as concretion-like rounded lumps in an older metabasite. Island of Österkobben, Sottunga.

of older schists and granites of the second group, partly also of gneissose granites in small islands in the water surface of Åva Fjärden. These big fragments of older rocks are arranged on the main periphery, but not strictly so. Next to the fragments equigranular varieties

Fig. 31. Two lamprophyric dykes in the Åva granite, cut by a vein of Åva pegmatite and faulted when the latter vein was formed. W. shore of the Åva Island, Brändö.

of the granite, partly aplitic, are more common than in other places. More basic rocks of dioritic composition also occur within this area, and have obviously a genetic connection with the granite into which they pass by gradations. Where they occur fragments of still more basic rocks are usually general, and these may also, when they are in the granite, have a narrow rim of a rock of dioritic composition

obviously formed by syntexis of a granite and a fragment. It seems possible that the dioritic rock, which occurs in great masses, may also have been formed by syntexis and thus has the same character as some of the granitized rock varieties in the Lemland area.

Very interesting are the lamprophyric dykes common in this area, which on the whole are arranged radially. One of them has a length of nearly 2 km., penetrating the surrounding gneissose

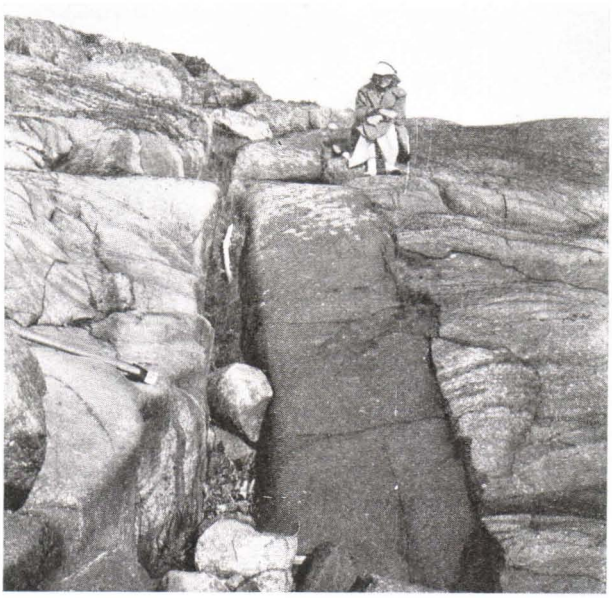

Fig. 32. The broader of the dykes shown on Fig. 31, looking towards the fault from a spot near the shore. Åva Island, Brändö.

rocks too, and many are about 200 m. long. Fig. 31 shows some of these lamprophyric dykes on the eastern shore of Åva Fjärden. The broadest dyke (Fig. 32) has a breadth of 1.8 m. These basic dykes are cut by a dyke of pegmatite which undoubtedly belongs to the Åva granite. The lamprophyric dykes have been faulted by the formation of the granitic dyke. It is thus obvious that the lamprophyre belongs to the same magma as the Åva granite. Analysis No. 3 in Table VII shows the composition of the narrower of the dykes described; its rock is homogeneous, while the broadest dyke contains numerous small tail-like strips of aplitic granite. Another lamprophyric dyke farther to the north contains a greater number of aplitic veins which have penetrated after the formation of basic dykes and also pervade the surrounding rock. The whole rock mass became plastic by the action of this aplitic granite and the dyke was folded.

Table VII.

1. Granite (Lemland granite). Nyhamn, Lemland, Åland.
   Analyzed by Lauri Lokka.
2. Granite (Åva granite). Quarry N.W. of the village of Åva, Brändö, Åland.
   Analyzed Elsa Ståhlberg.
3. Lamprophyre belonging to Åva granite. E. shore of Åva Fjärden, N.W. of the village of Åva, Brändö, Åland.
   Analyzed by Elsa Ståhlberg.

	1		2		3	
	%	Mol. prop.	%	Mol. prop.	%	Mol. prop.
SiO_2	70.80	1 160	72.63	1 211	47.73	796
TiO_2	0.96	12	0.29	4	1.91	24
Al_2O_3	13.53	133	13.33	131	15.86	155
Fe_2O_3	0.89	6	0.72	5	4.31	27
FeO	1.60	22	1.72	24	5.89	82
MnO	0.02	—	0.04	1	0.18	3
MgO	1.02	26	0.63	16	5.36	134
CaO	1.46	26	1.88	34	7.56	135
Na_2O	2.88	46	3.07	50	2.06	33
K_2O	5.70	61	4.82	51	5.10	54
P_2O_5	0.22	2	0.19	1	1.35	10
H_2O+	0.63	—	0.31	—	0.68	—
H_2O-	0.22	—		—		—
BaO	—	—	0.08	—	0.43	—
SrO	—	—	0.00	—	0.24	—
CO_2	—	—	0.21	—	0.29	—
S	—	—	0.11	—	0.42	—
Cl	—	—	0.09	—	0.07	—
	99.93		100.12		99.44	

A similar dyke in Långskär at the opposite side of Åva Fjärden cuts both the adjacent migmatite (Fig. 33) and the Åva granite.

Fig. 33. Dyke of Åva lamprophyre cutting a migmatite. Island of Långskär, W. side of Åva Fjärden, Brändö.

More to the east it ends abruptly, penetrated by aplitic granite belonging to the same magma and forming with the dyke a kind of breccia.

A narrow dyke in Gonskär on the southern shore of Åva Fjärden has a schistosity which is oblique towards the contacts of the dyke and shows that movements also took place after the formation of the lamprophyric dyke.

The composition of the more typical basic dykes associated with the granite is rather like that of a diabase or metabasalt. The lamprophyric rocks are, however, richer in potash, containing twice as much potash as soda. There are, however, also dykes belonging to the same suite which have a more acid composition passing into diorites or syenites. Some of these more acid dykes and veins are extremely folded and cut by a number of faults and granitic veins, and it seems as if they had in parts been earlier more basic, but have been changed by being soaked by granitic ichor.

The basic dyke rocks occur in such great quantities as seem to indicate that femic minerals in the granite crystallized at a late date. There may therefore have circulated in the rock magma remnants rich in femic constituents which were drained off when fissures were formed in the older crystallized portions of the rock masses. The intimate association between lamprophyre and aplite which is found here, but is rare in the same dyke, shows that they may have crystallized simultaneously. A fractionation of either the basic or the acid constituents led to the formation of these different dyke rocks. It is not absolutely necessary to imagine that all minerals crystallized freely floating in a magma. They may also have replaced portions of the rock more or less completely, thus changing its composition. It is also possible that the assimilation of older basic rocks contributed to the formation of this more basic portion of magma. There are in the contact breccias of the Åva granite fragments of older rocks of quite the same composition as the lamprophyric dykes.

All round the Åva area dykes of porphyritic granite are very common. Most of them follow the strike of the surrounding schistose rocks. Broad belts of Åva granite are thus numerous in the eastern part of the island of Åva and the middle part of the island of Bolmö. On the southern side of the Åva area dykes and veins of the Åva granite occur everywhere in the northern parts of the islands of Norrholm and Björnholm and the adjacent islands. In Norrholm dykes of porphyritic granite are very common in the northern part and follow the strike of the gneissose granite. In the promontories of the western shore of that island the contact relations of the Åva

granite and older granites are well seen. The dykes of the former granite clearly intersect veins of the granite of the second group in the gneissose granite. Some dykes of Åva granite have a quartz-porphyritic character although the texture is not quite typical.

In the northern part of the Åva area, in the middle island of the Rönnkobbarna occur two dykes of porphyritic granite quite similar to the granite of the Åva area, but very much sheared by a tectonic movement which took place only within these dykes. A little more to the south there is a dyke of quartz-porphyry 8—12 m. broad, and striking N. 40° E. It can also be seen in the next island towards the E. This rock has a certain similarity to the rapakivi quartz-porphyries, but shows some small influence of tectonic movement. — These porphyritic varieties are partly earlier than the main mass of granite, as shown in places by fragments of quartz-porphyry in a typical granite (Fig. 34).

Fig. 34. Fragment of a rapakivi-like porphyritic variety of the Åva granite, lying in the main granite. W. shore of the Åva Island, Brändö.

Similar quartz-porphyries have been found also S.W. of the Åva area. In the island of Utterklobb (N. of Björkö in the parish of Kumlinge) a dyke of quartz-porphyry cuts the older rocks in a direction N. 35° E., and is continued in the island of Ramsholm more to the N.E. The breadth of this dyke is about 4 m. In Utterklobb it has a grayish colour and is rather highly metamorphic. The quartz crystals are in parts drawn out, so that the rock may be referred to the so-called tail porphyries. In the outcrop lying more to the N.E. the rock is better preserved, especially near to the contact where it is almost aphanitic. The porphyritic crystals consist mainly of microcline and a quartz which has a blue colour. The ground mass of the rock is micro-pegmatitic. Another similar dyke of quartz-porphyry, which has a breadth of 6 m., occurs in the is-

land of Falkklobb, more to the N.N.E. It strikes N. 10° E., but is possibly a continuation of the dyke previously mentioned.

These dykes of quartz-porphyry certainly belong to the Åva granite which shows rather similar textures in some of the dykes of Norrholm.

It is of interest to note that some varieties of the quartz-porphyries occurring in these dykes are somewhat similar to the so-called Baltic porphyries (Östersjö-porfyrer) so common as glacial boulders in the regions S. and S.W. of the Baltic. It has been shown that they are derived from an area lying S.E. of the Åland Islands. It is very probable that there are sheets of effusive quartz-porphyries genetically connected with the granites of the third group at the bottom of the sea S. of the Åland Archipelago.

The Åva granite area with its rounded outline and its richness in fragments of older rocks, the more basic varieties and the lamprophyric dykes radiating from the centre of the area, shows a very interesting example of a granitic magma working itself upwards. The surrounding rocks are in many parts orientated along the margins of the granitic area. The general strike of the older rock masses S. and S.W. of the granitic area is N.W. and N.N.W., while the strike N. of the area is more W.—E. direction. The strikes in the Åva Islands follow the periphery of the granitic area, and they seem to have been re-arranged by the intrusion of the magma. The small islands S. and S.E. of the Åva Island have very varied strikes so it seems probable that the rock masses here form a mosaic of migmatite striking in different directions. The fragments of gneissose granite next to the southern contact are all orientated along the periphery of the granitic area, but in the N.W. part of the area we again find very varied strikes in the fragment-like portions of gneissose rocks in and next to the granite. A very detailed investigation of the tectonics of this granitic area connected with the petrological study of the interesting rocks would probably reveal new important facts.

The granites of the third group in the region now being described show great similarity to the Obbnäs, and in parts also to the Onas granite of the northern shore of the Gulf of Finland and the Graversfors granite near Norrköping in Sweden and many of the granites of the Småland area. All these granites are clearly younger than the surrounding migmatites which originated at the intrusion of the granites of the second group. The so-called post-Kalevian (or post-Jatulian) granites in northern Fennoscandia also show much analogy to these granites of south-western Finland.

POST-ARCHAEAN ROCKS.

While all the rocks hitherto described are more or less metamorphic because of the tectonic movements they have undergone, the youngest rocks of the same area are almost entirely devoid of traces of metamorphic action.

OSSIPITE-DIABASES.

Only the oldest of the post-Archaean rocks of that region show a slight influence of metamorphosing agencies. These are the so-called ossipite-diabases which occur as dykes of different breadths all over the region outside the area of rapakivi granite. The rock of the narrower dykes is a rather fine-grained basic rock showing an ophitic texture and consisting mainly of labradorite, enstatite-augite and ilmenite. They have usually been called »traps» by the older geologists, later also diabases. Associated with them coarse-grained rocks also occur, very rich in labradorite, in crystals measuring several centimeters, sometimes even 10—20 cm; enstatite-augite and ore also occur among them. These coarse-grained rocks have a lighter colour and are occasionally very rich in plagioclase, so that they may be called anorthosites or labradorites. In later years the name »ossipite» has been most commonly used for these rocks in Finland, but it must be remarked that the name refers only to the chemical composition and is used in the sense of Niggli. The rocks have not the mineral composition of the American ossipites.

The most coarse-grained variety of these ossipites occurs in the islands of Höggrunden in Eckerö (Fig. 35—37). They are on most sides surrounded by islands consisting of rapakivi granite, but they certainly belong to rock masses older than that. The southernmost parts of Höggrunden consist of gneissose granite, containing numerous black fragments of a middle-grained metabasitic rock belonging to the oldest supracrustal formation. These rocks are cut by dykes of granites of the second group. The ossipite cuts them all at the contact and also sends out apophyses of fine-grained diabase which cut all the older rocks. Next to the contact with the gneissose granite there is in some places a narrow zone of fine-grained aplite which also penetrates the ossipite and is the last crystallized residuum of its magma. — Two varieties of the ossipite of the easterly one of the islands of Höggrunden were analyzed, and the results are given in Table VIII. The first rock is a typical ossipite, the latter one consists mostly of labradorite and approaches an anorthosite in composition.

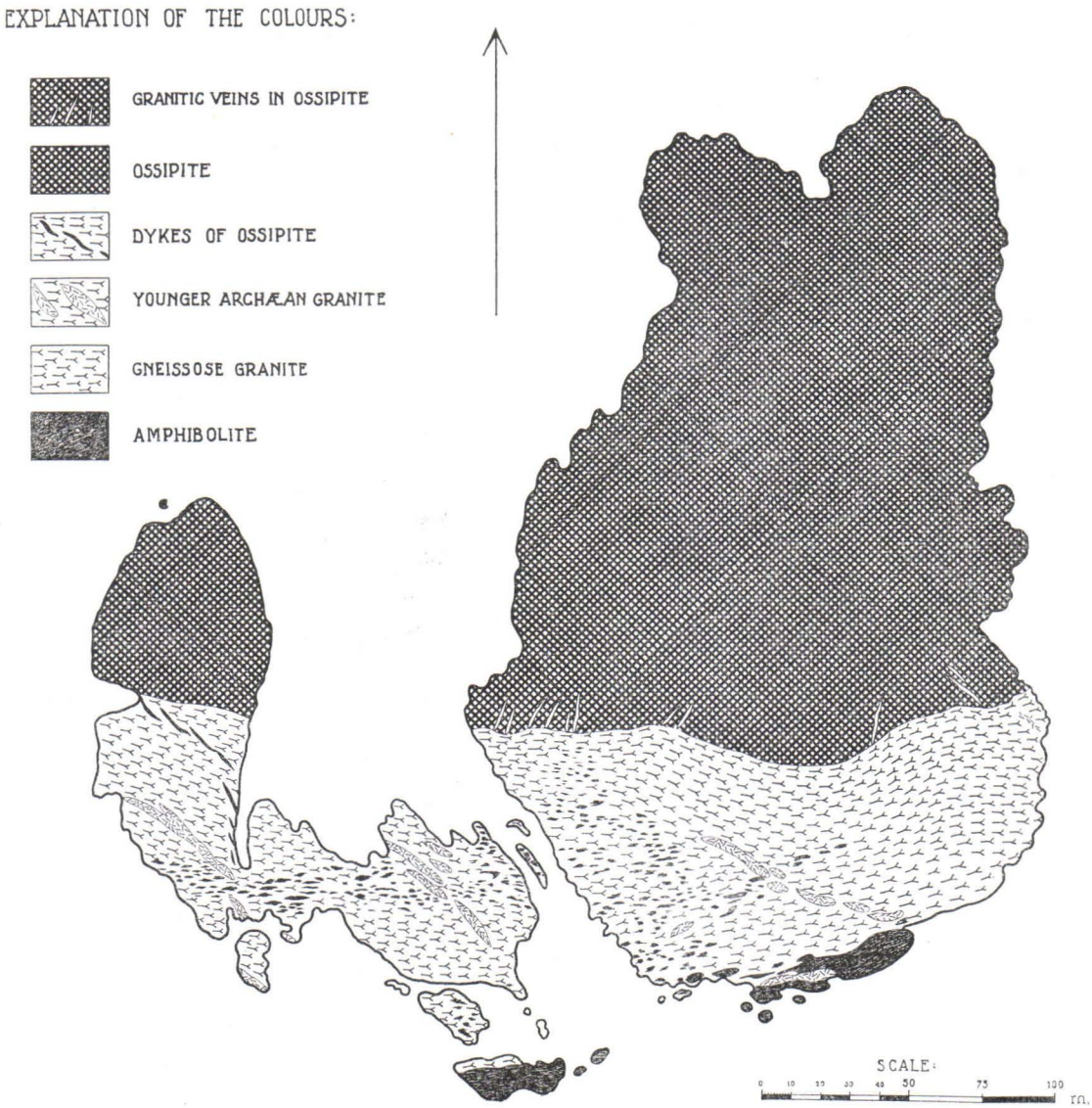

Fig. 35. Map of the islands of Höggrunden, Eckerö.

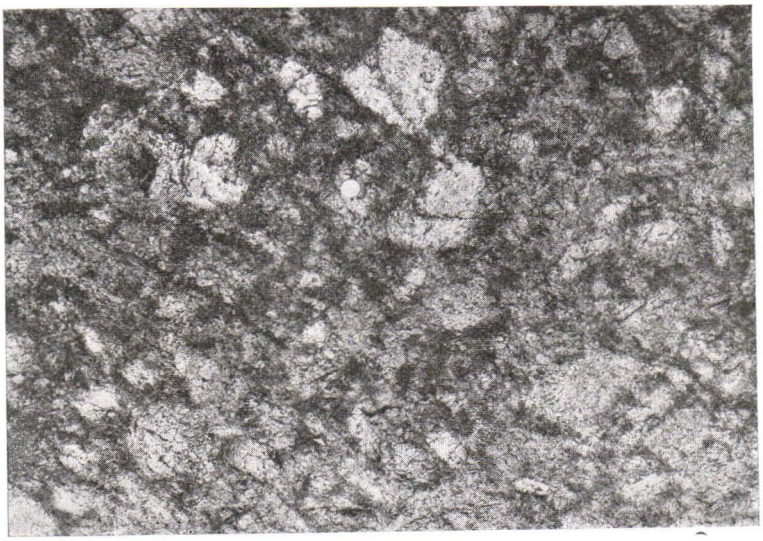

Fig. 36. Very coarse-grained ossipite. Höggrund, Eckerö. 1 : 6.

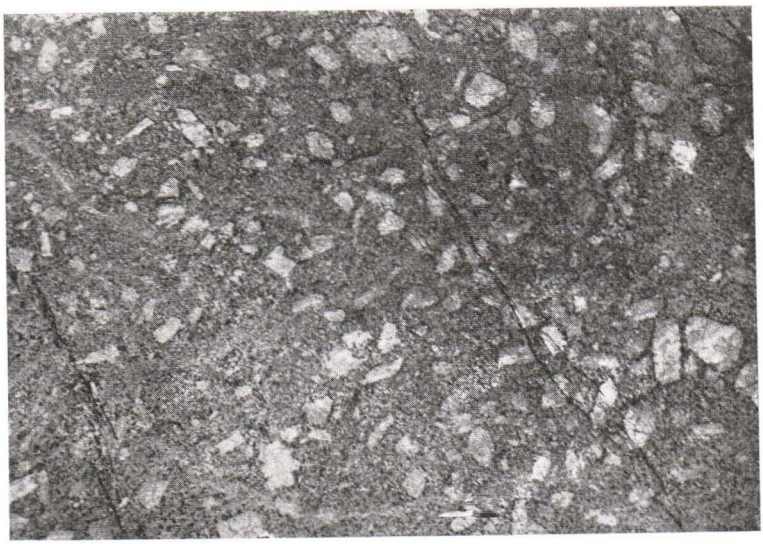

Fig. 37. Ossipite showing porphyritic labradorite crystals. Island of Öster Höggrund, Eckerö.

Table VIII.

1. Ossipite diabase, Öster Höggrund, Eckerö, Åland.
2. Anorthosite, connected with the ossipite diabase. Öster Höggrund, Eckerö, Åland.

Analyzed by Lauri Lokka.

	1		2	
	%	Mol. prop.	%	Mol. prop.
SiO_2	50.94	849	49.14	819
TiO_2	2.50	31	0.40	5
Al_2O_3	19.66	193	27.98	274
Fe_2O_3	2.58	16	1.19	7
FeO	6.14	85	1.66	23
MnO	0.07	1	0.01	—
MgO	2.13	53	1.96	49
CaO	10.20	182	13.18	235
Na_2O	3.02	49	2.46	40
K_2O	0.90	10	0.66	7
P_2O_5	0.28	2	0.15	1
H_2O+	1.40	—	0.85	—
H_2O-	0.06	—	0.14	—
	99.88		99.78	

Near to Skeppsvik in Eckerö there are several dykes of the same rocks.

The island of Storklobb or Notklobb (Fig. 38) consists mainly of an old amphibolite or metabasite penetrated by gneissose granite.

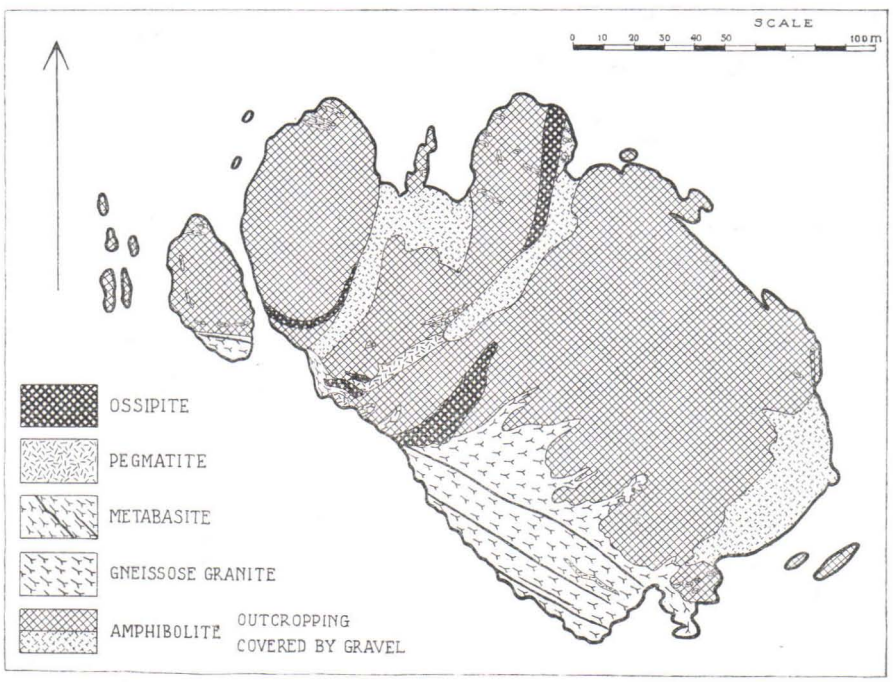

Fig. 38. Map of the island of Notklobb, Eckerö.

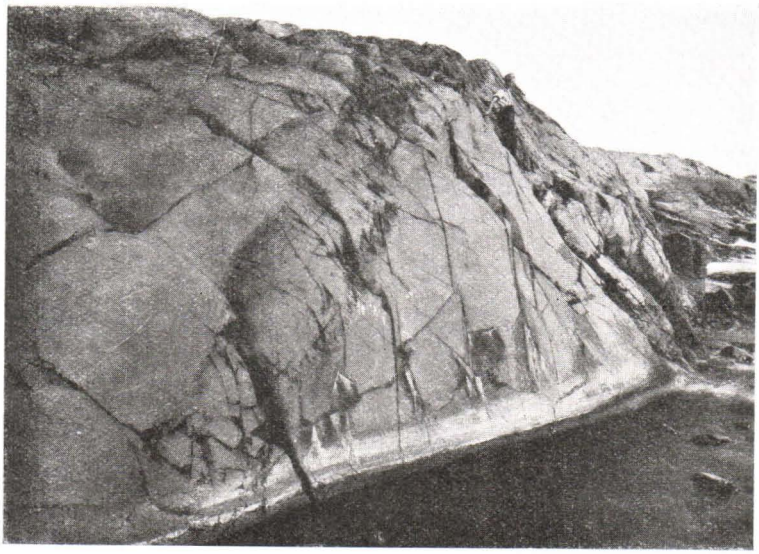

Fig. 39. Gently-dipping dyke of ossipite in an old amphibolite. Seen from the westerly, smaller island on Fig. 38. Island of Notklobb, Eckerö.

In this rock we again find some narrow veins of metabasite which is probably of the same age as the Bothnian metabasaltic dykes. Some broad dykes of pegmatite cut the older metabasite. Younger than all these rocks are dykes of ossipite which occur at several places (cf. Fig. 39). They lie at an inclination of about 30° towards north. In the eastern broader dyke very big crystals of labradorite occur, sometimes aggregated to anorthositic masses. In another island, Trutklobben, more to the S. broad dykes of rather coarse-grained ossipite also occur. At the shore S. of Skeppsvik there is a dyke of middle-grained diabase. The fissure is very irregular in form (Fig. 40). Farther to the S. we again find off the western shore of

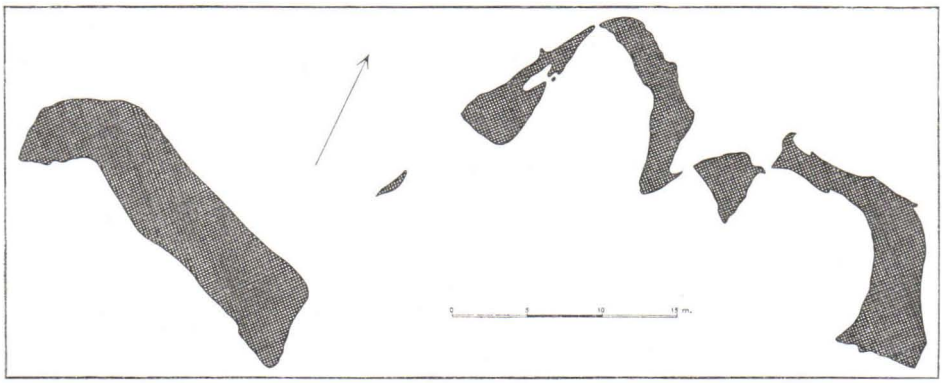

Fig. 40. Very irregular, faulted dyke of ossipite in the gneissose granite. Skeppsvik, Eckerö.

the island of Eckerö, a small island called Blåklobben which mostly consists of ossipite. It is here porphyritic with big crystals of labradorite in a middle-grained ground mass. In the S.E. we find gneissose granite cut by a narrow dyke of diabase which is an apophyse from the ossipite. On the S.W. shore, the ossipite is cut by a quartz-porphyry belonging to the rapakivi. The contact is irregular and the

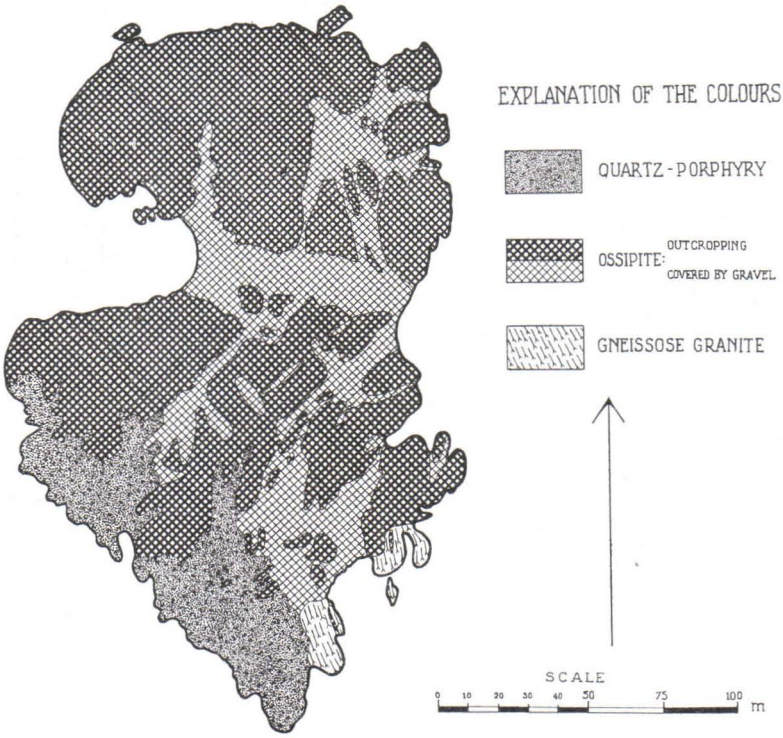

Fig. 41. Map of the island of Blåklobb, Eckerö.

older rock has been brecciated next to it and is penetrated by numerous veins of the porphyry (Fig. 41).

In the islands S.E. of Eckerö ossipitic rocks occur in several places. The whole of the little island of Västersten is composed of a rather coarse-grained rock rich in labradorite. Some portions have the composition of an anorthosite. On the western shore of Båkenskär a dyke of trap occurs. N. of it a broader dyke is visible and on the north-western shore a third dyke which is very irregular in form, the magma having filled out cavities between blocks that were faulted at the time of the opening of the fissure.

The basic dyke S. of Hammarudda mentioned by Frosterus[1] is a metabasalt, probably of Bothnian age.

In the area of Lemland granite no ossipitic dykes have been observed, but there is no doubt that the basic rock is younger than the granite.

The biggest outcrop of the rocks in question is in the archipelago S.E. of Föglö where it is found in a number of islands, the biggest of which has a breadth of 300 m. The direction of this broad dyke is N. 30—35° E. The predominant rock has a rather coarse-grained texture. It consists of broad laths of plagioclase about 3 cm. long, enstatite-augite, and ore. In Källsholm in the northern part of this dyke porphyritic varieties also occur with big feldspars in a rather coarse-grained ground mass. Besides the predominant rock of this dyke, of a grayish green colour, light red varieties also occur, although in small quantities, containing orthoclase and quartz, in some cases epidote too. They were formed by the consolidation of the last residuals of the magma in which the salic parts have segregated.

In northern Sottunga there are also several dykes of these more coarse-grained varieties of the ossipite-diabases. One of them outcropping in the little island of Norrgrund is very much mixed with a light granitic rock which penetrates the prevalent basic rock and is the last crystallized acid part of the same magma.

Another dyke of a similar rock forms the most north-westerly promontory of the island of Sottunga. At the contact with the migmatite on the southern side a fine-grained contact zone occurs and next to it there is a stripe rich in plagioclase crystals. Narrow veins of a granitic rock penetrate the diabase at the contact. The impression it gives is that the granite S. of it is younger, but it is only an acid part of the ossipite magma. All these dykes strike N. 45° E.

Farther to the S.E., S. of the island of Busö a dyke has been observed striking N. 45° E., and others N. 35° E. and N. 20° E. in the island of Dömmarskär in northern Kökar. They are fine-grained and have a breadth of 0.3—1.2 m.

In Kumlinge similar dykes are very common. They have been noticed in Ingersholm striking N. 40° E., N.W. of the church N. 35° E., in an island N.W. of the Kumlinge island N. 35° E. and in Långskär N. 45° E. In the Enklinge island two long dykes have a strike of N. 35° E. In Högholm, Långörn and Ljungskär there are 4—5 parallel dykes lying near each other which all strike N. 45° E.

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[1] Benj. Frosterus, Beskrifning till Kartbladet N:o 21, Mariehamn. 1892, p. 18.

Farther to the S.E. in the islands of Degerbrok and Långbrok there are four dykes striking N. 40—50° E., and one in the Gunnarskären N. 45° E. E. of the island of Lappo there are in Bärö four dykes N. 40° E., N.W. of the island of Öster Bergholm N. 45° E.

E. of the area shown in the map the predominant direction of the dykes of trap is also N.E. Very few have the direction E.—W., and two narrow veins have been observed running N.—N.E., but this is a local deviation from the general direction.

There are pronounced geomorphological features, straight lines which limit the different groups of islands and often run channel-like through the archipelago for a considerable distance, but these never follow the predominant direction of the trap-dykes, but are arranged in N.—N.W. and N.—N.E. directions. The assumption by several geologists that the most pronounced fissure lines in middle Fennoscandia originated at the time of the eruption of the ossipite-diabases, is not in agreement with the facts observed in this region.

While most of the rocks of the dykes in question show primary pyroxene, most of the narrow dykes in which the rock is fine-grained, next to the contacts even aphanitic, contain green hornblende which is obviously a secondary mineral. Thus these rocks are not entirely devoid of metamorphic phenomena.

These basic rocks have at several places shown a very close association with the rapakivi granite as to distribution. Thus we find them in the Ångermanland area in Sweden, in the Jaala—Mäntyharju area in Finland, where the basic rocks form the outher portion of the area while the rapakivi granite outcrops mainly in the middle, and also in connection with rapakivi in southern Russia where a coarse anorthositic rock, very similar to those of Fennoscandia, occurs in outcrops next to the rapakivi.

In the region now under discussion there is, however, no close association between the rapakivi granite and the basic rocks as regards distribution. On the contrary the latter form well-defined dykes cutting the older rocks, while rapakivi granite forms rounded areas of great extension, the contacts of which cut the basic dykes as well as all rocks older than these. Tectonically the rocks differ very much in character and there must be a marked difference in age, although the association in other regions shows that there may be a certain connection lower down.

RAPAKIVI GRANITES.

The rapakivi granites have the greatest distribution all over the region. The big Åland area measures at least 10 000 sq.km.

It is only when shown on a petrological map, where no account is taken to the distribution of land and water, that an adequate idea of its size is obtained. If the islands only are marked with the colour indicating the rocks, we get the impression that it is much smaller. Only at a few places in this area are there small outcrops of rocks younger than the rapakivi. In great parts of it the so-called Åland rapakivi is the predominant rock. This is a reddish brown rock showing the peculiar rapakivi texture characterized by round crystals of orthoclase more or less intergrown with quartz and surrounded by a shell of plagioclase which on the surface is visible as light-coloured and oval-shaped rings. The ground mass between these feldspar ovoids consists of feldspar, quartz and biotite, the last of which has very often crystallized later than the main part of the others. There are varieties in which the difference between rounded porphyritic crystals and the ground mass is not well pronounced. They have been called granitic rapakivi, but it is difficult to distinguish between them in the field because they rapidly and irregularly pass into each other by gradations. They are therefore on this map marked with the same colour.

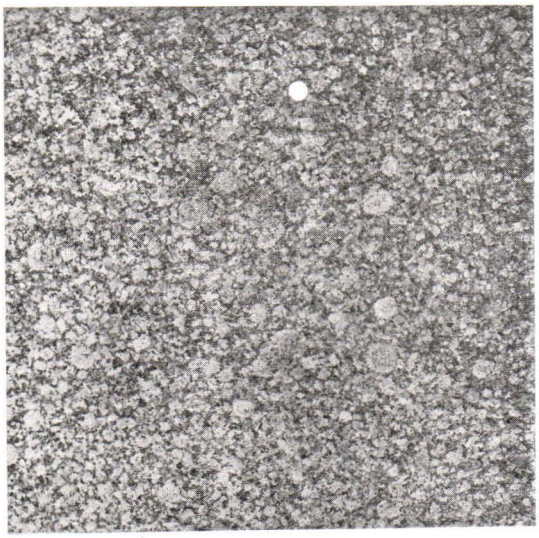

Fig. 42. Coarse variety of the rapakivi of the Åland area, like the main rock of the rapakivi area of Vehmaa. Islands N.W. of Enklinge, Kumlinge.

In the north-eastern part of the area, the Åland rapakivi in which the feldspar ovoids are very small, seldom more than 1 cm, gradually passes into a more coarse-grained rock in which the ovoids have a size of about 2 cm. (Fig. 42). It is rather similar to some of the predominant varieties in the Vehmaa area in the north-eastern part of the region mapped, but rocks of different character are here more general. On the map all rapakivis of the Åland area are shown with the same colour, different from that of the Vehmaa rapakivi.

On the other hand the Åland rapakivi passes gradually into quartz-porphyritic rocks. They occur especially in the S.W. margin next to the contact, for instance in the islands of Pepparn and Båkenskär and in Hammarudda, further — as already mentioned — in the little island of Blåklobb in Eckerö. This quartz-porphyry has a wonderful fluidal texture. It certainly solidified very near the surface of the earth. In the region of Emkarby there is a quartz-porphyritic rock with crystals of blue quartz. The ground masses here are a little less fine-grained than in the other varieties.

Among the other granitic rocks of this area the so-called Haga granite is rather well defined; it is middle-grained, red, and equigranular, and consists mainly of rather idiomorphic quartz, red orthoclase with some plagioclase and biotite. It has a rather sharp contact towards the rapakivi which it penetrates. Another more fine-grained granite also occurs in some smaller areas within the rapakivi and as dykes cutting it.

At one place on the S.E. shore of Lumparn Fjärden, N. of Lumparsund in Lumparland, Eskola has observed a narrow dyke of a lamprophyric rock cutting the rapakivi. Microscopically it gives the impression that its numerous small flakes of biotite crystallized in the consolidated mass of the other minerals, partly replacing them.

Dykes of pegmatite do not occur in the Åland rapakivi. Rocks, which may be called aplites, are also on the whole lacking. In a few cases the youngest granite occuring as dykes in veins may be similar to an aplitic granite; only in one case is there a dyke of gray granite. Pneumatolytic agencies caused a removal of the red colour characteristic of the Åland rapakivi. In the north-easternmost part of the area, where the rapakivi is similar to that of the Vehmaa area, gray porphyritic rocks with an abundant ground mass also occur.

The rapakivi granites of the Åland area have usually a very regular jointing. The most common fissures are nearly horizontal and lie, especially in the finer-grained rocks, very near to each other so that in quarrying it is difficult to get blocks thicker than 0.3 m. Vertical fissures also occur perpendicular to each other and to the horizontal jointing. The rocks are therefore subdivided into parallelipipedic blocks, and the rock slopes often show terraces at regular intervals. The most fine-grained rocks are more fissured than the others, subdivided into a number of smaller angular blocks.

The red colour and irregular forms of the hills, often steep on one side, make the archipelago of Åland very beautiful.

In the north-eastern corner of the region mapped lies the most westerly part of the Vehmaa area of rapakivi. Most of it

consists of a rather coarse-grained porphyritic rock similar to that of the north-eastern part of the Åland area, but still a little coarser and often somewhat richer in ground mass. Varieties with a reddish brown colour are most common, but grayish varieties sometimes occur. In the northernmost part of Skataudd N.W. of Lypertö there are also fine-grained varieties sometimes entirely equigranular, sometimes containing sparsely distributed rounded crystals of feldspar. N. of Lypertö in the north-westernmost promontory of Kattkuru a contact with older migmatitic rocks is observed. The migmatite is

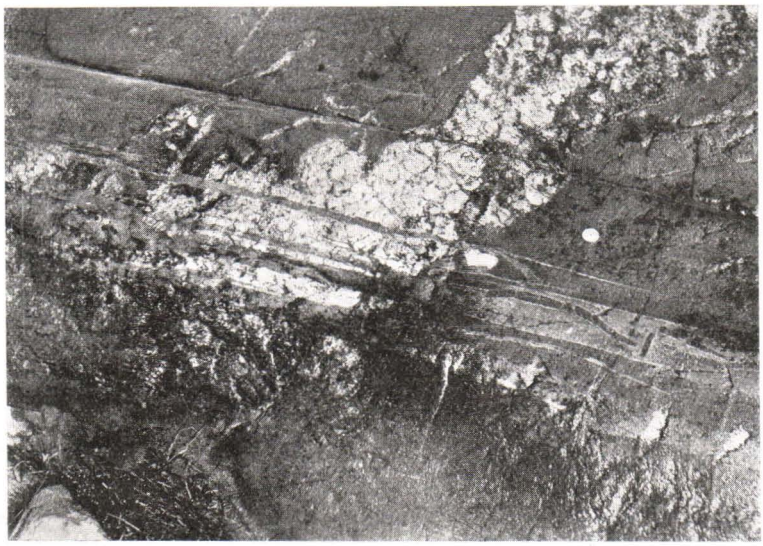

Fig. 43. Straight veins of the rapakivi granite of the Vehmaa area, cutting a migmatite. S. W. of the island of Lypertö, Kustavi.

subdivided into numerous fragments cemented by fine-grained aplitic rapakivi granite. In the northernmost part of Skataudd too, contacts of rapakivi granite and migmatite are visible.

In Malmö N.W. of the island of Korra the main contact between the rapakivi and the older rocks is also visible. In the S. there is a rather typical rapakivi with a sharp contact towards the gneiss. On the north-eastern shore of the island there are aplitic varieties of the rapakivi as dykes in the gneiss. Some of these dykes have a dark lamprophyric border zone not very basic in its composition. In one rock a rapakivi-aplite has filled several quite narrow, rectilineal fissures (Fig. 43). In the small island N. of Malö too the contact of the older rocks and the rapakivi granite, here coarse-porphyritic, is visible.

In the island S.W. of Korra the contact between the rapakivi and the gneiss can be seen all along the middle part of the island. In Storskär the most northerly promontory consist of gneiss, while most of the island is rapakivi. Finally there is a contact between rapakivi and the older rocks in those promontories of the island of Osnäs which lie nearest to the island of Poskär. The rapakivi sends out some apophyses cementing a breccia of fragments of the older rock.

In Kökars Fjärden, W. and S.W. of the island of Kökar, several small islands of a rapakivi granite occur. In the northernmost island of Norrharun it is a rather coarse-grained rapakivi containing several fragments of gneissose granite. This rock resembles the rapakivi of the Viipuri (Viborg) area or that near to Uusikaupunki (Nystad) more than the Åland rapakivi. In the island of Söderharun the rock has even greater resemblance to the typical rapakivi. On the island of Ändör and an adjacent island the rock is a granite-porphyry such as are common in connection with the rapakivi rocks.

In Fåfänggadd and Målsör the rock is a rather coarse-grained rapakivi granite in which the orthoclase crystals are not surrounded by a shell of plagioclase. This rock is rather similar to the rapakivi granite of Pyterlahti in the region of Viipuri (Viborg) which has been used extensively as building-stone in Petersburg.

Finally the island of Karlbybådan and some neighbouring small islands in the Baltic Sea consist of a similar coarse-grained rapakivi granite. As no islands lie between these two outcrops of rapakivi granites in the Kökar Fjärden it is difficult to say whether they belong to one area or two different areas.

In Table IX there are analyses of some representatives of rapakivi rocks occurring within the present area.

OLIVINE-DIABASES.

The islands of Märket and Sankan in the Åland Sea consist of an olivine-diabase with ophitic texture consisting of laths of labradorite interspersed with augite, olivine and ilmenite. The same rock, although a little less coarse-grained, occurs in the small island N. of Skeppsvik in Eckerö among the Åland Islands. It lies within the area of rapakivi granite and is certainly younger than that because it is found as dykes penetrating it at several places on the shore of the Gulf of Bothnia.

Table IX.

1. Rapakivi (Vehmaa Rapakivi). Katanniemi (Skataudd), Lypertö Kustavi.
   Analyzed by Lauri Lokka.
2. Rapakivi granite (Åland Rapakivi). Haraldsby, Saltvik, Åland.
   Analyzed by Naima Sahlbom.
3. Quartz-porphyry belonging to Åland Rapakivi. Blåklobben, Eckerö, Åland.
   Analyzed by Lauri Lokka.

	1		2		3	
	%	Mol. prop.	%	Mol. prop.	%	Mol. prop.
SiO_2	71.21	1 187	70.56	1 176	77.35	1 289
TiO_2	0.65	8	0.44	6	0.19	2
Al_2O_3	12.09	119	12.27	121	11.08	109
Fe_2O_3	0.80	5	2.74	17	1.28	8
FeO	3.89	54	2.93	40	0.50	7
MnO	0.08	1	0.14	1	0.04	1
MgO	0.12	3	0.65	16	0.22	6
CaO	1.61	29	1.87	34	0.39	7
Na_2O	3.39	55	3.20	52	2.84	46
K_2O	5.10	54	4.92	52	5.42	58
P_2O_5	0.24	2	0.13	1	0.09	1
H_2O+	0.76		0.60		0.37	
H_2O-	0.24				0.09	
BaO	0.11	—	—	—	—	—
ZrO_2	0.09	—	—	—	—	—
F	0.20	—	—	—	—	—
	100.58		100.45		99.86	

CAMBRIAN SANDSTONE.

Near to Långbergsöda in north-eastern Saltvik there are dykes of a grayish sandstone in which Tanner[1] has found fossils, among them a new species of Brachiopods called *Acrotreta Tanneri*. Similar, though very narrow, veins of sandstone are common in the rapakivi rocks in the north-eastern part of the area, e. g. in the islands of Bredan and Venningbådan. The occurrence of these dykes of sandstone, which are found at several places in south-western Finland and middle Sweden where they have yielded some Cambrian fossils, is of interest because it clearly defines the age of the rapakivi granite. Moreover the Jotnian sandstone in the Satakunta area and in Ångermanland in Sweden has also been directly superposed on the rapakivi granite which is thus not only late pre-Cambrian, but pre-Jotnian in age. In the present region no outcrops of Jotnian sand-

[1] V. Tanner, Über eine Gangformation von fossilienführendem Sandstein auf der Halbinsel Långbergsöda-Öjen im Kirchspiel Saltvik, Åland-Inseln. Bull. Comm. géol. Finl., N:o 25, 1911.

stones have been found, but in the little island of Rödakon in Lumparn a breccia was found by Dr. Asklund[1] who has studied the Jotnian area of middle Sweden. According to him it is similar to the basal breccias of the Jotnian in other areas. It consists only of angular fragments of rapakivi cemented by a rather coarse gravel of smaller, angular fragments.

ORDOVICIAN LIMESTONE.

In the northern part of the Lumparn Fjärden in Åland, near to the promontory called Tranviks Udd, there is a small rock of limestone usually under water, but visible at exceptional low water. It was first observed by Dr. Asklund, whose attention had been called to it by the people of the neighbourhood. The rock is of Ordovician limestone like that common as blocks both in the Åland area and especially S.E. of Lumparn Fjärden and in the northernmost part of the archipelago. To determine the thickness of the limestone it was diamond drilled, but this met with several difficulties especially as the limestone alternated below with a brownish clay that was not entirely consolidated and offered great resistance to the drilling. In any case it has been clearly proved that the limestone outcrops at this place. It lies obviously in a hollow limited by faults. This is the youngest rock observed in the region under discussion.

[1] B. Asklund och O. Kulling, Nya data till Ålands geologi (With a Summary in English). Geol. Fören. Stockh. Förh., Bd. 48, 1926, pp. 498—511.

Fascicules parus du Bulletin de la Commission géologique de Finlande.

N:o 1. Cancrinitsyenit und einige v erwandte Gesteine aus Kuolajärvi, von WILHELM RAMSAY und E. T. NYHOLM. Mit 4 Figuren im Text. Mai 1896 ..... 15: —

N:o 2. Ueber einen metamorphosirten präcambrischen Quarzporphyr von Karvia in der Provinz Åbo, von J. J. SEDERHOLM. Mit 12 Figuren im Text. Dec. 1895 15: —

N:o 3. Till frågan om det senglaciala hafvets utbredning i Södra Finland, af WILHELM RAMSAY, jemte Bihang 1 och 2 af VICTOR HACKMAN och 3 af J. J. SEDERHOLM. Med en karta. Résumé en français: La transgression de l'ancienne mer glaciaire sur la Finlande méridionale. Febr. 1896 ..... 25: —

N:o 4. Ueber einen neuen Kugelgranit von Kangasniemi in Finnland, von BENJ. FROSTERUS. Mit 2 Tafeln und 11 Figuren im Text. April 1896 ..... 20: —

N:o 5. Bidrag till kännedom om Södra Finlands kvartära nivåförändringar, af HUGO BERGHELL. Med 1 karta, 1 plansch och 16 figurer i texten. Deutsches Referat: Beiträge zur Kenntnis der quartären Niveauschwankungen Süd-Finnlands. Mai 1896 ..... 30: —

* N:o 6. Über eine archäische Sedimentformation im südwestlichen Finnland und ihre Bedeutung für die Erklärung der Entstehungsweise des Grundgebirges, von J. J. SEDERHOLM. Mit 2 Karten, 5 Tafeln und 96 Figuren im Text. Febr. 1899 75: —

N:o 7. Über Strandbildungen des Litorinameeres auf der Insel Mantsinsaari, von JULIUS AILIO. Mit 1 Karte und 8 Figuren im Text. April 1898 ..... 25: —

N:o 8. Studier öfver Finlands torfmossar och fossila kvartärflora, af GUNNAR ANDERSSON. Med 21 figurer i texten och 216 figurer å 4 taflor. Deutsches Referat: Studien über die Torfmoore und die fossile Quartärflora Finnlands. Dec. 1899 60: —

N:o 9. Esquisse hypsométrique de la Finlande, par J. J. SEDERHOLM. Avec 1 carte. Nov. 1899 ..... 25: —

N:o 10. Les dépôts quaternaires en Finlande, par J. J. SEDERHOLM. Avec 2 figures dans le texte et 1 carte. Nov. 1899 ..... 25: —

* N:o 11. Neue Mitteilungen über das Ijolithmassiv in Kuusamo, von VICTOR HACKMAN. Mit 2 Karten, 12 Figuren im Text und 4 Figuren auf einer Tafel. März 1900 25: —

* N:o 12. Der Meteorit von Bjurböle bei Borgå, von WILHELM RAMSAY und L. H. BORGSTRÖM. Mit 20 Figuren im Text. März 1902 ..... 20: —

* N:o 13. Bergbyggnaden i sydöstra Finland, af BENJ. FROSTERUS. Med 1 färglagd karta, 9 taflor och 18 figurer i texten. Deutsches Referat: Der Gesteinsaufbau des südöstlichen Finnland. Juli 1902 ..... 70: —

N:o 14. Die Meteoriten von Hvittis und Marjalahti, von LEON. H. BORGSTRÖM. Mit 8 Tafeln. April 1903 ..... 25: —

N:o 15. Die chemische Beschaffenheit von Eruptivgesteinen Finnlands und der Halbinsel Kola im Lichte des neuen amerikanischen Systemes, von VICTOR HACKMAN. Mit 3 Tabellen. April 1905 ..... 30: —

N:o 16. On the Cancrinite-Syenite from Kuolajärvi and a Related Dike rock, by I. G. SUNDELL. With one plate of figures. August 1905 ..... 15: —

N:o 17. On the Occurrence of Gold in Finnish Lapland, by CURT FIRCKS. With one map, 15 figures and frontispiece. Nov. 1906 ..... 20: —

N:o 18. Studier öfver Kvartärsystemet i Fennoskandias nordliga delar. I. Till frågan om Ost-Finmarkens glaciation och nivåförändringar, af V. TANNER. Med 23 bilder i texten och 6 taflor. Résumé en français: Études sur le système quaternaire dans les parties septentrionales de la Fenno-Scandia. I. Sur la glaciation et les changements de niveau du Finmark oriental. Mars 1907 ..... 50: —

* N:o 19. Die Erzlagerstätten von Pitkäranta am Ladoga-See, von OTTO TTÜSTEDT. Mit 1 Karte, 19 Tafeln und 76 Figuren im Text. November 1907 ..... 120: —

N:o 20. Zur geologischen Geschichte des Kilpisjärvi-Sees in Lappland, von V. TANNER. Mit einer Karte und zwei Tafeln. April 1907 ..... 15: —

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Out of print.

N:o 21. Studier öfver kvartärsystemet i Fennoskandias nordliga delar. II. Nya bidrag till frågan om Finmarkens glaciation och nivåförändringar, af V. Tanner. Med 6 taflor. Résumé en français: Études sur la système quaternaire dans les parties septentrionales de la Fenno-Scandia. II. Nouvelles recherches sur la glaciation et les changements de niveau du Finmark. Juni 1907 ..... 50: —

N:o 22. Granitporphyr von Östersundom, von L. H. Borgström. Mit 3 Figuren im Text und einer Tafel. Juni 1907 ..... 15: —

N:o 23. Om granit och gneis, deras uppkomst, uppträdande och utbredning inom urberget i Fennoskandia, af J. J. Sederholm. Med 8 taflor, en planteckning, en geologisk öfversiktskarta öfver Fennoskandia och 11 figurer i texten. English Summary of the Contents: On Granite and Gneiss, their Origin, Relations and Occurrence in the Pre-Cambrian Complex of Fenno-Scandia. With 8 plates a coloured plan, a geological sketch-map of Fenno-Scandia and 11 figures. Juli 1907 ..... 50: —

N:o 24. Les roches préquaternaires de la Fenno-Scandia, par J. J. Sederholm. Avec 20 figures dans le texte et une carte. Juillet 1910 ..... 25: —

N:o 25. Über eine Gangformation von fossilienführenden Sandstein auf der Halbinsel Långbergsöda-Öjen im Kirchspiel Saltvik, Åland-Inseln, von V. Tanner. Mit 2 Tafeln und 5 Fig. im Text. Mai 1911 ..... 15: —

N:o 26. Bestimmung der Alkalien in Silikaten durch Aufschliessen mittelst Chlorkalzium, von Eero Mäkinen. Mai 1911 ..... 10: —

N:o 27. Esquisse hypsométrique de la Finlande, par J. J. Sederholm. Avec une carte et 5 figures dans le texte. Juillet 1911 ..... 20: —

* N:o 28. Les roches préquaternaires de la Finlande, par J. J. Sederholm. Avec une carte. Juillet 1911 ..... 20: —

N:o 29. Les dépôts quaternaires de la Finlande, par J. J. Sederholm. Avec une carte et 5 figures dans le texte. Juillet 1911 ..... 20: —

* N:o 30. Sur la géologie quaternaire et la géomorphologie de la Fenno-Scandia, par J. J. Sederholm. Avec 13 figures dans le texte et 6 cartes. Juillet 1911 ..... 30: —

N:o 31. Undersökning af porfyrblock från sydvästra Finlands glaciala aflagringar, af H. Hausen. Mit deutschem Referat. Mars 1912 ..... 20: —

N:o 32. Studier öfver de sydfinska ledblockens spridning i Ryssland, jämte en öfversikt af is-recessionens förlopp i Ostbaltikum. Preliminärt meddelande med tvenne kartor, af H. Hausen. Mit deutschem Referat. Mars 1912 ..... 20: —

N:o 33. Kvartära nivåförändringar i östra Finland, af W. W. Wilkman. Med 9 figurer i texten. Deutsches Referat. April 1912 ..... 25: —

N:o 34. Der Meteorit von St. Michel, von L. H. Borgström. Mit 3 Tafeln und 1 Fig. im Text. August 1912 ..... 25: —

N:o 35. Die Granitpegmatite von Tammela in Finnland, von Eero Mäkinen. Mit 23 Figuren und 13 Tabellen im Text. Januar 1913 ..... 30: —

N:o 36. On Phenomena of Solution in Finnish Limestones and on Sandstone filling Cavities, by Pentti Eskola. With 15 figures in the text. February 1913 .... 25: —

N:o 37. Weitere Mitteilungen über Bruchspalten mit besonderer Beziehung zur Geomorphologie von Fennoskandia, von J. J. Sederholm. Mit einer Tafel und 27 Figuren im Text. Juni 1913 ..... 35: —

N:o 38. Studier öfver Kvartärsystemet i Fennoskandias nordliga delar. III. Om landisens rörelser och afsmältning i finska Lappland och angränsande trakter, af V. Tanner. Med 139 figurer i texten och 16 taflor. Résumé en français: Études sur le système quaternaire dans les parties septentrionales de la Fennoscandia. III. Sur la progression et le cours de la récession du glacier continental dans la Laponie finlandaise et les régions environnantes. Oktober 1915 ..... 150: —

N:o 39. Der gemischte Gang von Tuutijärvi im nördlichen Finnland, von Victor Hackman. Mit 4 Tabellen und 9 Figuren im Text. Mai 1914 ..... 20: —

N:o 40. On the Petrology of the Orijärvi region in Southwestern Finland, by Pentti Eskola. With 55 figures in the text, 27 figures on 7 plates and 2 coloured maps. October 1914 ..... 75: —

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N:o 42. Über Camptonitgänge im mittleren Finnland, von Victor Hackman. Mit 3 Figuren im Text. Aug. 1914 ..... 15: —

N:o 43. Kaleviska bottenbildningar vid Mölönjärvi, af W. W. Wilkman. Med 11 figurer i texten. Résumé en français. Januari 1915 ..... 20: —

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N:o 44. Om sambandet mellan kemisk och mineralogisk sammansättning hos Orijärvitraktens metamorfa bergarter, af PENTTI ESKOLA. Med 4 figurer i texten. With an English Summary of the Contents. Maj 1915 ..... 30: —

N:o 45. Die geographische Entwicklung des Ladogasees in postglazialer Zeit und ihre Beziehung zur steinzeitlichen Besiedelung, von JULIUS AILIO. Mit 2 Karten und 51 Abbildungen. Dezember 1915 ..... 50: —

N:o 46. Le gisement de calcaire cristallin de Kirmonniemi à Korpo en Finlande, par AARNE LAITAKARI. Avec 14 figures dans le texte. Janvier 1916 ..... 20: —

N:o 47. Översikt av de prekambriska bildningarna i mellersta Österbotten, av EERO MÄKINEN. Med en översiktskarta och 25 fig. i texten. English Summary of the Contents. Juli 1916 ..... 50: —

N:o 48. On Synantetic Minerals and Related Phenomena (Reaction Rims, Corona Minerals, Kelyphite, Myrmekite, & c.), by J. J. SEDERHOLM. With 14 figures in the text and 48 figures on 8 plates. July 1916 ..... 60: —

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N:o 50. Geochronologische Studien über die spätglaziale Zeit in Südfinnland, von MATTI SAURAMO. Mit 4 Tafeln und 5 Abbildungen im Text. Januar 1918 ..... 30: —

N:o 51. Einige Albitepidotgesteine von Südfinnland, von AARNE LAITAKARI. Mit 5 Abbildungen im Text. Januar 1918 ..... 15: —

N:o 52. Über Theralit und Ijolit von Umptek auf der Halbinsel Kola, von TH. BRENNER. Mit 4 Figuren im Text. März 1920 ..... 15: —

N:o 53. Einige kritische Bemerkungen zu Iddings' Classifikation der Eruptivgesteine, von VICTOR HACKMAN. Mit 3 Tabellen. September 1920 ..... 15: —

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N:o 55. On Volcanic Necks in Lake Jänisjärvi in Eastern Finland, by PENTTI ESKOLA. With 1 figure. Januar 1921 ..... 15: —

N:o 56. Beiträge zur Paläontologie des nordbaltischen Silurs im Ålandsgebiet, von ADOLF A. TH. METZGER. Mit 2 Abbildungen im Text. Oktober 1922 ..... 15: —

N:o 57. Petrologische Untersuchungen der granito-dioritischen Gesteine Süd-Ostbothniens, von HEIKKI VÄYRYNEN. Mit 20 Figuren im Text und 1 Karte. Februar 1923 ..... 25: —

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N:o 62. Tohmajärvi-konglomeratet och dess förhållande till kaleviska skifferformationen, av W. W. WILKMAN. Med 15 figurer och en karta. Deutsches Referat. September 1923 ..... 20: —

N:o 63. Über einen Quarzsyenitporphyr von Saariselkä im finnischen Lappland, von VICTOR HACKMAN. Mit 2 Figuren im Text. Mai 1923 ..... 15: —

N:o 64. Die jatulischen Bildungen von Suojärvi in Ostfinnland, von ADOLF A. TH. METZGER. Mit 38 Abbildungen im Text, 1 Taf. u. 1 Karte. Januar 1924 ..... 30: —

N:o 65. Über die Petrologie des Otravaaragebietes im östlichen Finnland, von MARTTI SAXÉN. Mit zwei Karten, 13 Abbildungen im Text und 5 Figg. auf 1 Tafel. Dezember 1923 ..... 30: —

N:o 66. On Relations between Crustal Movements and Variations of Sea-Level during the Late Quaternary Time, especially in Fennoscandia, by WILHELM RAMSAY. With 10 figures in the text. February 1924 ..... 20: —

N:o 67. Tracing of Glacial Boulders and its Application in Prospecting, by MATTI SAURAMO. With 12 figures in the text. March 1924 ..... 20: —

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N:o 73. Über das jotnische Gebiet von Satakunta, von AARNE LAITAKARI. Mit einer Karte und 14 Abbildungen im Text. Juli 1925 ..... 30: —

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N:o 77. On Migmatites and Associated Pre-Cambrian Rocks of Southwestern Finland. Part II. The Region around the Barösundsfjärd W. of Helsingfors and Neighbouring Areas, by J. J. SEDERHOLM. With one map, 57 figures in the text and 44 figures on IX plates. Dec. 1926 ..... 60: —

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N:o 81. On the Development of Lake Höytiäinen in Carelia and its Ancient Flora, by MATTI SAURAMO and VÄINÖ AUER. With 20 figures in the text and 4 plates. March 1928 ..... 14: —

N:o 82. Über Wiikit, von LAURI LOKKA. Mit 12 Abbildungen und 21 Tabellen im Text. März 1928 ..... 30: —

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N:o 88. Studier över kvartärsystemet i Fennoskandias nordliga delar. IV. Om nivåförändringarna och grunddragen av den geografiska utvecklingen efter istiden i Ishavsfinland samt om homotaxin av Fennoskandias marina avlagringar, av V. TANNER. Med 84 figurer i texten och 4 tavlor. Résumé en français. September 1930 ..... 150: —

N:o 89. Beiträge zur Kenntnis der Svecofenniden in Finnland. I. Übersicht über die Geologie des Felsgrundes im Küstengebiete zwischen Helsingfors und Onas, von C. E. WEGMANN. II. Petrologische Übersicht des Küstengebietes E von Helsingfors, von E. H. KRANCK. Mit 32 Fig. auf 16 Taf., 4 Textfiguren und einer Übersichtskarte im Masstabe 1 : 75 000. Juni 1931 ..... 40: —

N:o 90. Geologie des Soanlahtigebietes im südlichen Karelien. Ein Beitrag zur Kenntnis der Stratigraphie und tektonischen Verhältnisse der Jatulformation, von H. HAUSEN. Mit 23 Figuren im Text, 12 Figuren auf 4 Tafeln und einer geologischen Übersichtskarte im Masstab 1 : 80 000. April 1930 ..... 50: —

N:o 91. Pre-Quaternary rocks of Finland. Explanatory notes to accompany a general geological map of Finland, by J. J. SEDERHOLM. With a map and 40 figures in the text. August 1930 ..... 30: —

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N:o 93. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 4. Avec 12 figures dans le texte et 6 planches. Avril 1931 ..... 40: —

N:o 94. Mineraljordarternas fysikaliska egenskaper, av THORD BRENNER. Med 22 textfigurer. Deutsches Referat. Juin 1931 ..... 70: —

N:o 95. On the Sub-Bothnian Unconformity and on Archaean Rocks Formed by Secular Weathering, by J. J. SEDERHOLM. With one map and 62 figures in the text. November 1931 ..... 50: —

N:o 96. On the Physiography and Late-Glacial Deposits in Northern Lapland, by ERKKI MIKKOLA. With 25 figures in the text and 5 plates. May 1932 ..... 50: —

N:o 97. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 5. Avec 15 figures dans le texte. Mai 1932 ..... 40: —

N:o 98. On the Geology of Fennoscandia, by J. J. SEDERHOLM. With a map and a table. May 1932 ..... 30: —

N:o 99. The Problems of the Eskers. The Esker-like Gravel Ridge of Čahpatoaiv, Lapland, by V. TANNER. With 2 plates and 1 map. September 1932 .... 15: —

N:o 100. Über die Bodenkonfiguration des Päijänne-Sees, von J. J. SEDERHOLM. Mit einer Tiefenkarte und 3 Figuren im Texte. Juni 1932 ..... 50: —

N:o 101. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 6. Avec 17 figures dans le texte. Avril 1933 ..... 50: —

N:o 102. Compte rendu de la Réunion internationale pour l'étude du Précambrien et des vielles chaînes de montagnes, rédigé par C. E. WEGMANN et E. H. KRANCK, publié par J. J. SEDERHOLM. Mai 1933 ..... 30: —

N:o 103. Suomen Geologisen Seuran julkaisuja — Meddelanden från Geologiska Sällskapet i Finland — Comptes Rendus de la Société géologique de Finlande, 7. Avec 2 figures dans le texte. Août 1933 ..... 25: —

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N:o 105. Neuere chemische Analysen von finnischen Gesteinen, von LAURI LOKKA. September 1934 ..... 30: —

N:o 106. Das Rapakiwirandgebiet der Gegend von Lappeenranta (Willmanstrand), von VICTOR HACKMAN. Mit 15 Textfiguren, 6 Figuren auf 2 Tafeln, einer Analysentabelle und einer Karte in Farbendruck. October 1934 ..... 35: —

N:o 107. On Migmatites and Associated Pre-Cambrian Rocks of Southwestern Finland. Part III. The Åland Islands, by J. J. SEDERHOLM †. With two maps and 43 figures in the text. December 1934 ..... 40: —

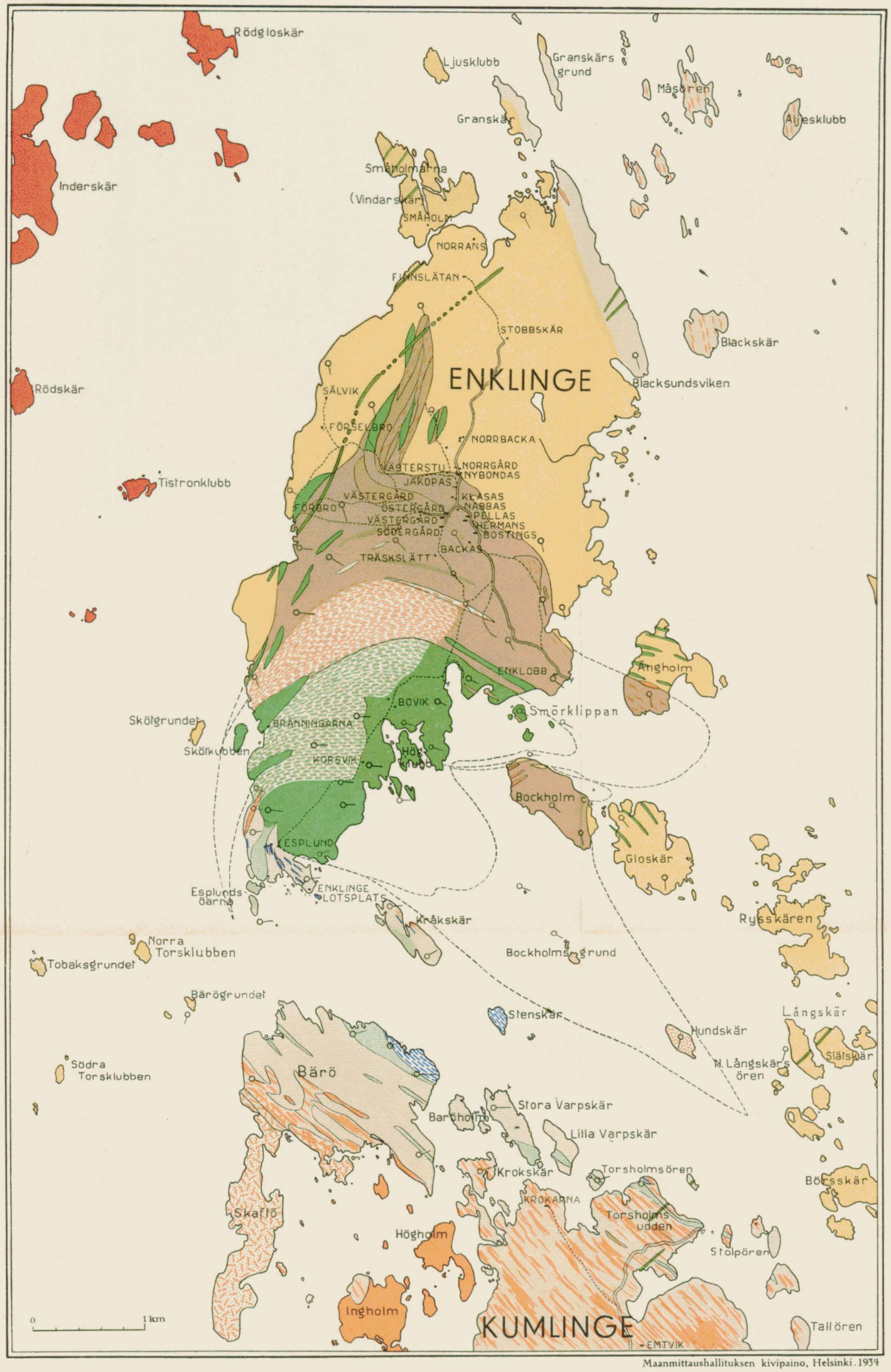
PETROLOGICAL MAP OF THE

ENKLINGE AREA

BY

J. J. SEDERHOLM AND E. MIKKOLA

1:40 000



EXPLANATION OF THE COLOURS

LATE-PRE-CAMBRIAN INTRUSIVE ROCKS

- Rapakivi
- Dykes of diabase

POST-BOTHNIAN GRANITE AND MIGMATITE

- Post-Bothnian granite (granite of the 2d group)
- Fine-grained granite and felsitic schist
- Arteritic migmatite of Ängholm and Enklinge
- Migmatite of Hundskär etc.
- Arteritic migmatite of Kumlinge etc.
- Agmatitic migmatite of Skaftö

SUPRACRUSTAL ROCKS OF THE ENKLINGE SERIES (BOTHNIAN).

- Metabasalt
- Pillow lava
- Ultra-metamorphic lava
- Mica-schist
- Ultra-metamorphic schist
- Salhrolithic schist

PRE-BOTHNIAN GRANITE AND MIGMATITE

- Gneissose granite
- Agmatitic variety of gneissose granite
- Migmatite with veins of gneissose granite

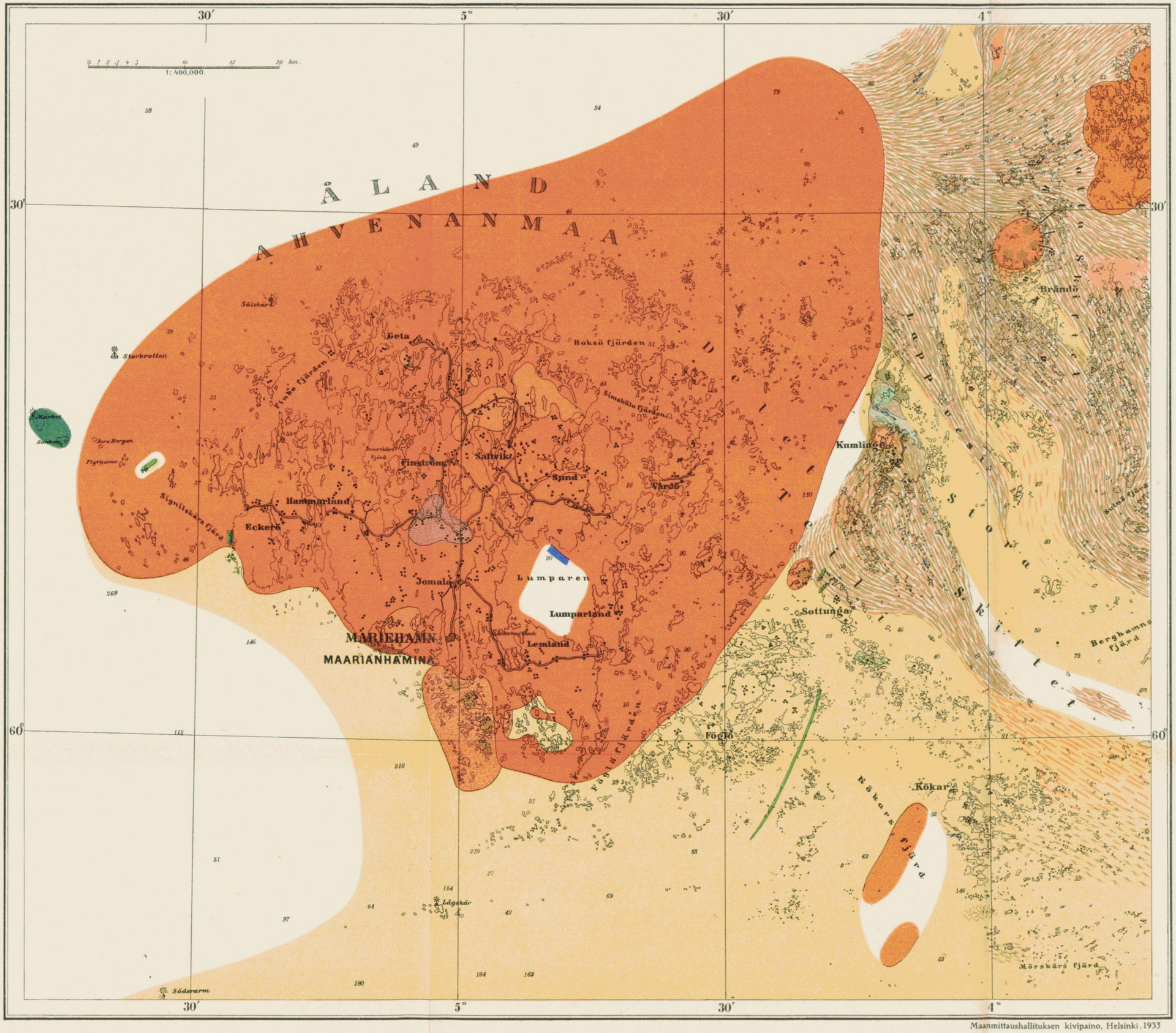
SUPRACRUSTAL ROCKS OF THE KUMLINGE SERIES (PRE-BOTHNIAN)

- Crystalline limestone
- Metadiabase and pillow lava
- Mica-schist and leptite

- Pitch of the axes
- C Conglomeratic structure
- Probable contact lines of Bothnian mica-schist and lava

Maanmittaushallituksen kivipaino, Helsinki. 1934

PETROLOGICAL MAP OF THE ÅLAND ISLANDS BY J. J. SEDERHOLM



Maanmittaushallituksen kivipaino, Helsinki. 1933