GEOLOGIAN TUTKIMUSKESKUS – GEOLOGISKA FORSKNINGSCENTRALEN
GEOLOGICAL SURVEY OF FINLAND

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PRECAMBRIAN GRANITOIDS
Petrogenesis, geochemistry and metallogeny

August 14–17, 1989, University of Helsinki, Finland

Excursion A1

RAPAKIVI GRANITES AND POSTOROGENIC GRANITES OF SOUTHWESTERN FINLAND

C. Ehlers and I. Haapala (Editors)

With contributions by :C. Ehlers, O. Eklund, I. Haapala, B. Lindberg, A. Vorma.

Espoo 1989

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CONTENTS

THE RAPAKIVI GRANITES AND POSTOROGENIC GRANITES OF SOUTHERN FINLAND

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Introduction

South Finland is the type area for rapakivi granites. The name rapakivi has been used by Finns for hundreds of years when referring to the weathered, easily disintegrating surface of certain granite outcrops and boulders. The Finnish word "rapakivi" literally means disintegrated, "rotten" rock or stone. It was first mentioned by the Swedish scholar Urban Hjärne in 1694, and it was introduced into the international geological litterature by J.J. Sederholm in 1891. Since the early 20th century, a number of studies have been published on the petrography, mineralogy and geochemistry of rapakivi granites in Finland (e.g. Wahl 1925, Kanerva 1928, Sahama 1945, Savolahti 1956, Simonen and Vorma 1969, Vorma 1971 and 1976, Haapala 1977a), on their intrusion mechanism (Ehlers and Bergman 1984, Bergman 1986), and on their metallogeny (Haapala and Ojanperä 1972, Haapala 1977b).

In southern Finland there is a group of postorogenic granites that differ from the later rapakivi granites; they form discrete, small, rounded complexes discordant with the country rocks.

Postorogenic intrusions

The postorogenic intrusions, which are often small ring-shaped complexes comprising lamprophyres, monzodiorites, monzonites, granodiorites and granites, have been described by Sederholm (1934), Kaitaro (1953), Ehlers and Bergman (1984), Bergman (1986) and Hubbard & Branigan (1987). In SW Finland there are four intrusions: Lemland, Mosshaga, Seglinge and

Åva (Fig. 2). The intrusions have ages around 1.79 Ga (Welin et al. 1983, Patchett and Kouvo 1986, Suominen 1987) and thus predate the rapakivis of the same area by some 0.2 Ga. Most of the complexes are rounded, 4-5 kilometres in diameter and show distinct phases of mingling and mixing of coeval mafic and granitic magmas (Hubbard and Branigan 1987, Lindberg and Eklund 1988). There are signs of rapid emplacement at high crustal levels (ring structures, gently inward dipping or steep cone sheets and breccia sheets with angular xenoliths of the local wall rock, occasional tuffisites).

The postorogenic ring complexes are cut by a regional swarm of diabase and quartz porphyry dykes of rapakivi age (Ehlers and Ehlers 1977, Ehlers and Bergman 1984).

The postorogenic granites are coarse, porphyritic, red rocks with a foliation defined by tabular microcline megacrysts. The foliation is mostly due to a flow fabric that is distorted around xenoliths and irregularities in the wall-rock (Hubbard and Branigan 1987). The mineralogy of the postorogenic granites is characterized by rotated and sometimes fractured porphyroclasts of microcline. The quartz is strained and recrystallised; sometimes the plagioclase is strained too. Hornblende, biotite, sphene, magnetite and apatite form elongated aggregates. The granodioritic - monzonitic varieties are less porphyritic, and the megacrysts are only weakly oriented (Seglinge).

The granodiorites are medium grained with a mottled appearance caused by clusters of biotite and hornblende together with sphene-rimmed magnetite. The progression to monzodiorite is marked by an increase in hornblende and biotite at the expense of quartz and microcline (Hubbard and Branigan 1987). Contrary to most rapakivi granites, the postorogenic granites are rich in sphene and magnetite and can be identified on aeromagnetic maps as strongly magnetic areas.

The rapakivi complexes

Anorogenic or postorogenic, usually middle-Proterozoic rapakivi granites are known from several Precambrian shield areas (Bridgwater and Windley 1973, Vorma 1976, Emslie 1978, Velikoslavinsky et al. 1978, Anderson 1983). In Finland as in many other areas, the rapakivi granites are associated with coeval gabbros, anorthosites and diabases. This bimodal association indicates involvment of both mantle-derived and crustal materials in the formation of these igneous complexes.

The rapakivi granites of southern Finland (Fig. 1) form four large batholiths (Wiborg, Åland, Vehmaa, Laitila) and several smaller satellitic batholiths and stocks (Suomenniemi, Ahvenisto, Onas, Bodom, Obbnäs, Kökar, Fjälskär, Eurajoki, Kokemäki). The rapakivi plutons cut sharply the early Proterozoic Svecofennian crust, the bulk of which formed in the interval 1.9 - 1.87 Ga from newly mantle-derived material (Huhma 1986). The Svecofennian crust consists of high- to medium-grade metamorphic supracrustal rocks and orogenic plutonic rocks (mainly synorogenic 1.9-1.87 Ga I-type granitoids). Subsequent anatectic partial melting of the thickened Svecofennian crust produced migmatite-forming, late-orogenic S-type granites about 1.83 Ga ago (Nurmi and Haapala 1986, Huhma 1986).

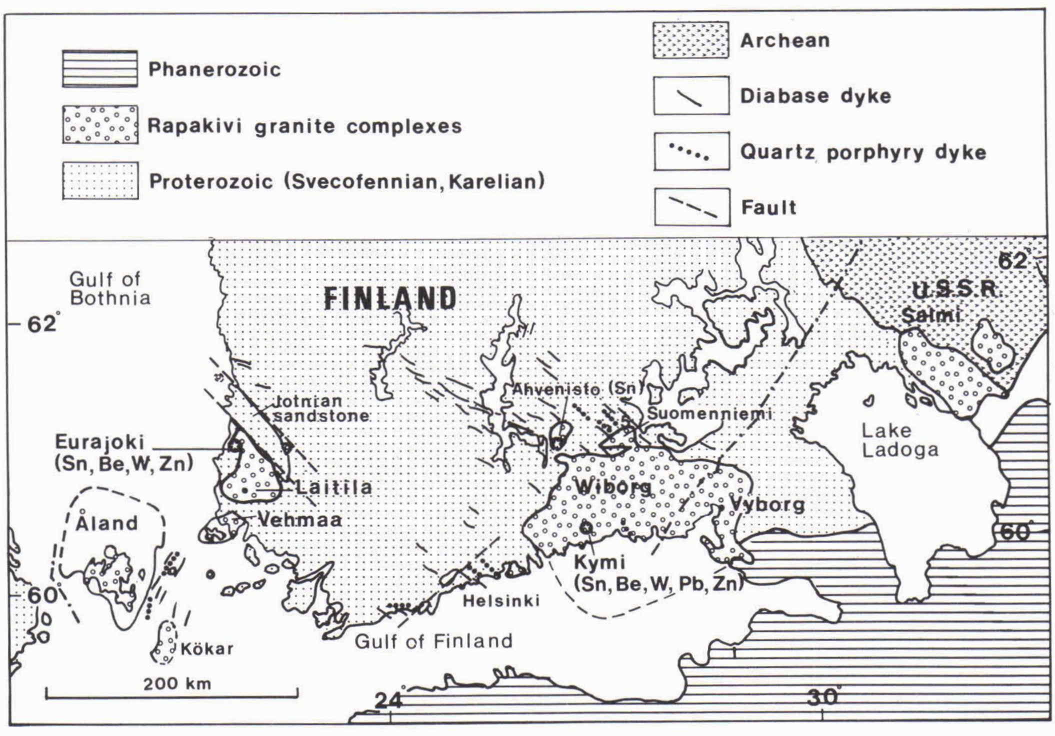


Fig. 1. The rapakivi granite complexes of southeastern Fennoscandia. Marked in the figure are also sets of rapakivi-age diabase and quartz porphyry dykes, the sandstone-filled Jotnian graben and mineralization associated with the rapakivi granites.

The age of the anorogenic rapakivi granites ranges from 1.69 to 1.54 Ga (Vaasjoki 1977); they are thus 0.2-0.3 Ga younger than the main crust-forming orogenic stage.

Interpretation of gravimetric data across the Wiborg and Laitila batholiths has shown that these huge complexes are in fact thin sheets (laccoliths) with deep marginal roots (Laurén 1970). The rapakivi batholiths and stocks are epizonal multiple intrusions consisting of several different granite types. Minor gabbroic and anorthositic bodies and quartz porphyry dykes are also associated with the rapakivi complexes. The intrusion mechanism was cauldron subsidence and magmatic stoping (Ehlers and Bergman 1984, Bergman 1986).

The diabase and quartz porphyry dykes of rapakivi-age occur as dyke swarms striking WNW in the Häme area (Laitakari 1969, Törnroos 1984) and NE in the Åland-Vehmaa area (Fig. 2), (Ehlers and Ehlers 1977, Suominen 1987). Large faults trend in the same directions including those bordering the 1.3-1.4 Ga old Jotnian sandstone-filled graben in the Pori area (Figs. 1 and 2). The rapakivi-age diabases exhibit the chemical characteristics of continental plateau basalts, whereas the younger (1.27 Ga) olivine diabase sheets intruding the sandstones of the Jotnian graben have a chemical composition closer to that of rift volcanics or oceanic basalts (Pihlaja 1987). In the Åland area, mixing between coeval rapakivi-age basaltic and quartz-porphyry magmas has been described by Eklund & Lindberg (1988). All this suggests that the rapakivi granites intruded into an extensional continental tectonic regime, later forming local graben structures (incipient rifting; Nurmi and Haapala 1986).

Petrography of the rapakivi granites

There are marked differences between the rapakivi granites of the various intrusion phases. Among the earliest rapakivi varieties are the even-grained or porphyritic fayalite-bearing biotite-hornblende granites. Wiborgite (biotite-hornblende granite containing plagioclase-mantled K-feldspar ovoids) and pyterlite (a similar rock with unmantled K-feldspar ovoids) represent the main intrusive phases in most of the complexes. Biotite granites with different textures and grain sizes crystallized later.

In many complexes, the last intrusive phase is represented by minor stocks and cupolas of topaz-bearing microcline-albite granite with lithian siderophyllite (protolithionite) as the dark mica. Typical accessory minerals in the rapakivi granites are fluorite, zircon, anatase, allanite (in the early and main intrusive phases), monazite (in the later intrusive phases), ilmenite, apatite and, locally, magnetite. The late-stage granites contain topaz, monazite, bastnaesite, xenotime, ilmenite, Nb- and Ta-rich cassiterite, columbite and thorite as accessory minerals (Haapala 1974 and 1977a). The rapakivi granites thus normally show the characteristics of the ilmenite series, althought locally the magnetite abundance (and magnetic susceptibility) is so high that the granite belongs to the magnetite series of Ishihara (1977).

The rapakivi granites typically crystallized from water-undersaturated magmas. Only the latest intrusive phases (e.g. the Väkkärä granite in Eurajoki) crystallized from water-saturated melts, as indicated by numerous miarolitic cavities, pegmatite pockets, mineral alteration and hydrothermal veins (Haapala 1977a). Kuroda et al. (1978) observed that the hornblende and biotite from rapakivi granites in Finland have a disequilibrium type D/H fractionation, which they attributed to crystallization from water-deficient magma.

Geochemistry of rapakivi granites

The rapakivi types show considerable variation in chemical composition. Further, the variation diagrams and mean composition (Vorma 1976) of individual rapakivi batholiths clearly differ from each other, suggesting differences in the composition of the source and/or in the degree of partial melting. The findings of Eklund and Lindberg (1988) suggest mixing of different coeval magmas as a possible cause of the local chemical variations.

The normal rapakivi granites are characterized by higher abundances of SiO2, K2O, K/Na, Fe/Mg, F, Rb, Ga, Zr, Th, U, and REE (except Eu) than in granites on average. The topaz-bearing, late-stage granites are anomalous, with very high F, Li, Rb, Ga, Sn and Nb values and low Ti, Mg, Mn, Ba, Sr, and Zr (Haapala 1977a, 1977b). They thus show the characteristics of tin-bearing granites. The mineralogical and geochemical characteristics of the late-stage granites are due to extreme fractionation and superimposed fluid-rock interactions.

Mineralization

Greisen type Sn (-Be-W-Zn-Pb) occurrences have been found in association with geochemically specialized late-stage granites (Haapala and Ojanperä 1972, Haapala 1977b). In addition to the greisen veins, there are some galena-dominated sulphide veins in the rapakivi granites and their country rocks (Bergman and Lindberg 1979, Vaasjoki 1977). In the Åland rapakivi area, a number of early Palaeozoic sandstone dykes are found in the rapakivi granites and surrounding rocks, indicating that about 0.5 Ga ago erosion in that area had reached almost exactly the present level. Some of these sandstone-filled fractures are mineralized with galena.

In some of the postorogenic ring complexes, minor molybdenite showings are hosted by late intrusions of aplitic rock.

Petrogenesis

Recent isotope geochemical studies (made by Tapani Rämö at the Unit for Isotope Geology of the Geological Survey of Finland) have shown that the rapakivi granites and quartz porpyry dykes in the Suomenniemi area have uniform ϵ Nd(T) values between -1.9 and -0.8 and the diabases between -1 and +2 (Haapala and Rämö 1988, 1989). These results fit the model proposed by Haapala (1985, 1988) and Nurmi and Haapala (1986) that the rapakivi magmas were generated by partial melting of Svecofennian lower crust; the melting was initiated by mantle-derived magmas now occurring as diabase dykes and gabbroic bodies. These events took place in continental tectonic settings, 0.2-0.3 Ga after the orogenic syn-collisional crust-forming stage.

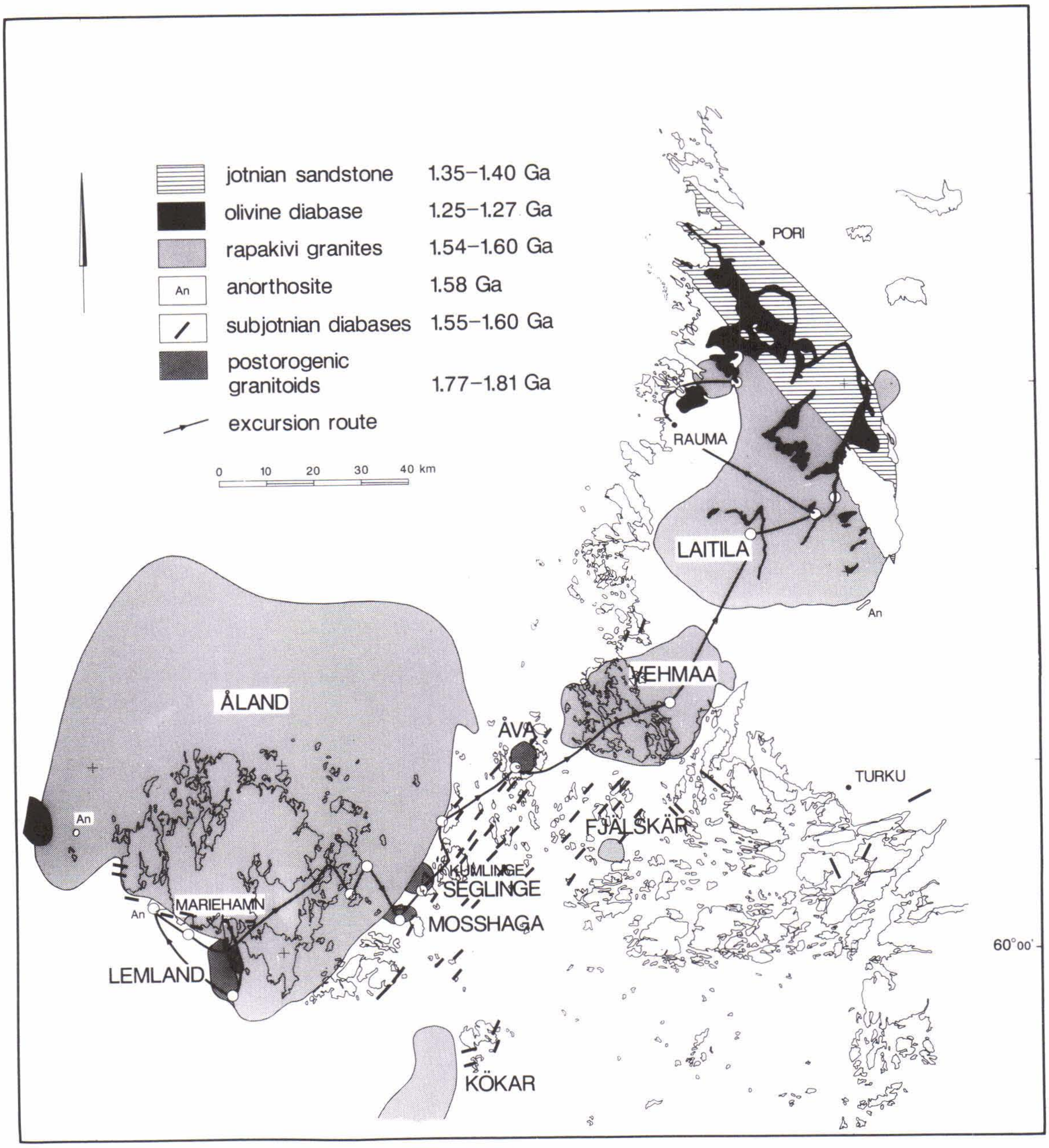


Fig. 2. The excursion route through the Postorogenic granites and rapakivis of southwest Finland.

THE POSTOROGENIC LEMLAND INTRUSION AND THE SOUTH-WESTERN BORDER OF THE ÅLAND RAPAKIVI COMPLEX

Olav Eklund and Bo Lindberg, Department of Geology and Mineralogy, Åbo Akademi

The Lemland intrusion

The Lemland intrusion (1770 +- 2 Ma, Suominen, 1987) is the largest of four postorogenic granitoid intrusions in the archipelago of southwestern Finland. The present areal extent of the intrusion is about 3 x 13 km, but that is only a part of the original pluton, which was later intruded and replaced by subseqent younger rapakivi granites (Fig. 3).

The major rock type in the Lemland intrusion is a porphyritic granite showing igneous foliation that is more pronounced near the original outher margins. Close to the inferred original intrusion, there is a zone, 1-2 km wide and striking NNW-SSW, that consists mainly of intermediate rocks with compositions from granodiorite to quartz-monzodiorite and quartz-monzonite (Bergman, 1981, 1986). In the northeastern part of the intrusion, the porphyritic granite and intermediate rocks are cut by an even-grained aplitic granite also belonging to the Lemland intrusion. Inside the Lemland intrusion, there are a few small portions of younger rapakivi granite.

STOP 1. The Pungö area

The excursion will visit the Pungö area (Fig. 4) in the southern part of the Lemland intrusion, where interaction between contrasting magmas can be studied.

The geology of this area was recently described by Lindberg and Eklund (1988). The central part of Pungö is dominated by basic-intermediate rocks forming a ring-like structure with a diameter of about 1.2 km surrounded by porphyritic granite.

The ring structure is made up of three units from the rim towards the centre: 1) fine-grained pillowed mafic rocks in porphyritic granite,
2) mixed rocks with mafic inclusions in a hybrid matrix, and 3) medium-grained mafic rock.

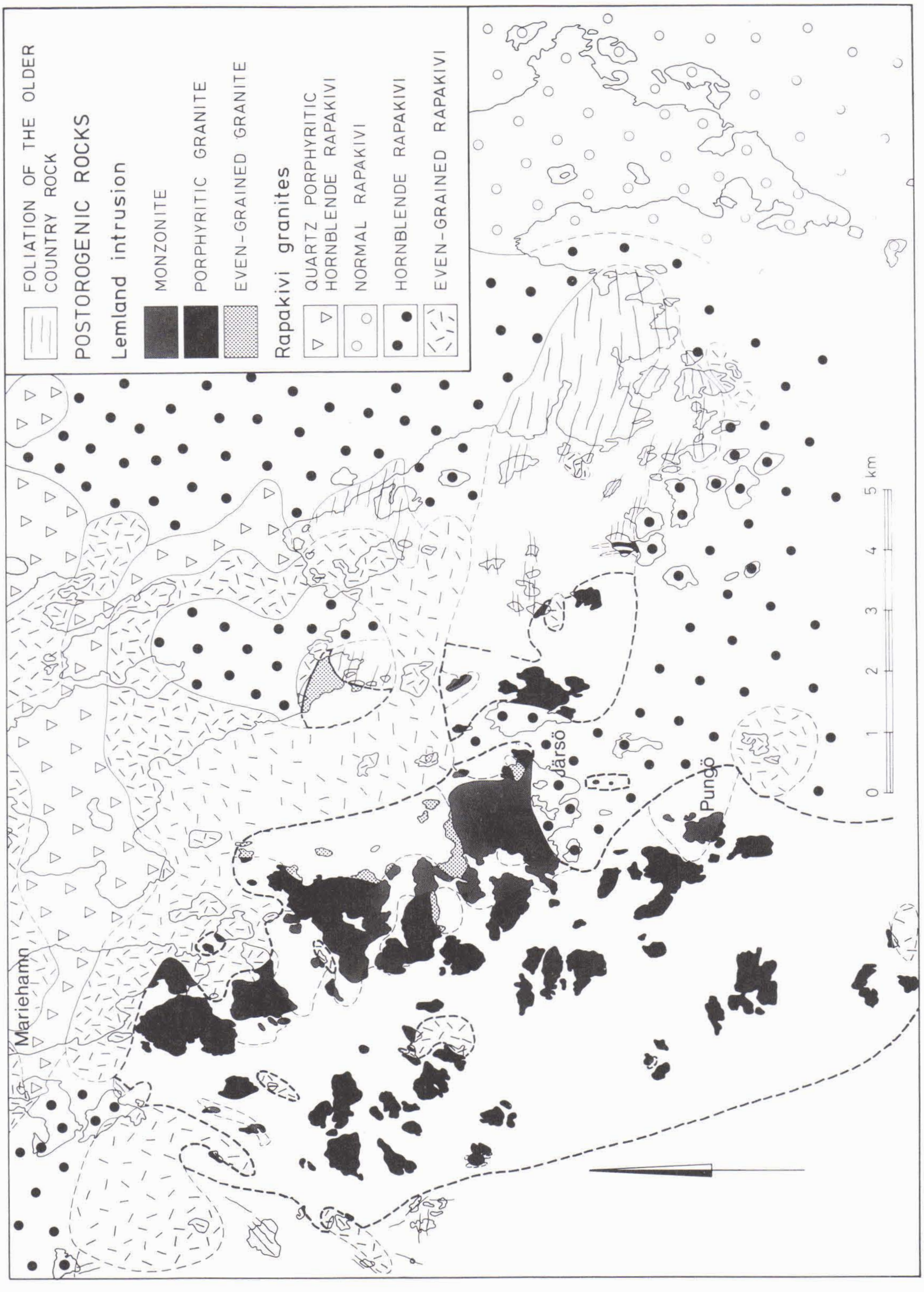


Fig. 3. Geological map of the Lemland intrusion and adjacent areas.

The sequence of emplacement (Fig. 4) seems to have started with the intrusion of basic magma into overlying acid magma, creating mafic pillows in the acid magma. Subsequent intrusion of mafic magma brought about mixing of the acid and basic magmas. The mixed magma with mafic inclusions then invaded the zone of early pillows.

The linear distribution of the major elements, the occurrence of quartz ocelli and mantled feldspars, and the results of mixing tests confirm the hybrid origin of the matrix in the mixed rock unit.

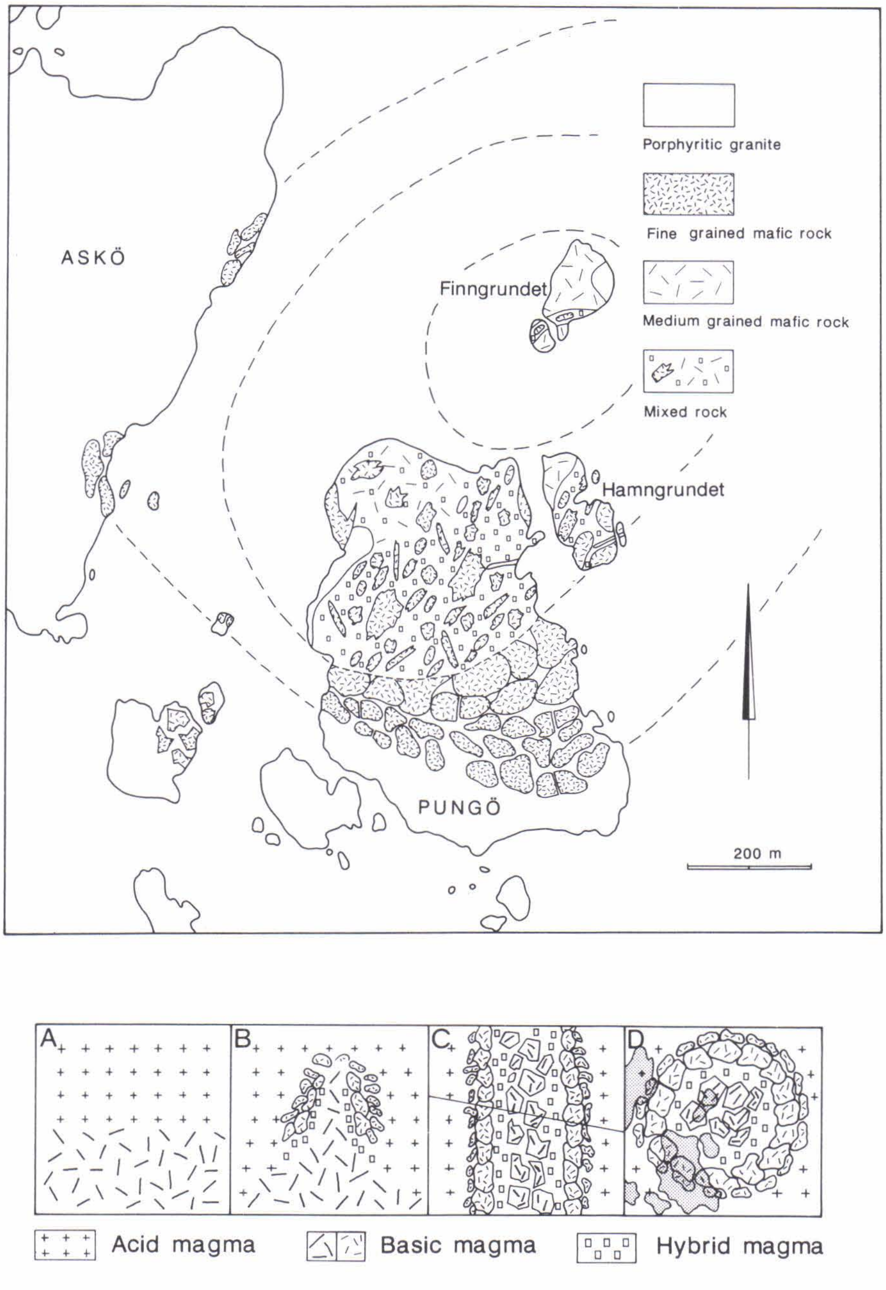


Fig. 4. Geological map of the Pungö area and a model for the intrusion events.

The southwestern contact between the Åland rapakivi complex and the country rock

Close to the contact between the middle-Proterozoic rapakivi complex of Åland and the older Svecofennian gneisses and granites, there is a bimodal rock sequence overprinting the rapakivi complex. (1571+-9 - 1577+-12 Ma, Suominen 1987). The sequence consists of different types of intrusive rocks from anorthosites and anorthosite-bearing diabases to quartz porphyries, that intruded as dykes or sills and as small stocks (Fig. 5). The composition of these intrusive rocks varies from gabbro-anorthosite and diorite-monzodiorite with subalkaline tholeiitic affinities to quartz porphyries and rhyolitic ignimbrites.

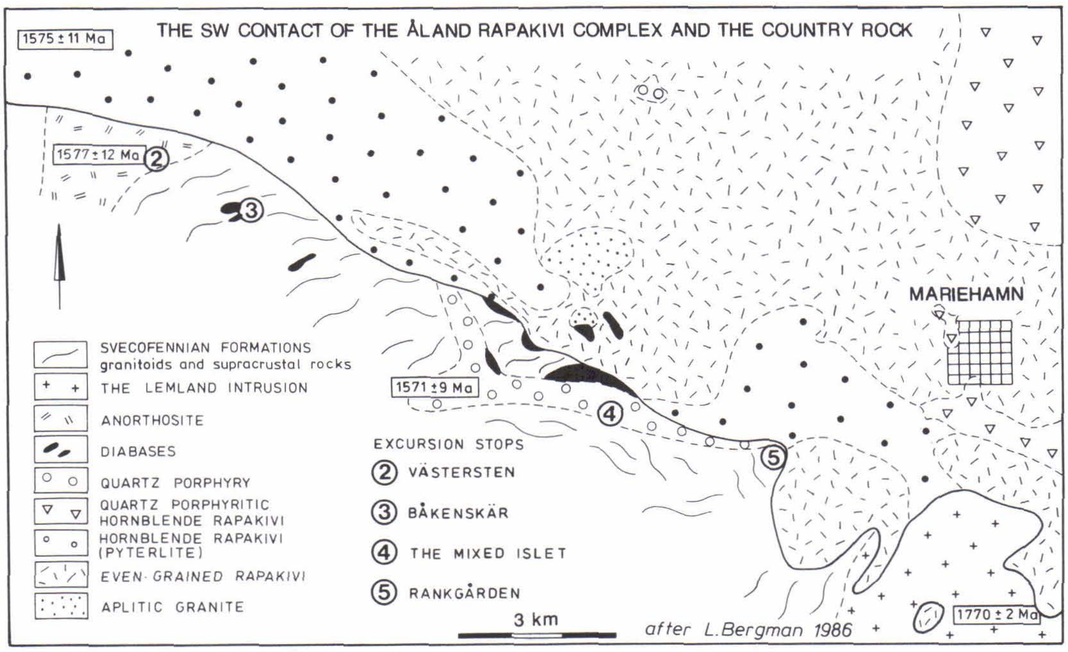


Fig. 5.

The excursion will examine the intimate relationship and the indistinct relations between the Svecofennian formations, anorthosite-bearing diabases, quartz porphyries and rapakivi granites.

The mafic rocks of the sequence clearly postdate and cut the Svecofennian formations. In a number of localities melting of the country rock by the diabases can be seen.

In the quartz porphyry, as well as in some types of rapakivi, the diabases occur as enclaves. In places, the enclaves contain plagioclase-mantled K-feldspars and ocelli (amphibole mantled quartz grains). These enclaves have an intermediate composition between the diabases and the quartz porphyry. In Harker plots, they have a linear trend between the diabases and the quartz porphyries, indicating a magma mixing origin for the intermediate enclaves.

The quartz porphyries are epigranitoids with sharp chilled margins against the country rock. They are cut by rapakivi granites. Chemically they range from a brown amphibole-bearing type with approximately 60% SiO2 to a red variety with 77% SiO2. The mean SiO2 abundance of the quartz porphyries is 72%. In composition they vary from monzogranite to alkaligranite. They show peraluminous as well as metaluminous affinities. The brown type often displays plagioclase-mantled K-feldspar megacrysts and ocelli, suggesting that they may be of mixed origin. The red varieties have K-feldspar megacrysts and rounded quartz grains. Labradorite megacrysts up to 5 cm across and probably originating from the anorthosite diabases have been met with in the quartz porphyries.

STOP 2. The islet of Västersten

The islet of Västersten is an outcrop of a larger (2 - 3 km wide) anorthosite area southwest of the Åland rapakivi complex (Fig. 5). The U-Pb age for the anorthosite is 1577+-12 Ma, and for the rapakivi 1575+-11 Ma (Suominen 1987). The anorthosite consists of lighter cumulates and darker intercumulus. The composition of the plagioclase is labradorite. The cumulus grains may be up to 20 cm in size and polysynthetic twinning is visible in the outcrops.

STOP 3. The islet of Båkenskär

On the islet of Båkenskär (Fig. 6) anorthosite enclave bearing diabases cut and interact with the Svecofennian gneissose granite

In the northern part of the islet (area 1 in Fig. 6), the diabases brecciate and melt the gneissose granite. The breccia appears in several shapes: one has large fragments of gneissose granite in a dark matrix, and another consists of small plagioclase-mantled gneissose granite fragments, and ocelli in a lighter matrix. Ocelli are also typical in amphibole-bearing quartz porphyries.

On the eastern shore of the islet (area 2 in Fig.6), a diabase dyke cutting gneissose granite turns horizontally and grades into a porphyry-like, hybrid intermediate rock. The porphyry contains restites of the gneissose granite and fragments of graphic granite, perhaps metasomatically altered gneissose granite, and anorthositic lumps.

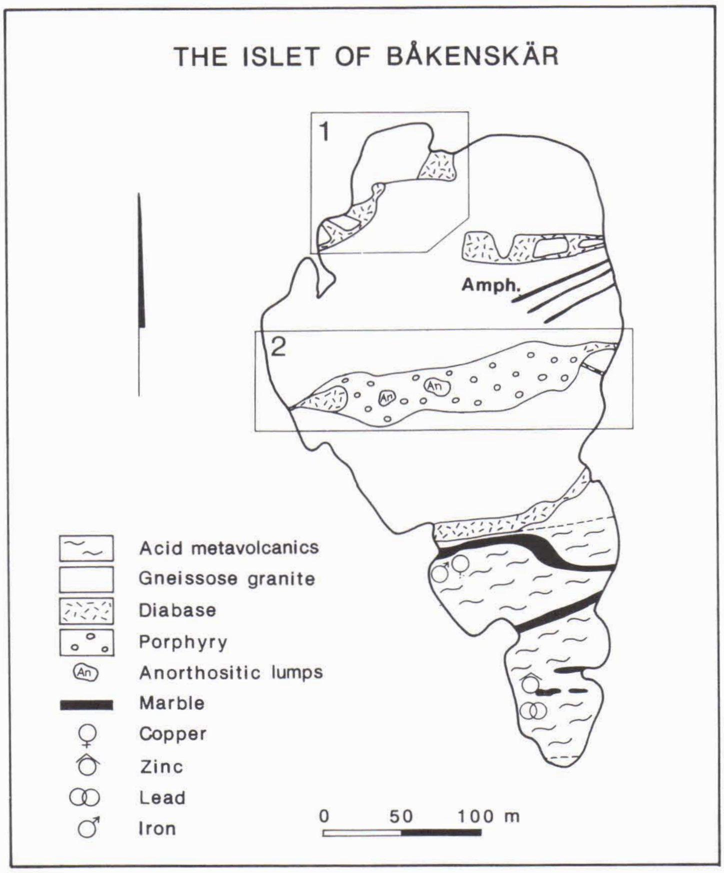


Fig. 6.

STOP 4. The mixed islet

This small islet consists mainly of a coarse-grained quartz porphyry with mafic enclaves. In composition the mafic enclaves are similar to the anorthosite enclave bearing diabases outside the quartz porphyry that cut the Svecofennian formations. Some of the enclaves have ocelli and K-feldspars, with or without plagioclase mantles, in a lighter matrix. To determinate whether or not these enclaves are of mixed origin a least-squares mixing test was made, whith an anorthosite bearing enclave being chosen as the basic end member and the quartz porphyry as the acid end member. A K-feldspar and ocelli-bearing intermediate enclave represented the hybrid. The sum of squares of residuals was 0.535, corresponding to a mixture of 56.3% quartz porphyry and 43.7% mafic enclave material.

The quartz porphyry also contains labrador megacrysts, ocelli and plagioclase-mantled K-feldspars. These features may result from an earlier mixing event during which the enclaves disintegrated as a result of thermal equilibrium between the basic and acid magmas.

STOP 5. The island of Rankgården

A contact between the older gneissose granite, the quartz porphyry and the rapakivi granite (pyterlite) is exposed in the southern part of the small island of Rankgården.

The quartz porphyry is chilled against the gneissose granite. The chilled margin is 1-1.5 m and very fine grained. The quartz porphyry contains mafic enclaves and xenoliths cut by the rapakivi. The grain size of the pyterlitic rapakivi decreases towards the quartz porphyry and the gneissose granite.

On the western shore of the island some greisen veins occur in the pyterlitic rapakivi.

RAPAKIVI GRANITES AND POSTOROGENIC GRANITES IN THE AREA BETWEEN THE ÅLAND AND THE VEHMAA BATHOLITHS

Carl Ehlers, Department of Geology and Mineralogy,
Åbo Akademi

On the second and third days the excursion will go by boat through the archipelago between the Åland islands and the mainland of Finland. The route will take the participants through three localities in the eastern parts of the Åland rapakivi complex and over three different postorogenic ring complexes: Mosshaga, Seglinge and Åva.

STOP 6. Träskholm

Träskholm, an island on the eastern side of the Åland rapakivi massif, is composed of different varieties of rapakivi granite (Fig. 7). The excursion locality is situated at the northern end of a little island at the contact between a coarse wiborgitic rapakivi granite and a younger aplitic rock with porphyric texture. The contact dips gently towards the north, and the wiborgite forms a cap over the aplitic rock.

A number of thin (10 cm) veins of greisen can be studied along the contact. Most of the veins occur within the aplitic rock and consist of dark thin sheets of hydrothermally altered aplitic rapakivi. The mineralogy is simple: chlorite, quartz, magnetite and very fine-grained cassiterite. The greisens contain about 300 ppm tin (locally some dykes have up to 2.3% tin).

The contacts of the hydrothermally altered greisen sheets are very sharp and cut through single feldspar megacrysts.

The majority of the greisen dykes in this area occur in the roof zones of similar, slightly younger aplitic rapakivi intrusions intruding the earlier, more coarse rapakivi plutons.

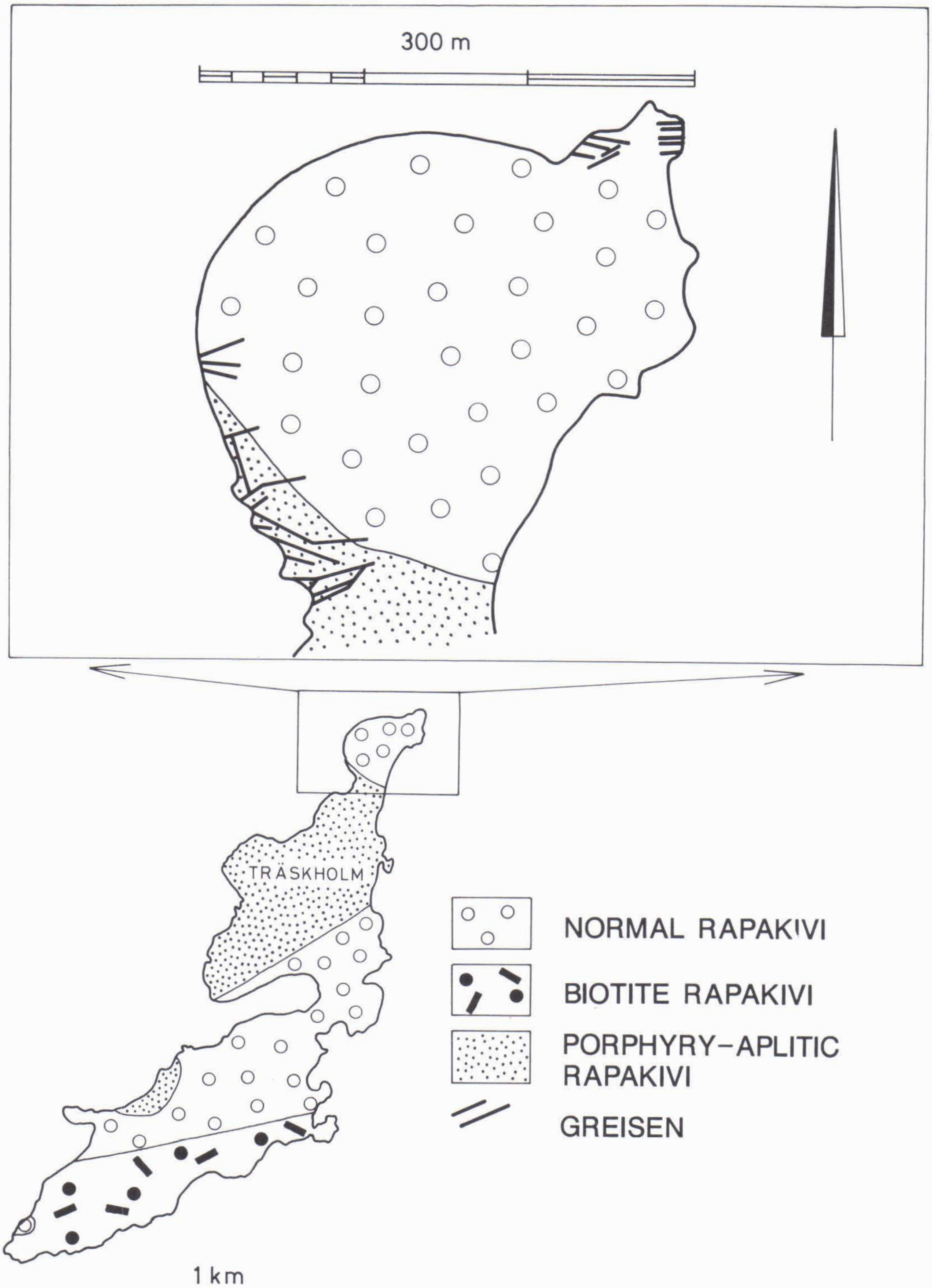


Fig. 7. Geological map of the Träskholm island.

STOP 7. Loören

Some 250 predominantly N-S trending clastic dykes have been observed within the Åland rapakivi granite area (Bergman 1982). In lithology, most of the dykes are siltstones and sandstones. Their ages, based on microfossils, are Lower

Cambrian to Lower Ordovician (Tynni 1982).

On the little islet of Loören we shall examine a set of clastic sandstone dykes and galena dykes in the coarse-grained rapakivi (Fig. 8). One of the clastic sandstone dykes grades into a galena, pyrite, marcasite-rich dyke.

According to Bergman and Lindberg (1979), the galena has a sedimentary-chemical origin. The lead-bearing solutions were squeezed out of the sand during compaction and diagenesis, and galena was precipitated in pores and open fissures.

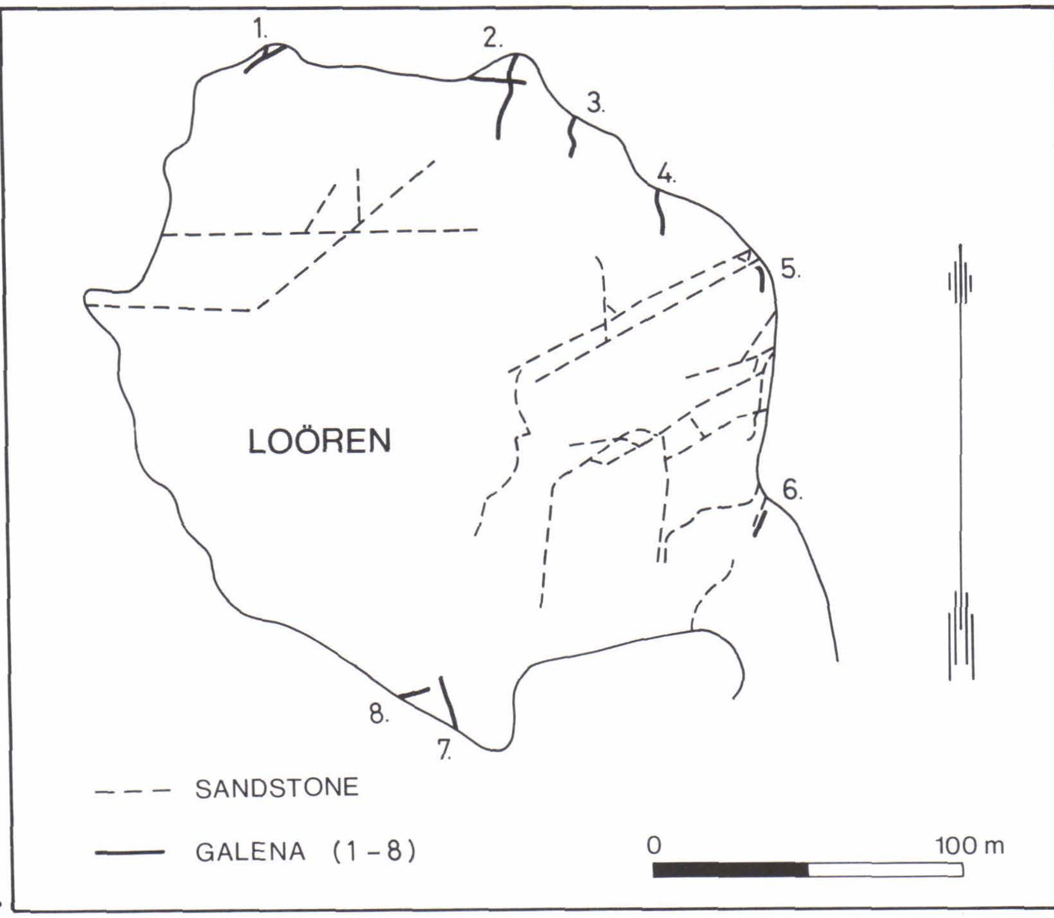


Fig. 8.

The postorogenic Mosshaga complex

The Mosshaga intrusion complex (1788 +- 11 Ma., Welin et al. 1983) is elliptical in shape (Fig. 9). Nearly vertical ring intrusions separated by non-brecciated county rock screens are minor and confined to the periphery of the complex. The main body of the Mosshaga intrusion consists of sheets of granodiorite/monzonite and granite dipping gently towards the centre, forming a shallow cone and being cut by sheets of pegmatite dipping gently inwards (Branigan 1986, Hubbard and Branigan 1987). To the west, the Mosshaga complex is cut and intruded by the younger Åland rapakivi granites (Fig. 9).

The excursion will examine three localities in this intrusive complex: Blekskär, Långskär and Rödgrund (Fig. 9).

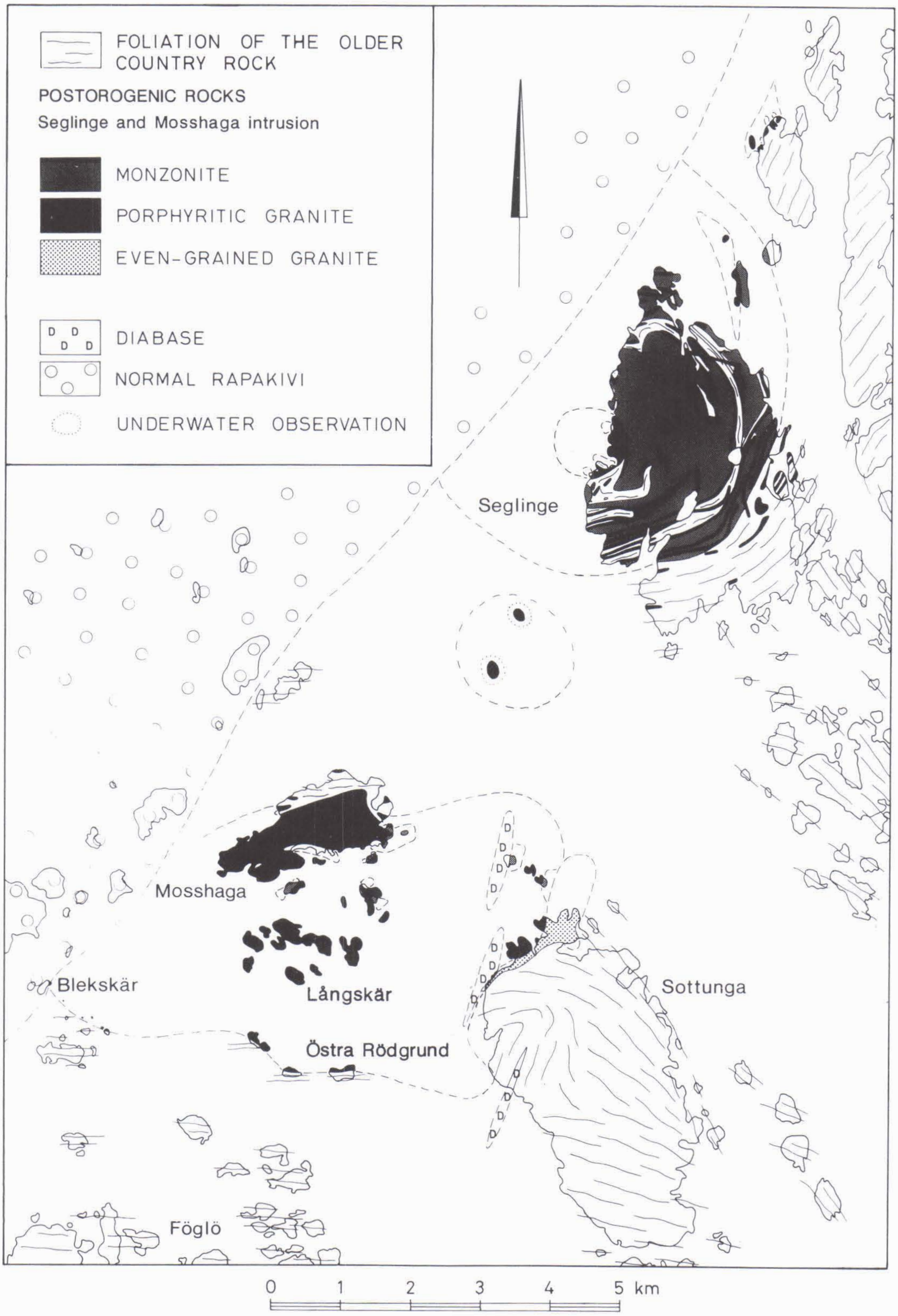


Fig. 9. The postorogenic complexes of Mosshaga and Seglinge.

STOP 8. Blekskär

Blekskär is a small island at the eastern rim of the Åland rapakivi massif (Fig. 9), where the Mosshaga monzonites and granites are cut by rapakivi type rocks. The local geology is further complicated by abundant breccia fragments of older gneisses and gabbros.

The excursion will study the contact relationships between the slightly foliated and porphyric Mosshaga granite and the cross cutting rapakivi granite. The coarse rapakivi granite is intruded by a slightly younger, aplitic rapakivi granite.

STOP 9. Långskär

Långskär is an island in the central part of the Mosshaga massif (Fig. 9), where there is a massive coarse-grained porphyric granite with foliation. Mixed rocks with rounded enclaves of monzodiorites and monzonites can be observed along the shore. A set of gently dipping pegmatites forms the last intrusion phase.

STOP 10. Östra rödgrund

The contact between the early postorogenic Mosshaga granite and the old strongly deformed early Proterozoic "basement", which consists of amphibolite banded syntectonic granodiorites (Fig. 9). The contact is very sharp and steep and cuts the foliation in the old granodiorite at a low angle.

A narrow lamprophyric dyke cuts the Mosshaga granite.

The postorogenic Seglinge complex

The Seglinge intrusive complex intrudes a succession of older gneisses and granites and is similar in age and type to the other postorogenic intrusions in SW Finland. The Seglinge complex consists of an intrusion of a very inhomogeneous central body of granodiorite/monzonite surrounded by screens of brecciated country rocks between concentric cone sheets of monzonite and granite (Fig. 10). The cone sheets dip steeply towards (70 - 80 degrees) the centre of the complex. The granitic and aplitic cone sheets constitute the last intrusive phase, and there is a intrusive sequence from basic to acid compositions. The contact relations between different intrusive phases are complicated, and pillowing and veining are common (Hubbard and Branigan 1987). Late intrusions of lamprophyric dykes occur in the peripheral areas of the complex.

The Seglinge massif is strongly sheared, and the western half of the complex is displaced to the south (5-6 kilometres according to the geomagnetical map), leaving the eastern half of the massif exposed. On the eastern side of the complex, sheared slices of Seglinge rocks have been found displaced some 10 -12 kilometres to the north within strong shear zones.

Hybrid rocks are a typical feature of the Seglinge massif as of all early postorogenic intrusions; they are well displayed in the central parts of the complex. The hybrids intruded as pulses of mixed magmas, each successive phase intruding and pillowing the older, more mafic phases. The end-members: granite and lamprophyre are the last intrusion phases forming coeval intrusive sheets around the hybrid stock and ring dykes (Hubbard and Branigan 1987).

STOP 11. The SW shore of Seglinge island

The locality is situated within the outer rim of the Seglinge complex (Fig. 10). The excursion will examine several cone sheets (between screens of country rocks) consisting of granitic rocks mixed (mingled) with pillowed lamprophyric and amphibolitic rocks. The cone sheets are rich in angular fragments of country rock showing the earlier Svecofennian deformation.

The Seglinge rocks are locally strongly sheared along N-S trending ductile shear zones.

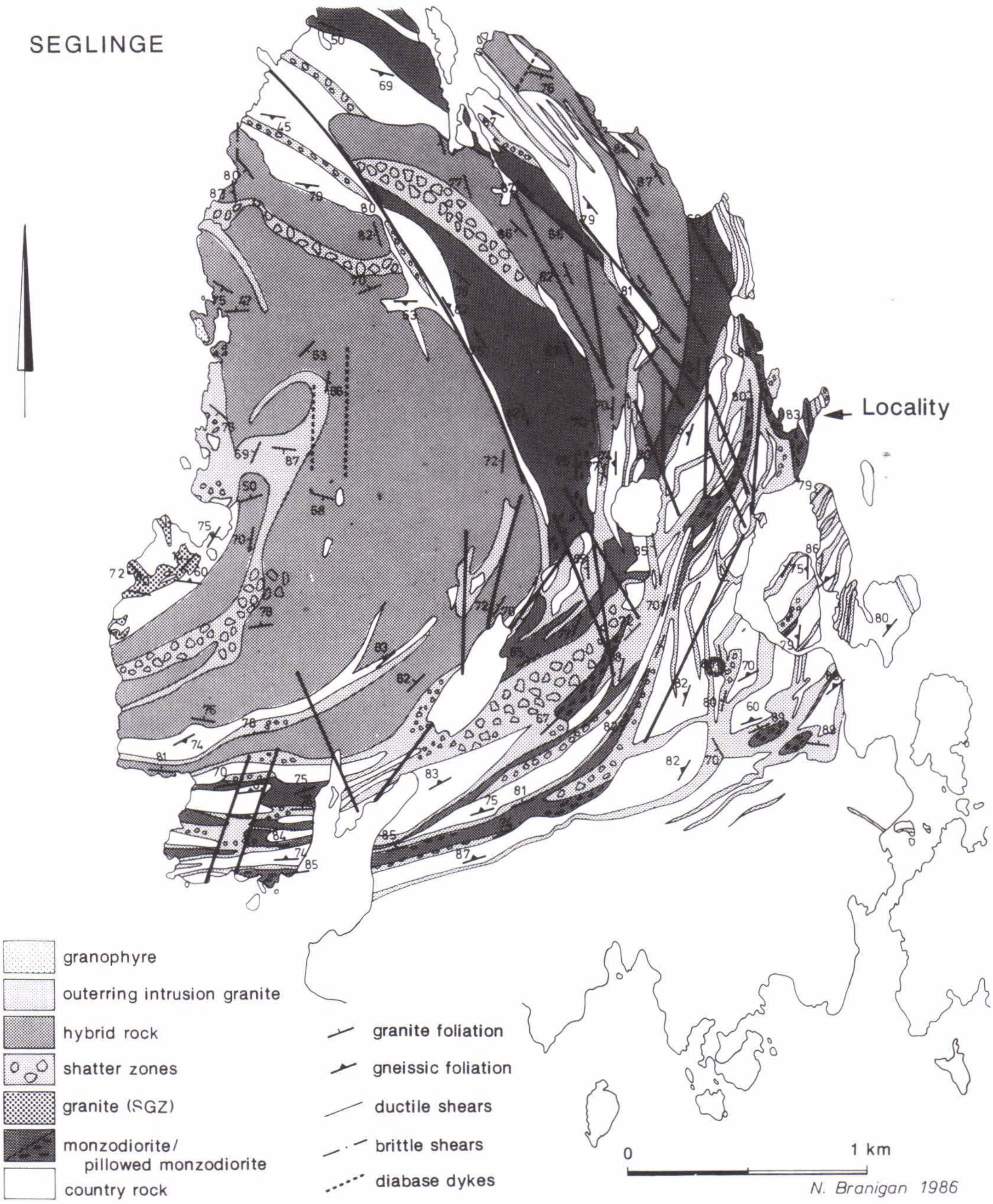


Fig. 10. Geological map of the postorogenic Seglinge complex.

The Åva intrusive complex

The Åva intrusion, the best preserved and exposed ring structure in SW Finland, is well known from the descriptions of Sederholm (1934) and Kaitaro (1953). Ehlers and Bergman (1984) re-interpreted the geology and suggested that the Åva intrusion centers on an older diapiric granite that deformed the surrounding gneisses into a steeply inwardly dipping ring. The older granite forms the centre of the ring subsequently intruded and brecciated by the porphyric Åva granite.

The Åva intrusion complex is composed of a central breccia rimmed by concentric monzodioritic and granitic cone sheets (Fig. 12). The cone sheets are separated by screens of brecciated country rock invaded by Åva granite.
The dip of the cone sheets increases from 30^{o} to 80^{o} from the central parts towards the periphery of the ring complex. The monzonite in the ring dykes is commonly pillowed and veined by the Åva granite, and hybrid rocks are common. A late, fine-grained aplite rock in the central parts of the Åva massif is mineralized by molybdenite and other sulphides.

A set of lamprophyre dykes cuts the complex of cone sheets in a radial pattern (Fig. 13).

STOP 12. The islet of Njuran

The locality is a small island situated at the eastern contact of the large Åland rapakivi massif. The outcrop consists of a large breccia with two different rapakivi types: an older pink, coarse-grained "normal" rapakivi and a younger grey, fine-grained rapakivi intruding and brecciating the older one (Fig. 11). The coarse-grained rapakivi forms a subhorizontal domed roof over the slightly younger intrusion of grey granite. The roof of red rapakivi granite is exposed at both ends of the islet, which are topographically a couple of metres higher than the middle part of the island.
Dark schlieren with folds and rotations showing turbulent deformation are common in the fine-grained granite along some of the contacts with the coarse rapakivi (Fig. 11). Chemically, both granite types are almost identical, while the dark schlieren petrographically and chemically show a concentration of biotite and hornblende.

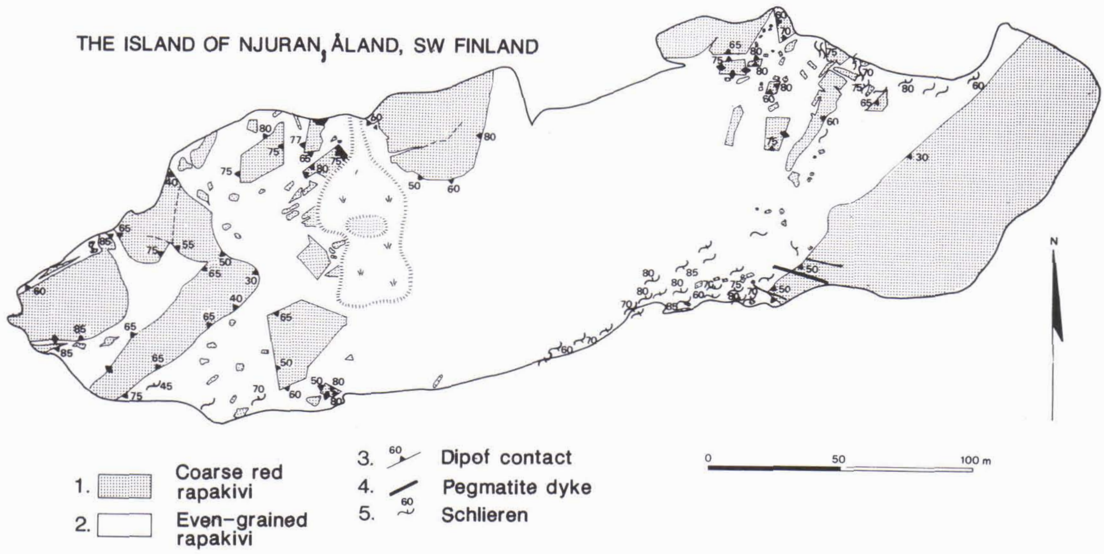


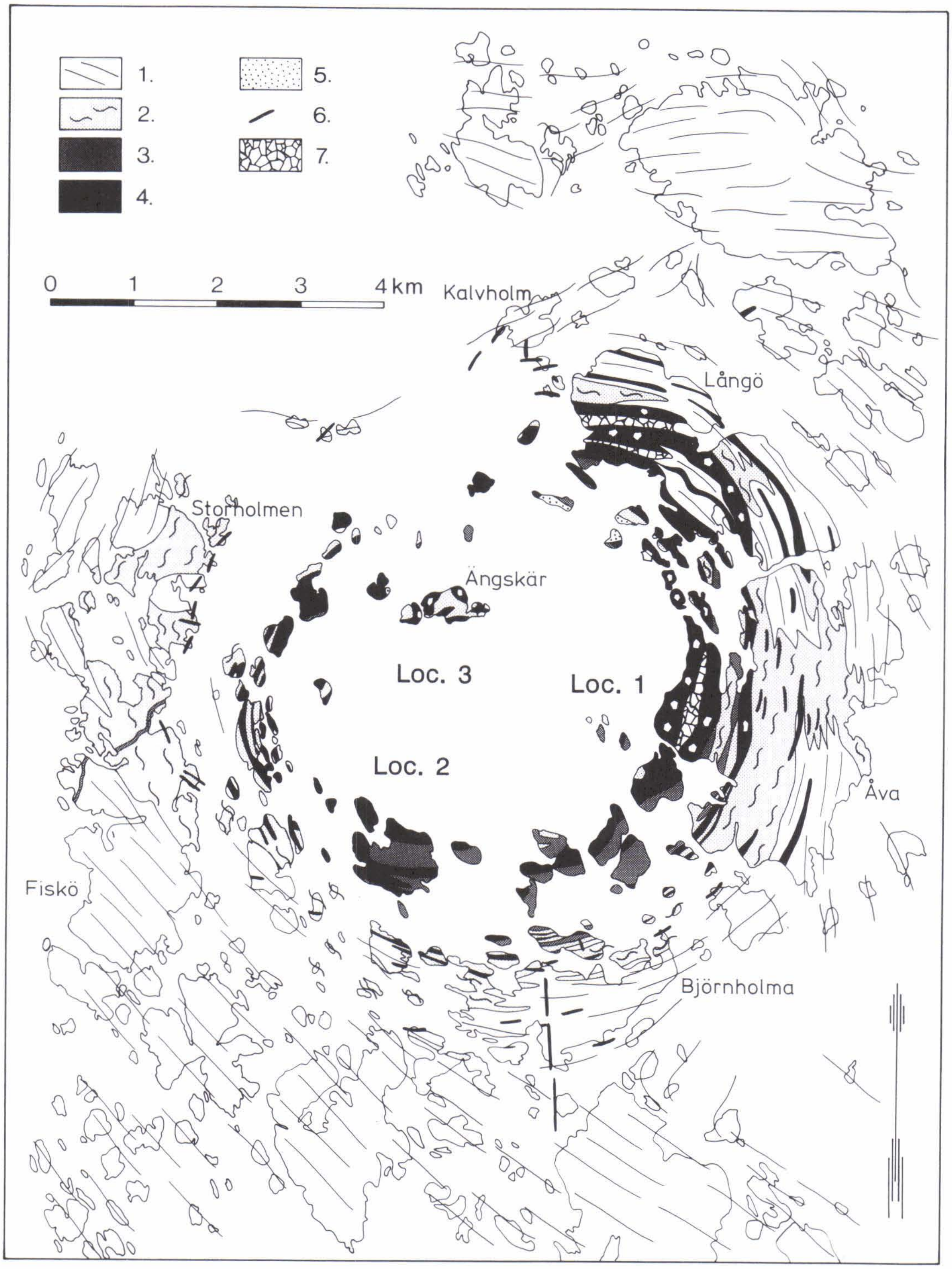
Fig. 11.

STOP 13A. The western shore of Åva island.

The locality is a large outcrop consisting of parts of a gently dipping granite ring intrusion with rounded "soft" fragments of monzonitic rocks and angular "brittle" fragments of country rocks. A couple of lamprophyric dykes belonging to the concentric dyke system are visible in the outcrop.

STOP 13B. The island of Ängskär

The island is close to the centre of the Åva intrusive complex and is part of a large shatter breccia consisting of large angular blocks of a pre-Åva granite intrusion. The breccia is cemented by coarse porphyric Åva granite.



1. COUNTRY ROCKS
2. MIGMATITES
3. MONZONITE
4. GRANITE
5. MICRO GRANITE
6. GRANITE DYKE
7. BRECCIA SCREEN

Fig. 12. Geological map of the Åva intrusive complex.

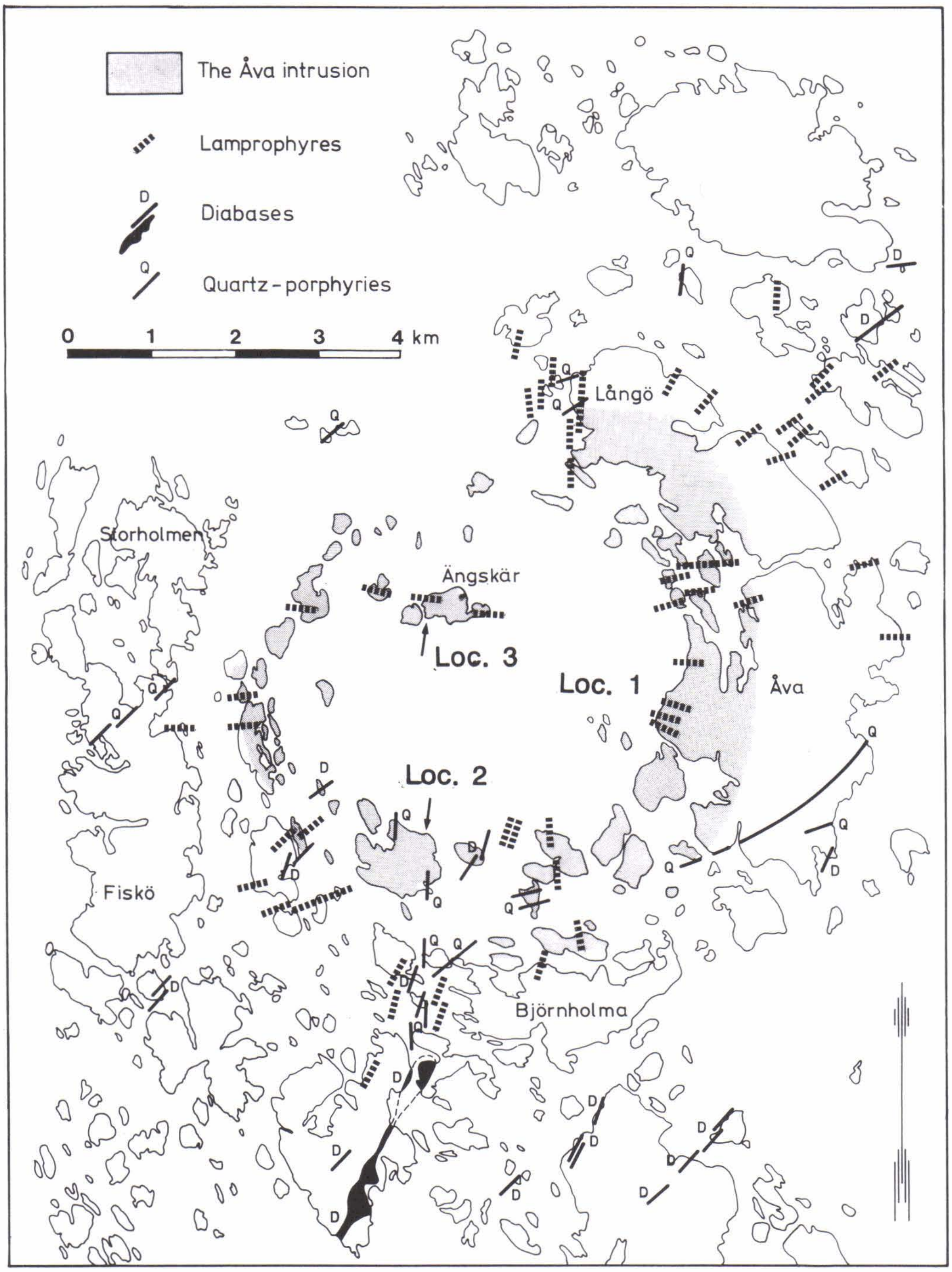


Fig. 13. Lamprophyre dykes cut the Åva intrusive complex in a radial pattern.

THE VEHMAA AND LAITILA RAPAKIVI BATHOLITHS

Atso Vorma, Geological Survey of Finland

Vehmaa rapakivi

The Vehmaa batholith (c. 700 sq.km) is composed mainly of rapakivi granite similar to the normal Laitila rapakivi to be described later. It is intruded by younger (pyterlitic, even-grained and porphyritic) varieties of the rock (Kanerva 1928). The age (1590 Ma) of the Vehmaa rapakivi (Vaasjoki 1977) is practicaly the same as that of the adjacent Laitila rapakivi. No up-to-date geological map of the Vehmaa rapakivi is available although a new mapping project is currently under way. Because of the good quality of the even-grained Vehmaa rapakivi, it is quarried on a large scale as building stone (as "Balmoral Red") in many places. The excursion will visit the Uhlu quarry (Fig. 2, stop 14).

Laitila rapakivi

After the Åland batholith, the Laitila rapakivi batholith (Vorma 1976) is the second largest (c. 1.400 sq.km) occurrence of rapakivi in SW Finland (Fig. 14). It was emplaced 1 570 Ma ago (Vaasjoki 1977) into the cratonized parts of the Svecofennidic complexes. It is an epizonal composite batholith with granitic rocks and basic rocks (anorthosite) on one side and porphyry dykes on the other. Contact breccias and chilled margins are often encountered in the Svecofennidic country rocks. The roof breccias and other country rocks exhibit signs of high temperature contact metamorphism even though the Svecofennidic country rock underwent regional metamorphism under conditions of the upper part of low-pressure amphibolite facies, occasionally reaching conditions of granulite facies, before the emplacement of the rapakivi.

Gravity data (Lauren 1970) suggest that the granite complex is a sheet with an average thickness of 5 km but being about 20 km thick in the root zone. It is an elongate, mushroom-shaped intrusion. The present erosion level is apparently near the roof of the batholith.

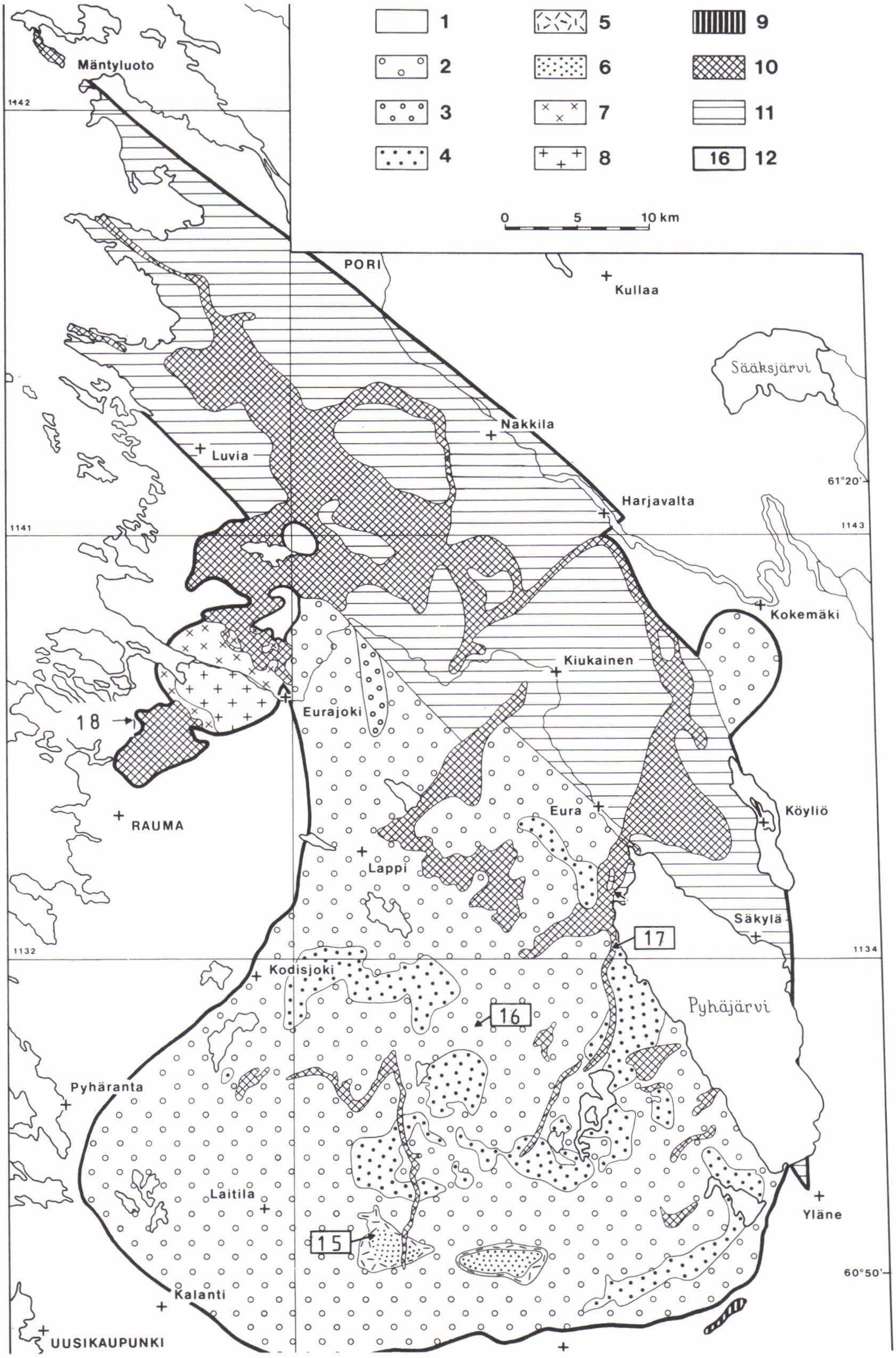


Fig. 14. Geological map of the Satakunta area. 1. Svecofennidic orogenic rocks, 2 - 9. Sub-jotnian rocks, 2. Normal Laitila rapakivi, 3. Granite porphyry, 4. Biotite rapakivi, 5. Marginal Ytö and Suutila granite, 6. Central Ytö granite and Katinhäntä aplite, 7. Tarkki granite, 8. Väkkärä granite, 9. Anorthosite, 10 - 11. Jotnian rocks, 10. Olivine diabase, 11. Sandstone, 12 Excursion stop.

Geochemically, rapakivi granites are richer in K, F, Rb, Zr, Hf, REE, Th and U, and poorer in Ti, Al, Fe, Mn, Mg, Na, P and Sr than granites in general, and are characterized by exceedingly low Mg/Fe and K/Rb ratios and a high Ca/Sr ratio (Vorma 1976). In places the youngest intrusive phases have geochemical characteristics of stanniferous granites.

The mineral composition of the rapakivis is truly granitic, the most basic varieties being either quartz syenites or quartz monzonites. The major minerals are potassium feldspar, either orthoclase or microcline, oligoclase and quartz (idiomorphic "high quartz"). Mafic minerals are represented by very iron rich varieties of biotite, hornblende, olivine and grunerite.

The bulk of the Laitila rapakivi batholith consists of what is known as normal Laitila rapakivi (Stop 16), which is similar in texture to the classic pyterlite of Wiborg rapakivi but is closer in mineral and chemical composition to the classic wiborgite rapakivi than to pyterlite. The ovoidal texture is well developed. The rare plagioclase mantles around the alkali feldspar ovoids are thin. The ovoids measure from 2 to 4 cm in diameter. The brownish variety of rapakivi is a hornblende-biotite rapakivi, whereas the pink variety is a biotite rapakivi. In addition to hornblende and biotite, the dark-brown varieties usually contain small amounts of fayalite and grunerite.

The rock does not only vary in colour but also in texture. Variations in ovoid size are best seen near the contact of the batholith. In places, the ovoids become increasingly small and sparse over a distance of 100-200 m from the contact. In many places, a contact zone a few tens of metres wide and compsed of medium- and even-grained granite occurs against the nonrapakivitic country rock. The "chilling" of rapakivi magma against the country rocks is not general.

Another textural variety near the contacts is the granite-porphyritic contact variety, which forms zones tens of metres wide against the country rock.

A minor part of the Laitila batholith consists of rapakivi varieties that deviate so much from the normal Laitila rapakivi in textural features that they are designated by special names. These granites form bodies from tens of centimetres to several kilometres in diameter. Some are evidently autolithic, formed from magma chilled first and then brecciated by the same magma; others are certainly a result of early segregation. Some of the biotite granites were evidently produced by autointrusion. The Honkilahti, Lellainen and Elijärvi granites, to mention but a few, evidently belong to this category (Stop 16). Finally, many of the biotite granite bodies, e.g. those of Ytö and Suutila, formed from intrusive phases of rapakivi that differed completely from those from which the normal Laitila rapakivi crystallized (Stop 15). They were probably emplaced as a result of underground cauldron subsidence. In mineral composition, the Ytö granite and related rocks possess certain characteristics that distinguish them from other rapakivis of the Laitila batholith. All these granites are biotite-muscovite granites, even though their bulk composition, is close to that of hornblende-biotite granite. In addition to the characteristic accessory minerals of most Laitila rapakivis (fluorite, zircon, apatite and opaques), these rocks also have monazite as an accessory. In contrast to most rapakivi granites, which are pinkish brown or pink, these granites are grey. They occur in two major varieties: a centrally located small-grained granite and a younger porphyritic, marginal variety.

The Laitila rapakivi batholith is cut by granite, aplite, pegmatite and quartz dykes. Miarolitic cavities associated with certain late rapakivi varieties are quite common, indicating the presence of a fluid phase under low confining pressure. Unlike granitic rocks crystallized deeper in the earth's crust, pegmatites are rare.

The Laitila rapakivi batholith has a small number of satellite rapakivi bodies, e.g., the Eurajoki stock and the Kokemäki granite. In the NW part of the area, the Eurajoki stock, with the horse-shoe shaped, even-grained marginal hornblende (Tarkki) granite and a younger central topaz-bearing (Väkkärä) granite, was studied in detail by Haapala (1977) for its tin. The central Väkkärä granite is a typical stanniferous granite with various greisen bodies. The Eurajoki stock is cut by sets of porphyry dykes. The Kokemäki granite is regarded as a rapakivi because of its composition and age. Although the same in age as the Laitila massif, it is separated from the main Laitila massif by the down-faulted Satakunta rift filled with Jotnian sandstone.

It has been postulated that rapakivi magma was generated in the lower crust either during the Svecokarelidic orogeny (the emplacement being postorogenic) or after it (the emplacement being postorogenic, the granite anorogenic).

Excursion stops

STOP 14. Uhlu, Vehmaa (1044, x = 6427.1, y = 541.7).
Equigranular Vehmaa rapakivi, "Balmoral red".

STOP 15. Kusni, Laitila (1132, x = 6750.5, y = 545.2).
Contact between Ytö granite (Vorma 1976, p. 48-55, Fig. 21) and Laitila rapakivi (op.cit., Fig. 22). Ytö granite has flow structure parallel to the contact, and the autoliths (op.cit., Fig. 23) are oriented along the contact.

STOP 16. Hinnerjoki (1133, x = 6765.3, y = 553.0).
Road cut between Laitila and Eura. Lellainen-type equigranular rapakivi in contact with normal Laitila rapakivi (Vorma 1976, p. 45).

STOP 17. Mestilä, Eura (1134, x = 6670.7, y = 562.2).
Contact between diabase and normal Laitila rapakivi.

THE EURAJOKI STOCK

Ilmari Haapala, University of Helsinki

The Eurajoki rapakivi granite stock is a satellite of the Laitila batholith, which it just touches in one outcrop. The stock is 8-9 km in diameter and intrudes the Svecofennidic gneisses and migmatites (Fig. 15). It is composed of three mineralogically different granite types: 1) a hornblende-biotite granite known as Tarkki granite (the oldest), 2) biotite granites, and 3) a topaz-bearing microcline-albite granite (the youngest) in which the dark mica is lithian siderophyllite. Quartz porphyry dykes, some of them topaz-bearing, cut the Tarkki granite. In addition, there are three odd porphyry dykes which differ in chemical and mineralogical composition from the quartz porphyry dykes (megacrysts include labradorite, K-feldspar and quartz).

The even-grained Tarkki granite contains orthoclase, quartz, calcic andesine, biotite and hornblende as the major constituents; typical accessory minerals include fayalite and its alteration products (iddingsite and grünerite), ilmenite, apatite and zircon.

The topaz-bearing Väkkärä granite is generally porphyritic, with megacrysts of microcline perthite and quartz, rarely albitic plagioclase. Ubiquitous accessory minerals are fluorine-rich lithian siderophyllite (1-5 vol.%), topaz (1-3 vol.%), monazite, ilmenite, Nb- and Ta-rich cassiterite, columbite and bastnäsite. The presence of miarolitic cavities, pegmatite pockets and hydrothermal alterations suggest that the Väkkärä granite magma was water-saturated during its final stage of crystallization.

The topaz-bearing granite is characterized by marked subsolidus reactions which are in part autometamorphic adjustments of the minerals to falling temperature (exsolution, recrystallization), in part metasomatic mineral replacements. Topaz, which is largely a metasomatic mineral is also partly a primary constitutent of the rock. It is also found in the quartz porphyry dykes. Interaction between fluorine-rich fluids and plagioclase has changed the plagioclase to a turbid albite with very small inclusions of fluorite, topaz, quartz and sericite ($CaAl_2Si_2O_8 + 4HF = CaF_2 + Al_2F_2SiO_4 + SiO_2 + 2H_2O$). Intergranular water-clear albite at microcline-microcline and plagioclase-microcline boundaries was probably formed mainly by exsolution from the alkali feldspar. The accessory cassiterite

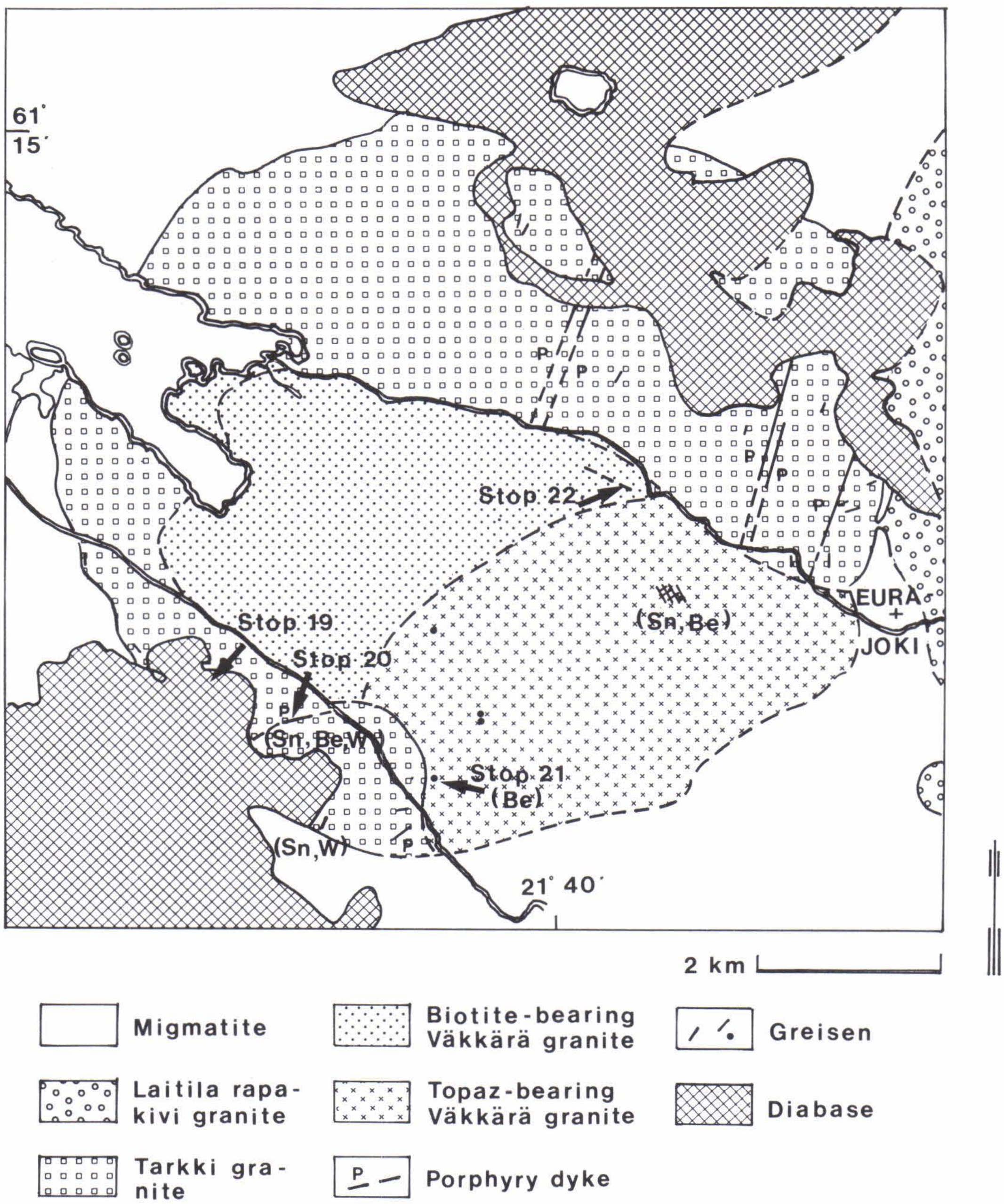


Fig. 15.

of the granite differs in composition (Nb_2O_5 3.5, Ta_2O_5 2.5 wt. %) from the cassiterite of the pegmatite pockets and veins (Nb_2O_5 2.2, Ta_2O_5 0.5 wt. %) and from the cassiterite of the greisen bodies (Nb_2O_5 0.3, Ta_2O_5 0.0 wt. %) within the Eurajoki stock; this indicates early (late-magnetic) origin of the accessory cassiterite of the granite.

The topaz-bearing Väkkärä granite is geochemically anomalous, showing features typical of a tin granite. It is highly enriched in F (0.9 - 1.3 wt. %), Li (mean of 31 analyses 240 ppm), Ga (66 ppm), Rb (870 ppm), Sn (84 ppm) and Nb (about 55 ppm), and impoverished in Sr (mean <40ppm) Ba (100 ppm) and Zr (70 ppm). The REE pattern is characterized by a deep negative Eu anomaly and relative enrichment in HREE in comparison with normal rapakivi granites. The geochemical anomalies of topaz-bearing granite are due to the combined effect of extreme fractionation and superimposed alternation.

Greisen-type Sn-Be-W-Zn mineralizations are found in several places in the Eurajoki stock. In the Tarkki granite, the ore minerals are in greisen and quartz veins; the topaz-bearing Väkkärä granite also hosts irregular greisen bodies. Two mineralized areas were studied by diamond core drillings, but no economically viable deposits were found.

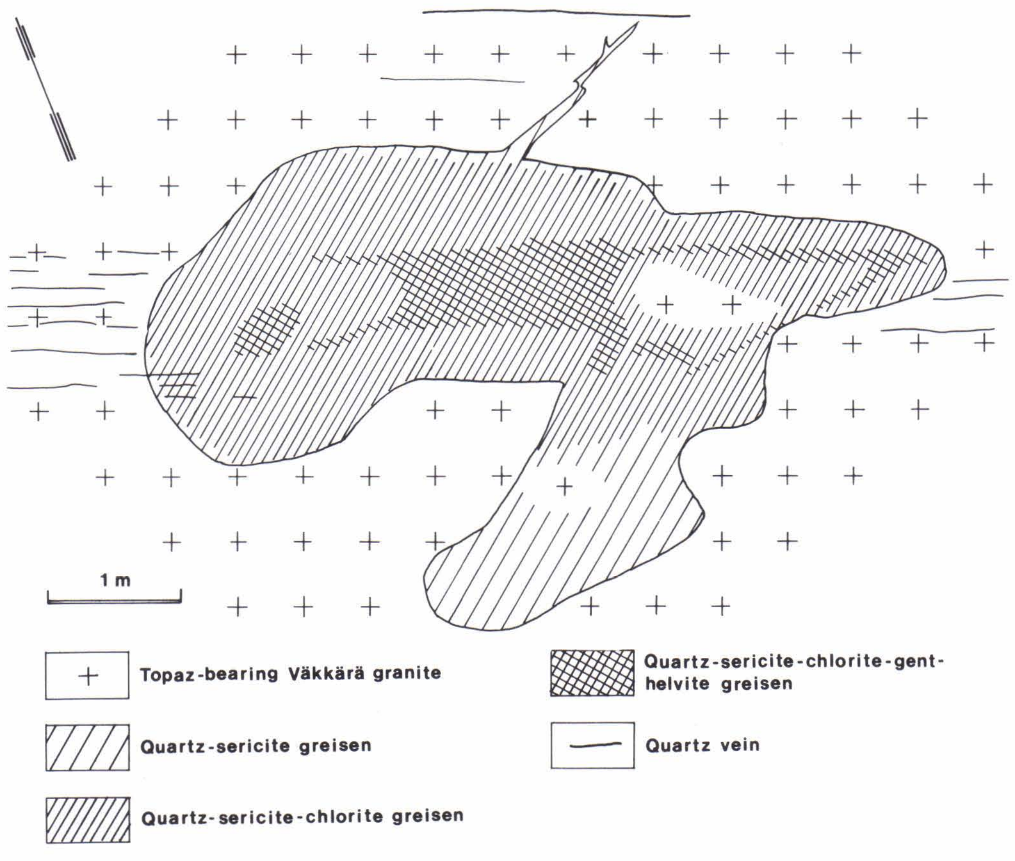


Fig. 16. A genthelvite-bearing greisen body in the topaz-bearing Väkkärä granite, stop 21 (after Haapala and Ojanperä 1972)

Excursion stops

STOP 19A. Rauma-Sorkka (x = 6785.08 , y = 529.16).

Contact between the subhorizontal Sorkka diabase sheet and the underlying Svecofennidic migmatite.

STOP 19. Hankkila (x = 6787.7, y = 532.4).

A diabase quarry. Palingenic dykes from the surrounding granite intrude the diabase dykes.

STOP 20. Lapijoki (x = 6787.22, y = 533.0)

A swarm of greisen veins in the hornblende, and fayalite-bearing granite (Tarkki granite). The veins contain cassiterite, wolframite, molybdenite, sphalerite, chalcopyrite and galena as ore minerals; beryl is common in the central quartz veinlets. The distribution of tin is irregular, and locally its abundance in the greisen is about 20 wt.%. Fluid inclusion studies show that cassiterite crystallized from fluids at a minimum temperature of 260^{o}-390^{o} C, with a gross salinity equivalent to 3-17 wt.% NaCl, and that beryl crystallized from fluids at a minimum temperature of 360^{o}- 410^{o}C with a salinity equivalent to 11-17 wt.% NaCl (Haapala and Kinnunen 1979). Close to the greisen swarm there is a topaz-bearing quartz porphyry dyke.

STOP 21. Koivuniemi (x = 6786.5, y = 534.62).

A greisen lens in the topaz-bearing Väkkärä granite. The greisen body has a zonal structure with quartz-sericite-chlorite-genthelvite greisen at the centre (Fig. 16). This greisen body is noteworthy as it contains the rare beryllium mineral genthelvite (Zn, Fe, Mn) $(Be\ SiO_4)_3\ S$.

STOP 22. Eurajoki (x = 6789.97, y = 536.00).

A dark porphyry dyke in the Väkärä granite. The dyke contains insets of corroded and partly altered labradoite, K-feldspar and corroded quartz crystals. The dyke was probably formed by mixing of mafic and felsic porphyry magmas.

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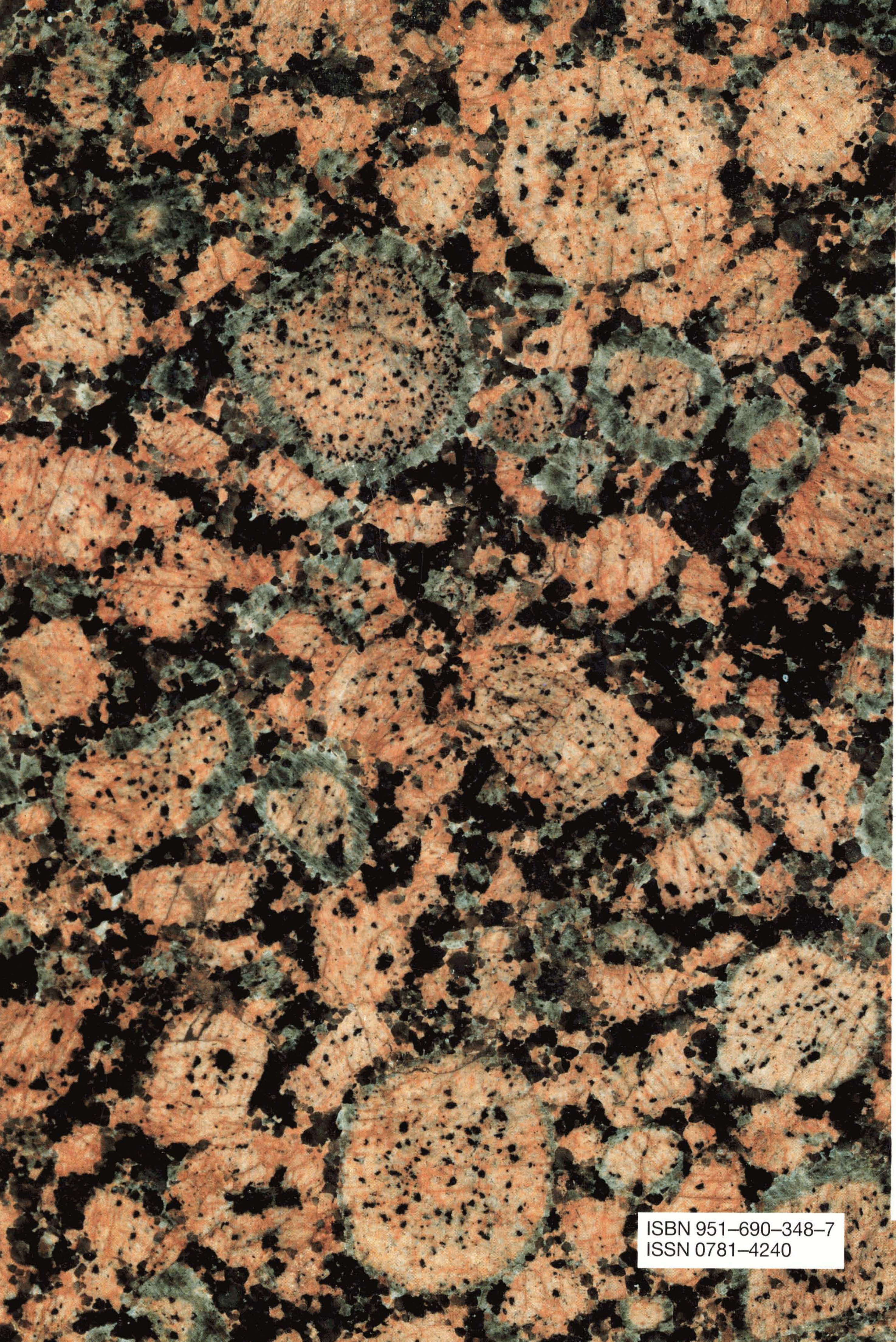

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