

SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 773 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 74 NR 1

ANDERS WIKSTRÖM, SVEN AARO
AND
MATS LAGMANSSON

THE GRAVERSFORS AND STAVSJÖ GRANITES

AND SOME PROBLEMS CONNECTED WITH
THE MAGMATISM IN THE FINAL STAGES
OF THE SVECOKARELIAN OROGENY



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ABSTRACT

Wikström, A., Aaro, S., and Lagmansson, M., 1980: The Graversfors and Stavsjö granites and some problems connected with the magmatism in the final stages of the Svecokarelian orogeny. Manuscript received Sept. 1979.

A postorogenic Svecokarelian event is described. An older Stavsjö igneous suite of a mild calc-alkaline character can be distinguished. It displays a differentiation ranging from norite to granite. The youngest granite of this suite is characterized by rectangular, oriented microcline megacrysts. Rocks of the suite are enriched in accessory minerals, above all sphene and apatite. Within the area no marked events seem to separate the late orogenic processes from the beginning of the postorogenic magmatic episodes.

Further west and towards the main body of postorogenic granitoides in central Sweden, the somewhat younger Graversfors granite can be distinguished in a rounded massif, 10 km in diameter. In the west conformable structures have been developed and the tectonic influence of the granite can be traced about 5 km from the contact. On the other hand the eastern contact shows a lobate pattern with dykes of the granite arranged radially. These features indicate that the eastern half represents a section much deeper than the western half. During the initial (magmatic) intrusion the strain rate was high, with a brittle fracturing of the overburden. During a later stage a hat of the diapir started to spread slowly, and conformable structures were created. Finally fault movements striking north—south brought the two halves together. The western half is clearly more heterogeneous, with supracrustal xenoliths, colour variation and acid, late differentiates.

In spite of its variable chemical composition the granite is fairly homogeneous in texture. It is coarse-grained, with more or less well-defined rounded perthitic megacrysts, sometimes showing plagioclase mantling. Monoclinic X-ray patterns have been found in some of the potash feldspars. The majority of these can be related to thermal disturbances in contact zones.

Gravity and petrophysical measurements have been made as a part of the investigation.

Gravity highs can be seen both over the Graversfors and Stavsjö massifs. From these measurements, the three-dimensional structure of the Graversfors granite has been calculated. A mushroom-shaped diapiric structure has been established, with the root in the eastern part of the massif. As a whole the Graversfors granite is somewhat heavier than the surrounding bedrock.

I. GENERAL PART

By

ANDERS WIKSTRÖM

INTRODUCTION

The Graversfors and Stavsjö granites are here regarded as postorogenic Svecokarelian (Svecofennian). They form smaller massifs to the east of the extensive area occupied by the Småland—Värmland granites with which they can be regarded as roughly parallel in time of development. No radiometric ages are available for them, however. The old term "Gothian" previously applied to these rocks is now less commonly used.

Graversfors and Stavsjö are small villages situated approximately 170 and 150

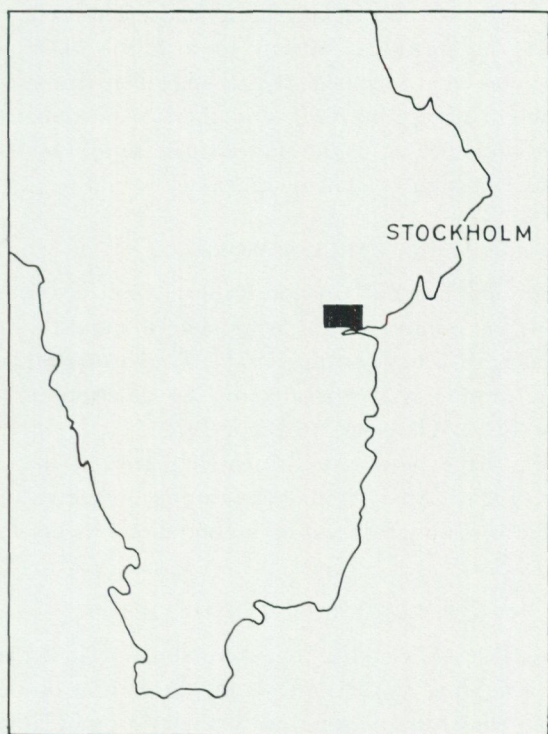


Fig. 1. Geographical position of the investigated area.

km to the southwest of Stockholm. They are located on the topographic mapsheets Katrineholm SV and SO respectively.

Of the two rock types the Graversfors granite is the youngest. The normal type is coarse-porphyritic with more or less rounded microcline megacrysts, sometimes plagioclase-mantled (Fig. 4). A common dark mineral is hornblende. The granite forms a rounded massif approximately 10 km in diameter. Outside the eastern contact smaller satellite bodies of the granite form a radially arranged pattern. Contrary to this the western contact is characterized by conformable structures. Here the tectonic influence of the granite on the country rocks can be traced almost 5 km to the west of the contact. The diapiric structure revealed especially by the gravimetric measurements (Aaro and Lagmansson, second part of this paper), the general magmatic character of the granite and the fact that it is somewhat heavier than the surrounding rocks creates problems regarding the interpretation of the intrusion mechanism.

The somewhat older Stavsjö granite is the youngest member of a differentiated suite in which the oldest rock is a norite. Macroscopically the main difference compared with the Graversfors type is that the feldspar megacrysts are more rectangular in shape and do often show a grain orientation (Fig. 12). The

coarser porphyritic types are also lacking hornblende. The basic members of the Stavsjö suite display no intrusive contacts towards the older rocks, all being surrounded by the more acid members of the suite. Petrographically these rocks form a rather coherent group, however, and there is no doubt that the norite and the other basic rocks belong to the postorogenic suite. One common feature of the Stavsjö rocks is a high content of sphene.

EARLIER WORK

The Graversfors granite has not previously been described in detail. Shorter notes can be found, for instance in the works by Holmquist (1906), Hedström (1908), Asklund (1925), Lundegårdh (1971), Gorbatshev (1971) and Wikström (1974). The granite is also treated in the descriptions to the maps of the area (Nathorst 1877, Wikström 1976 and 1979).

The Stavsjö rocks have been more extensively treated in a doctor's thesis made by Asklund (1925). Apart from petrographical descriptions of the main types, Asklund's work is mainly focussed on a "liquation" theory for the evolution of these rocks.

POSITIONS OF LOCALITIES

In the text all positions of localities are approximately indicated by a square number (e.g. 2b) according to the symbols in the margin of Fig. 2. For more detailed information the reader is referred to the two topographical map-sheets Katrineholm SO and SV (where the square numbers are the same). All coordinates in this paper are given in the Swedish National grid.

GENERAL GEOLOGY

The two rock groups are surrounded by older Svecokarelian rocks. English summaries of the geology in these areas are found in the descriptions accompanying the Geological Survey of Sweden bedrock maps Katrineholm SV and SO (Wikström 1976 and 1979). The general geology of the area is also summarized in Figs. 2 and 3.

The oldest map-unit is a supracrustal pile to which no basement has been identified. These rocks show highly variable compositions but are generally metamorphosed to veined gneisses in amphibolite facies. More pelitic layers contain some of the minerals garnet, cordierite, sillimanite and andalusite in various proportions.

These rocks have been intruded by different pre- to synkinematic (primorogenic) plutonics of calc-alkaline character. Even these rocks are often highly migmatized.

A second set of granitoids can be distinguished which in Fig. 2 has been called younger late-kinematic plutonics. Their compositions vary between granodiorite and granite. A certain scattering of their ages might be expected

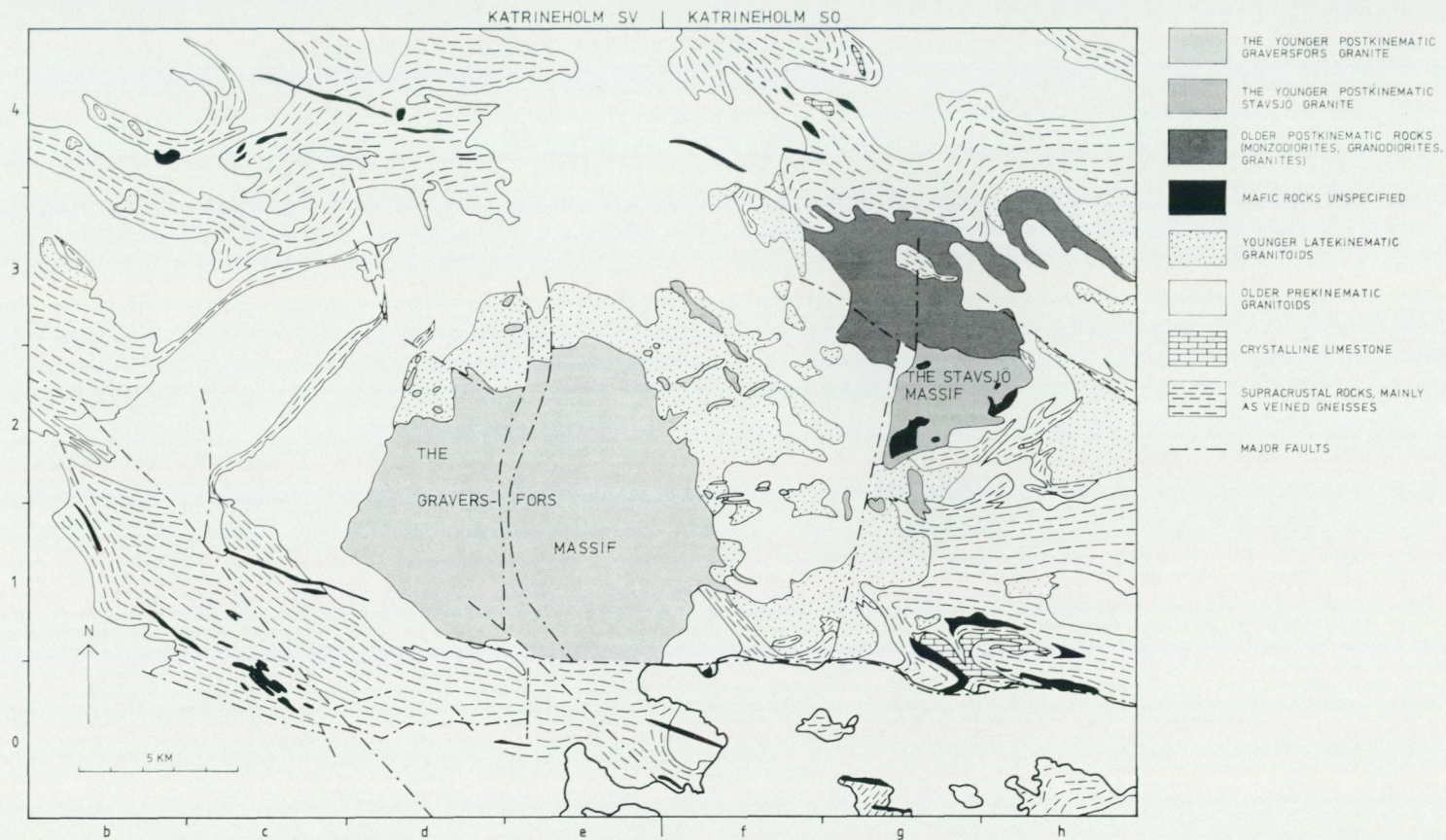


Fig. 2. General bedrock geology of the investigated area. The map is a simplification of published Swedish Geological Survey maps (Wikström 1976 and 1979).

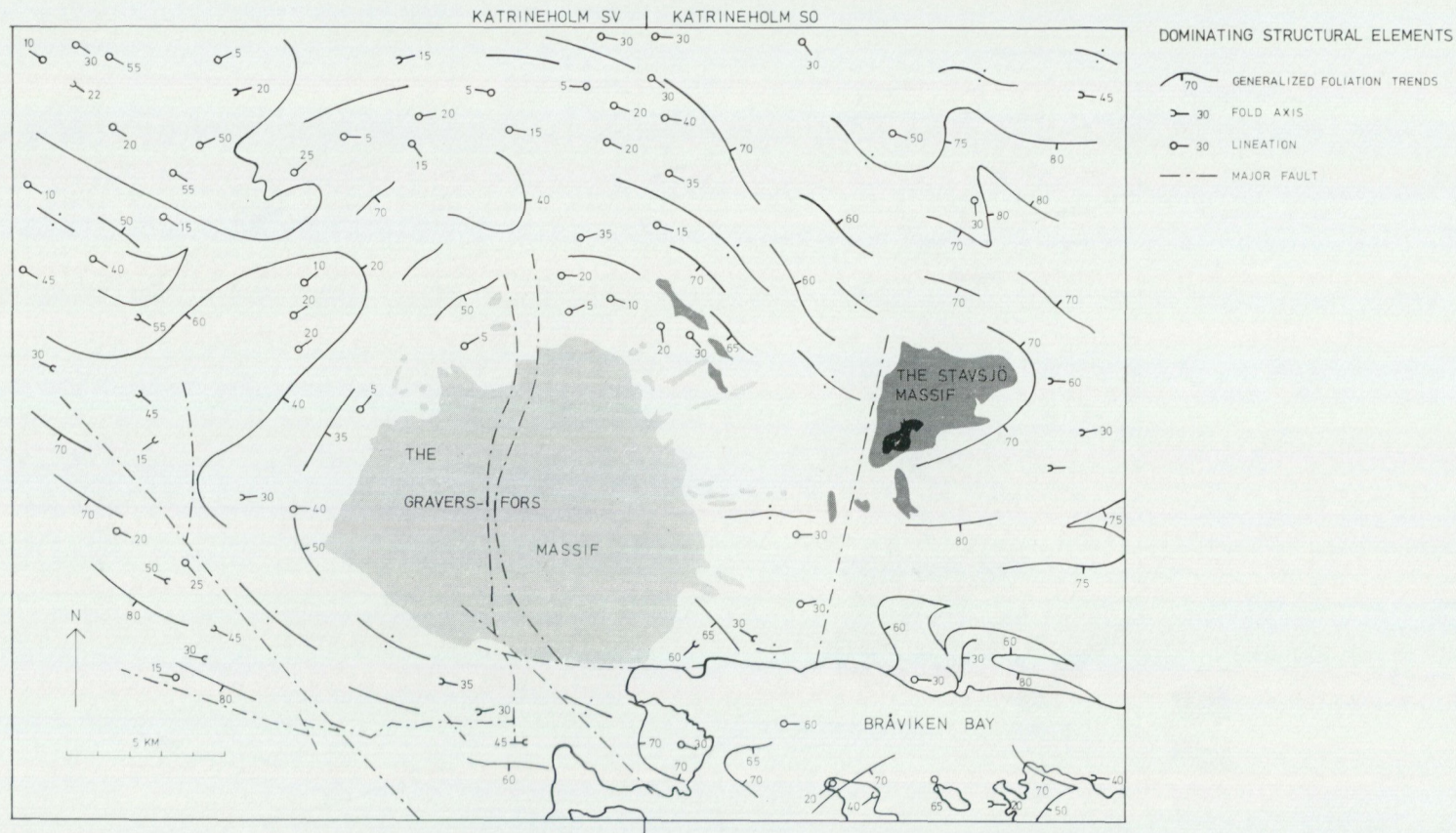


Fig. 3. Main structural features of the area.

since their main distinctive feature is their intermediate stratigraphic position between the older plutonics and the Stavsjö—Graversfors rocks. Some of the Stavsjö rocks are rather similar to these cross-cutting granitoids, and in the field it is sometimes difficult to distinguish between them.

The magmatic evolution to the east of the Graversfors massif and in the surroundings of Stavsjö is complex, and more work can certainly be done to separate different varieties. This multitude of granites in the area was already noticed by Nathorst (1877). The younger granite to the north of the Graversfors massif is red, medium-grained and massive. It is clearly older than the Graversfors granite and shows gradual contacts towards ghost-like remnants of the older plutonic group. However, its geographical location near the Graversfors massif suggests a genetical relationship to this. It might thus be interpreted as a remelted product of the pre- to synkinematic plutonics of the area.

The youngest Precambrian rocks in the area form a set of olivine dolerite dykes predominantly striking WNW—ESE. These dykes are easily seen on the aeromagnetic map in Fig. 23.

The general Svecokarelian fold axes and lineations are mainly oriented within east—west striking axial-planes showing high dips. A strong maximum is displayed by intermediate plunges towards the east or ESE. The fold patterns are characterized by different interference types. Especially around the Graversfors granite and to a minor extent around the Stavsjö massif, too, this pattern has been disturbed, as can be seen in Fig. 3. The correlation between these features and the general postorogenic character of the rocks concerned will be discussed on page 28.

THE GRAVERSFORS GRANITE

The normal type of this rock can be seen in Fig. 4. The colour of the perthitic, microcline-dominant megacrysts varies from red, reddish brown and brownish violet to different shades of grey. Reddish tints seem to dominate. This is relevant at least for superficial samples. When deeper sections are available a change towards grey can sometimes be observed. The grain size is fairly constant throughout the massif. Also in narrow dykes of the granite outside the main body, the grain size is coarse even close to the contact. Texturally both porphyritic and uneven-grained varieties can be distinguished although the difference between these is very small and gradual. No foliation or grain orientation has been found in the granite except for zones of local crushing. Fig. 5 shows the variable chemical composition of the rock. In the main, gradual transitions can be found between darker and lighter normal types although the colour is not directly dependent of the SiO_2 content. On the other hand, a compositional gap exists between the granite described and an acid, non-porphyritic type. This granite has a very limited areal distribution, however. In most outcrops there are small



Fig. 4. The Graversfors granite, normal type.

amounts of aplitic segregations, which rarely exceed 5% of the bedrock. Occasionally, similar rock types have also been identified as partly dissolved xenoliths of the late-kinematic granites.

INDUSTRIAL USE

The Graversfors granite was quarried to some extent from around 1870 to the start of the first world war. Mainly the red, nonporphyritic type with blue quartz (sample Gr 10) was used. This rock was discovered during the construction of the railway between Norrköping and Katrineholm. It was partly exported under the name "Rose Swede". In Sweden it can for instance be studied in the fountain outside the central office building of the University of Lund and in basins outside the Royal castle in Stockholm. The more coarse-

porphyritic types were also used, though to a limited extent, probably owing to imperfect mechanical quality. Colour photographs of the main types used in the industry have been presented by Hedström (1908).

MORPHOLOGY

Within the granite area the morphology is characterized by steep cliffs and deep valleys. This high relief can be seen on the official topographical map-sheets, and the approximate distribution of the granite can be traced already on these maps.

The granite massif has also had an armouring effect on the surrounding rocks. An area bordered in the west by a fault from lake Risten (1c) to Ringstad (0d, map-sheet Katrineholm SV) and in the east by a fault running through the lakes Torsjön (1g) and Björnsjön (2g, map-sheet Katrineholm SO) is on the average situated higher above sea level than the surroundings.

AREAL DISTRIBUTION OF DIFFERENT GRANITE TYPES

As seen from the tables and figures in this paper, the massif can be separated into an eastern and a western part, the two halves being separated by a north—south striking fault, the "Näkna fault", along the western shore of lake Näknen (1d, e). Movements have also taken place along the eastern shore.

The western half is comparatively more heterogeneous. Both the lightest, most acid and the darkest varieties are met with here, as well as xenoliths of older rocks which locally become abundant. From the gravimetric investigation it can be concluded that the western part displays a thin tongue of the hat of the mushroom-shaped whole-structure of the granite (Fig. 24). The heterogeneity apparently depends on the bottom-near position.

The acid type is found in a limited area to the southwest of the Näkna village (2d) and in contact with the major Näkna fault. The above mentioned quarried type displays gradual contacts towards paler and somewhat coarser and less "beautiful" varieties. Contacts towards the normal types have not been observed but it is assumed that the acid type is the youngest.

The darker type is found to the west and south of the acid variety. Most frequently it has undergone strong weathering in outcrop. In fresh road-cuts it exhibits a very dark and almost greyish black colour. Blue quartz is common also in this rock. In addition, some accessory orthopyroxene and olivine occur, as evident from the microscopical description (p. 13).

In the same area, to the west and south of Näkna (2d), numerous xenoliths of older rocks are also found. Southeast of lake Skärgölen (2d) seven small iron testpits are located to inclusions of supracrustal rocks rich in garnet, cordierite and magnetite.

Finally a red, fine- to medium-grained leucogranite has been observed in some

places, especially around lakes Skomakaren (2d) and Norra Flåtögölen (1d). The age position of this rock is uncertain. In some cases it cuts the megacrysts of the normal Graversfors type, in other cases late potassium feldspar megacrysts have grown into it. On the whole, this granite type behaves like a late differentiate. It is much more fine-grained than and differs texturally from the acid type to the west of Lake Näknen, however.

The eastern half is more homogeneous and represents a deeper crystallization level in the diapir. Compared with the normal types of the western half it is mainly characterized by an increase of the hornblende and biotite contents.

Very locally, as for example in a road-cut east of lake Mossbrogölen (2e), secondary alterations of the dark minerals can be seen to appear as fine-grained masses containing such minerals as chlorite, epidote calcite and muscovite.

The colour of the potassium feldspar megacrysts in the dykes outside the eastern contact is in normal cases brownish, sometimes with a tint in violet.

SOME MICROSCOPICAL CHARACTERS OF THE GRAVERSFORS GRANITE

Normal, coarse-porphyritic to uneven-grained type

Main minerals (> 25 %): 1, potassium feldspar, generally microcline, with distinct crosshatching. Perthite is very common with string types predominating. Plagioclase mantling can sometimes be seen, and myrmekite is common in the border zones. When the potassium-feldspar is orthoclase it generally lacks crosshatching and is frequently twinned according to the Karlsbad law. In one of the samples with a monoclinic X-ray pattern a diffuse microcline grating has been observed. 2, quartz, which fills interstices between the larger feldspar individuals. It is often arranged as linear aggregates and has most frequently been weakly strained.

Essential minerals (5—25 %): 1, plagioclase in variable quantities, sometimes exceeding 25 %, mostly developed as large irregular grains with albite or pericline twins. The anorthite content varies between 25 and 35 %. Secondary alterations are common. 2, amphibole (yellowish green—green—brownish green), mostly quartz—poikilitic with scattered grains of magnetite. 3, biotite (greenish brown—brown—dark brown), frequently forming symplectitic intergrowths with quartz.

Subordinate minerals 1—5 %): apatite.

Accessories (< 1 %): sphene, magnetite, zircon, calcite, chlorite, muscovite. The accessory minerals are often attached to the dark minerals.

Acid type

Main minerals: 1, potassium-feldspar, both as orthoclase and microcline. The X-ray pattern mainly shows monoclinic character. Microcline seems to represent a somewhat younger development, and diffuse microcline grating in some cases occurs along marginal zones of orthoclase. Both minerals are strongly perthitic, and myrmekitic intergrowths are common. Microcline can sometimes be found bordering plagioclase. 2, quartz, and 3, plagioclase (15–20% An), the latter most frequently strongly secondarily altered and sprinkled with minute hematite grains responsible for the bright red colour of the rock.

Subordinate minerals: 1, amphibole, most probably common hornblende (yellowish green—green—dark green), appearing as rare, prismatic, preserved crystals often exceeding one centimetre in length. 2, biotite developed as scattered, very small flakes (light green—green—very dark greenish brown).

Accessories: calcite, apatite, muscovite, zircon, magnetite, hematite.

Dark type

Main minerals: 1, plagioclase (An content around 35%) as large grains with weak or no alteration and mainly forming well-defined albite twins. 2, quartz, and 3, orthoclase, the latter as comparatively large, untwinned, generally non-perthitic grains locally showing myrmekitic development.

Essential minerals: amphibole (yellowish green—green—brownish green), often as comparatively large, skeletal crystals along grain boundaries, also poikilitic, with quartz, apatite and magnetite as predominant inclusions.

Subordinate minerals: 1, orthopyroxene (bronzite) as comparatively small grains often surrounded by amphibole. 2, magnetite.

Accessories: clinopyroxene, olivine, apatite, sphene, zircon, biotite.

GEOCHEMICAL PARAMETERS OF THE GRAVERSFORS GRANITE

Sampling. The samples have been collected according to a scheme implying a rough geographical covering of the massif. No statistical methods have been involved. The main reason for this is the presence of a weathered superficial layer (3–10 dm) in the granite. This means that drilling and heavy blasting ought to be necessary in order to get acceptable samples. Accordingly the overwhelming majority of analyzed samples were collected in road cuts, each sample amounting to 5–10 kg. The analyses have been made at the SGU laboratory. A few blank tests show that the analytical variation of some elements is somewhat greater than normal. This probably depends on the coarse grain size of the granite and the resulting difficulties to get homogeneous samples during the preparation. Only the major elements have therefore been analyzed and

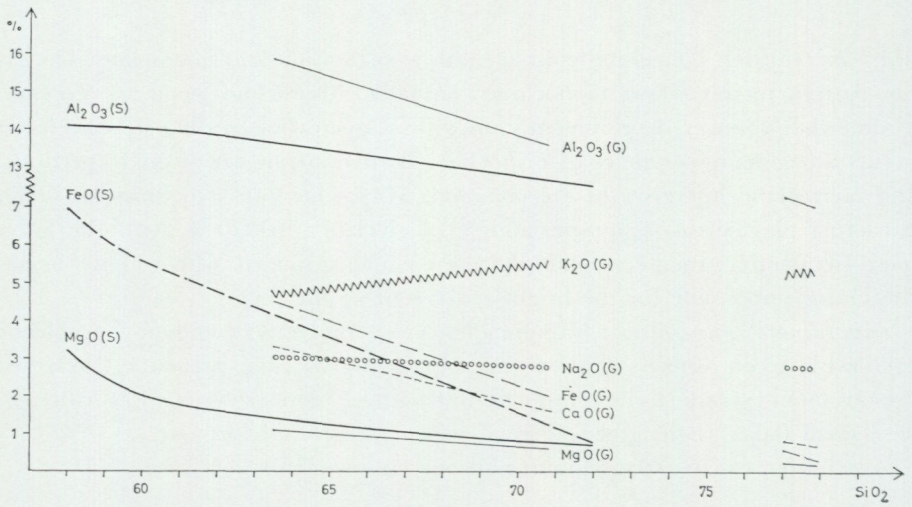


Fig. 5. Compilation of the chemical variance of some major elements within the Gravfers granite (G) and the Stavsjö suite (S).

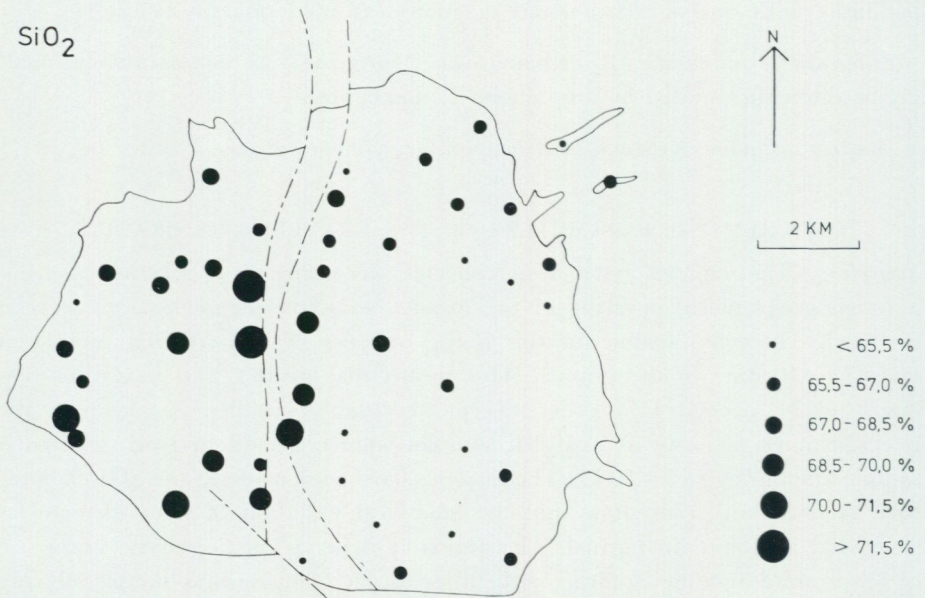


Fig. 6. Areal distribution of the silica content within the Gravfers granite.

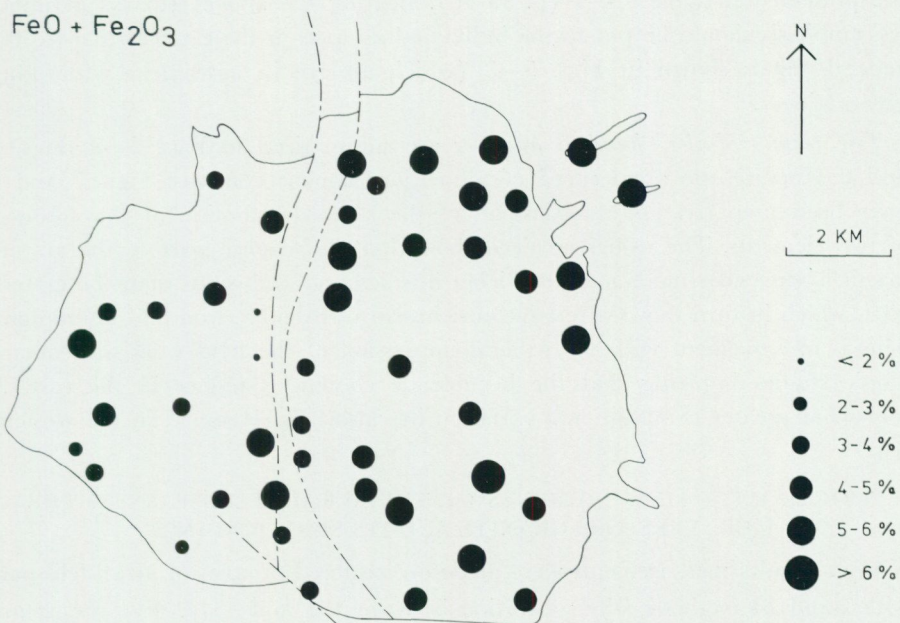


Fig. 7. Areal distribution of the iron content within the Graversfors granite.

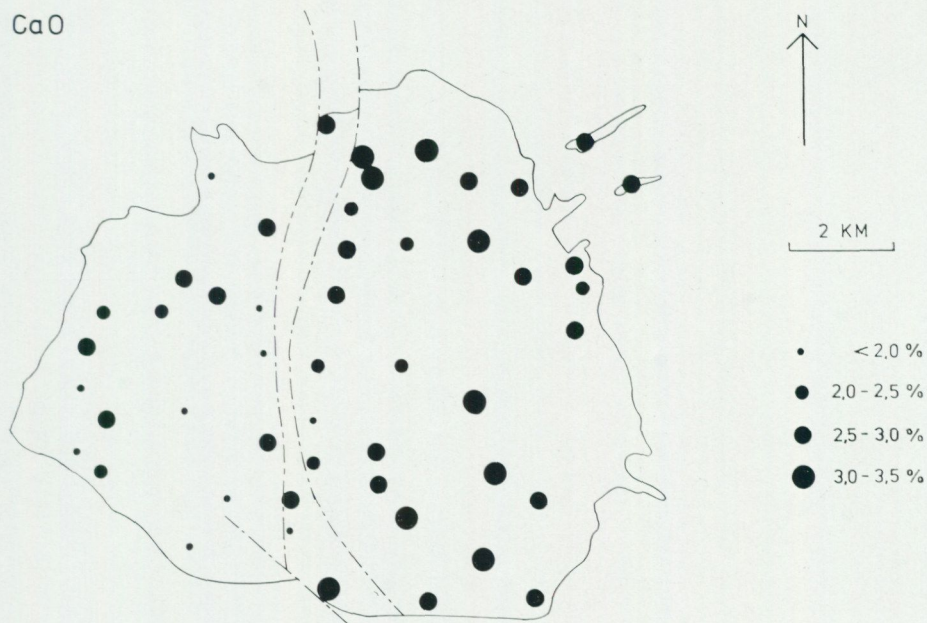


Fig. 8. Areal distribution of the calcium content.

are presented in tables 1—5 (p. 43 ff.). Bearing the above remarks in mind, less emphasis should be put to the individual samples in these tables than to the general trends shown in Figs. 5—8 (which all are in agreement with other observations).

The results of the chemical analyses are summarized in Figs. 5—8. Figs. 5 and 6 visualize the areal spread of all major element contents. Figs. 7 and 8 have been prepared just as examples of the areal distribution of the contents of two elements. The values received show that the western part of the granite massif is somewhat more acid and richer in silica and potassium than the eastern part, which in turn shows a relative enrichment of calcium, iron and aluminium. This is in agreement with the general impression of the field work and microscopic studies implying that the hornblende content is higher in the east. A somewhat greater compositional variation has also been observed in the western part.

TRICLINICITY MEASUREMENTS OF THE ALKALI FELDSPARS IN THE GRAVERSFORS GRANITE AND ITS SURROUNDINGS

X-ray obliquity measurements were made on scattered samples of alkali-feldspars with standard methods (the separation between 131 and $1\bar{3}1$). The results are shown in Fig. 9.

It has been maintained in a number of papers (e.g. Laves 1950, Kornfält 1969, Christie et al. 1970, Lundqvist 1973) that the thermal history of the rock investi-

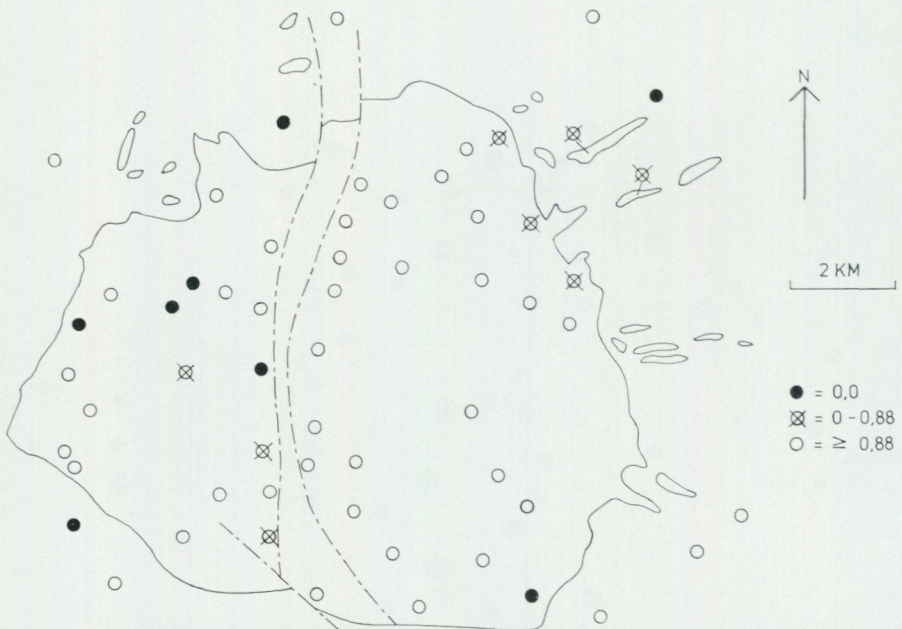


Fig. 9. Triclinicity of potassium feldspar in the Graversfors granite and its surroundings.

gated is a major factor among those controlling the crystalline state of the alkali feldspar. The appearance of monoclinic, non-ordered patterns has been related to a quick crystallization process or a fairly strong reheating of earlier triclinic crystals. The intermediate stage giving blurred X-ray patterns might be interpreted as a sign of non-equilibrium where the processes mentioned above have not proceeded to completion.

As regards the Graversfors massif, monoclinic or blurred patterns are found:

- a, just outside the granite in the country rocks (mainly prekinematic granitoids),
- b, within the granite near the contact (both horizontally and vertically),
- c, near the Näkna fault,
- d, in the vicinity of supracrustal xenoliths.

In the first case a reheating of the contact-near country rocks can be expected in connection with the intrusion, whereas in the later cases disturbances during the crystallization can be expected. The patterns near the Näkna fault are not fully understood, however, but might indicate a position near the base of the granite. No direct relation to chemical or modal compositions has been observed.

ELECTRON MICROPROBE ANALYSES

Some partial analyses of different minerals were made with a microprobe. Biotite and hornblende individuals were investigated regarding their iron/magnesium ratio. Magnetite and ilmenite grains were tested as to their contents of the molecules ulvöspinel and hematite respectively. Finally, some potassium-feldspar megacrysts were analyzed in order to see if variations of colours and contents of some major elements possibly could reveal correlations.

Biotite and hornblende show different compositions in the Graversfors and Stavsjö rocks. This is mainly due to the comparatively iron-richer character of the former which will be somewhat discussed in the last chapter. A small tendency towards higher Mg/Fe ratios in biotite as compared to hornblende can be seen in the Graversfors samples, while the opposite is true for the few Stavsjö samples. If these tendencies are real or not is, however, not clear.

The magnetites were found to be fairly pure Fe_3O_4 . Indeed, the contents of titanium and other expectable components were below or around the detectability of the instrument.

The ilmenite grains do not only contain iron and titanium but also some manganese. The calculation of the hematite molecule, actually involving some question marks, has shown a variation between one and ten percent.

The magnetite and ilmenite compositions thus indicate a low temperature and probably a deuteric type of formation.

SIGNS OF THERMAL EFFECTS IN THE SURROUNDINGS OF THE GRAVERSFORS GRANITE

In spite of an unfavourable geological situation, various contact-metamorphic phenomena have been observed. Such phenomena are most easily detected in pelitic rocks, which are lacking in the surroundings of the granite. All observable contacts border on older granitoids.

As previously stated and discussed, monoclinic feldspars have been found in the country rocks bordering on the granite and have thus been interpreted as an indication of contact-metamorphism.

In the northwest, flecky structures in granitoids have locally been noted about 50—500 m from the contact. The spots are composed of cordierite, andalusite and green biotite. No identifiable supracrustal remnants have been recognized, but possibly the spots have grown at places where the surrounding granite has dissolved some pelitic rocks. Their formation may eventually be coupled to the intrusion of the Graversfors magma.

In the neighbourhood of the Graversfors granite signs of metamorphism caused by a heat flow prior to the Graversfors intrusion have also been found. West of the massif, the Holpen antiform which plunges towards the northeast (Wikström 1976, p. 70) has been found to depend on the Graversfors intrusion. Within this antiform one can find a locally slightly deformed, greyish white plagioclase granite (trondhjemite) essentially composed of oligoclase (An_{15}), quartz and some accessory hornblende. During the mapping (Wikström 1976) the age position of this plagioclase granite remained uncertain. It may now be interpreted as a remelting product of the older prekinematic (primorogenic) granodiorite. This process ought to have taken place just before or during the folding connected with the Graversfors intrusion. A similar development has also been stated in the north and in the east. The older prekinematic (primorogenic) granitoids are here generally acid and relatively rich in potassium. The younger granites of the area have also been enriched in this element. Indeed, the close geographical connection with the Graversfors granite along its northern contact suggests a genetic relationship. However, as earlier mentioned, the younger granite is clearly older than the Graversfors granite, actually bordering upon it with sharp contacts. On the other hand it displays gradual contacts on and contains ghostlike remnants of the older prekinematic (primorogenic) rocks. The same situation is also met with along the eastern part, although the area is there somewhat more heterogeneous and offers problems regarding the distinction between the late-kinematic (serorogenic) migmatization and the mobilization originated by the Graversfors intrusion. All observations made support an interpretation implying that extensive remelting of the older crust occurred prior to the major intrusion.

The aeromagnetic map (Fig. 23) shows a radial pattern along the eastern margin of the Graversfors granite. The anomalies approximately coincide with

the dykes of the Graversfors granite. The coincidence is not complete, however. This can be related to an observation of porphyroblastic growth of magnetite in the surrounding granitoides. The magnetite crystals might be as large as one centimetre in diameter.

MECHANISM OF INTRUSION

Some of the data now given for the Graversfors granite and its surroundings can be used for speculations about its intrusion mechanism. Ramberg's (1967) model experiments on diapirs show that the viscosity ratio between a diapir and its surroundings should amount to 10^3 in order to allow the development of the observed structures. Accordingly, he concluded that granites forming diapirs in a fairly stiff crust should intrude in a solid crystalline but plastic condition.

Since the Graversfors granite is somewhat heavier than its surroundings (Fig. 20), a simple "crystalline" diapir model cannot be maintained in the first place. According to the model experiments it is still possible that the driving force could have been created at great depths in the crust. The granite ought then to have had enough energy to penetrate a lighter layer on its way up. No arguments in favour of such an interpretation have been found, however.

Since the granite has a pronounced igneous character, a magmatic model seems more probable. Intuitively the apparent large gap in the effective viscosities between a magma and its crystalline surroundings could in part be compensated by a very low strain-rate. The rate of granite intrusion could be of the order of about 5 mm/year and the rate of the spreading hat (Fig. 10; cf. Fyfe 1970) could be even slower. Even a partial melting of the country rocks (some 5–10% of the migmatitic veining can be directly related to the orientation structures to the west of the massif) would reduce this difference. The previously mentioned granites in the surroundings could also be coupled to a remelting just before the main intrusion.

Unfortunately it is very difficult to get an approximation of the viscosity of a somewhat melted rock with its mixture of liquid and solid during a very slow rate of flow. No equations applicable to the present problem have been recognized. The Einstein formula used by Fyfe (1970) does not seem to fit these purposes even approximately.

Some hypothetical stages in the development of the Graversfors diapir are summarized in Fig. 10.

An estimate of the viscosity contrast between a diapir and its surroundings can also be made from the spacing of adjacent granitic bodies (Ramberg 1968). Lindh (1977) made an attempt to use this relation when encountering difficulties to match the magmatic character of the Blomskog (c. 965 Ma) granites with experimental data. A final model was constructed where the initial doming took place in a solid state but a melting occurred prior to the final intrusion.

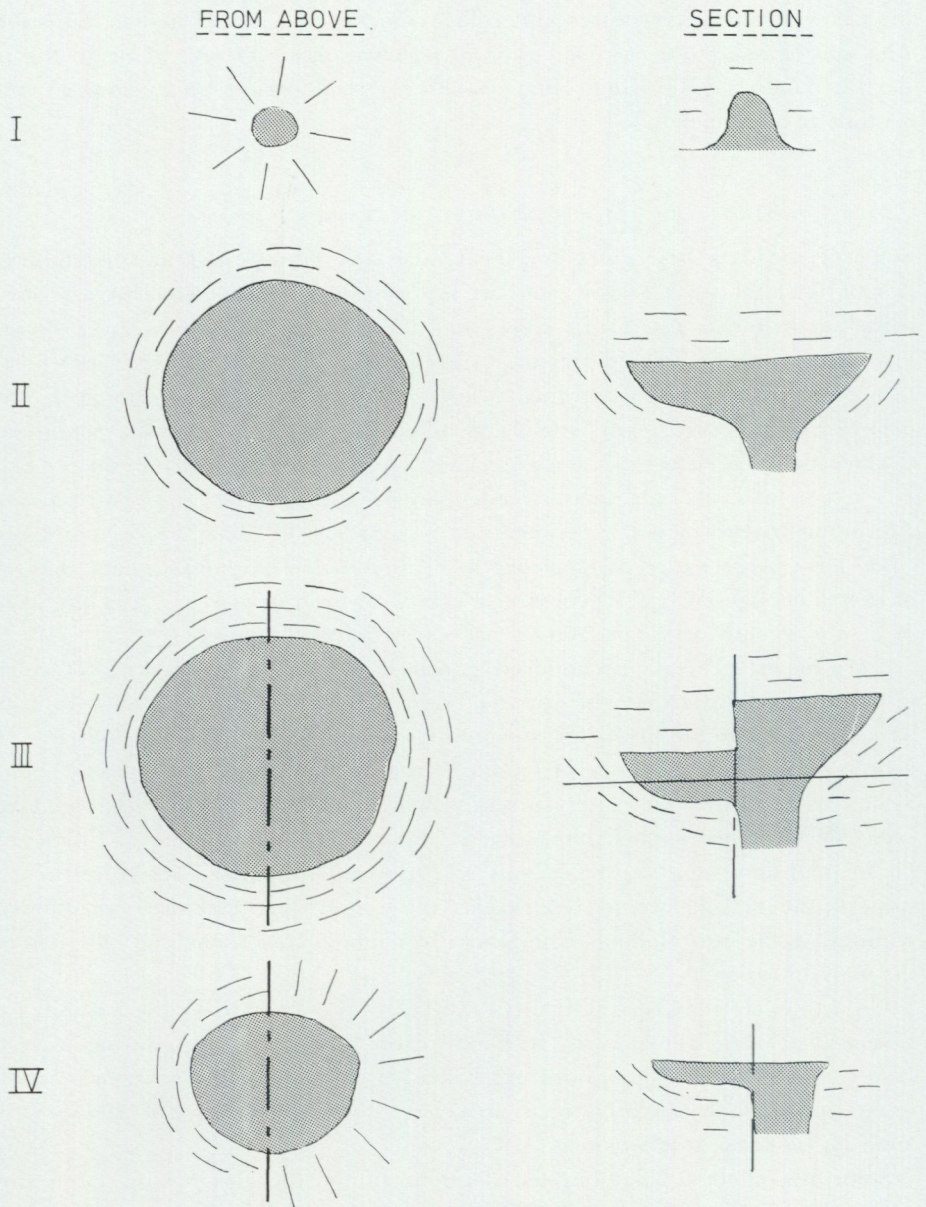


Fig. 10. Hypothetical steps in the evolution of the Graversfors diapir.

- I. Initial intrusion, high strain rate, brittle fracturing of overburden.
- II. Diapir reaches a higher layer where the buoyancy diminishes. A horizontal spreading starts, and the deformation in the surroundings is characterized by a low strain rate. Conformable structures are created. Heat from the granite melts about 5% of the rocks in the surrounding area. The average viscosity of the surroundings is reduced.
- III. Faulting along the Näkna zone.
- IV. Erosion to the present level which displays the older and deeper brittle fracturing in the east and the conformable structures in the west.

Returning to the Graversfors granite area an identical, much larger body, the Roxen granite, occurs about 20 km to the west (Gorbatshev 1971). Only the southernmost parts of this granite are covered by modern maps, however (Gorbatshev et al. 1976, Kornfält 1975). It forms the northern margin of the extensive area of Småland granites in the Småland—Östergötland region. An extension of the Graversfors type thus appears in massifs oriented approximately ENE—WSW. The Stavsjö rocks can also be found along this strike. Apparently the development just reported has something to do with the regional intrusion mechanism, which is, however, so far not understood. Since the details of the whole massif of the Roxen granite are unknown, e.g. whether it forms one coherent massif or not), speculations about the spacing of diapirs in the area cannot be made. Anyhow, it is intuitively felt unnecessary to postulate a crystalline state to be connected with the initial updoming of the granite massifs of the Graversfors type.

GEOLOGICAL COMMENTS ON THE AEROMAGNETIC MAP

The main pattern of the aeromagnetic map is seen in Fig. 23, which forms an excerpt of the already published SGU maps of the area (Wikström 1976, 1979). Some general features can be noticed, especially for the Graversfors massif. The different characters of the eastern and the western parts are immediately recognizable. They have been separated by the Näkna fault (which mainly follows the railway).

In the western part of the massif, the outward contacts can hardly be traced in the map. On the other hand the eastern contact is rather distinct, with the exception of the southeastern part where supracrustal rocks border on the granite. The coincidence does not attain 100 %, however, which can be explained by the previously mentioned, restricted growth of magnetite observed in the country rocks along the eastern contact. The radial and lobate character of this contact is also clearly visible.

GAMMA-RADIATION MAP

Simultaneously with the airborne magnetic measurements, the gamma-radiation was also registered (U, Th, K). This was made 1970, and the data from that time do not permit automatic separation of the different channels. The radiating pattern has therefore to be commented unspecifically.

As evident from Fig. 11, the Graversfors granite as a whole shows a fairly low intensity. The difference between the eastern and western halves is manifested by the stronger radiation of the eastern part. To the north of the granite the Näkna fault is visible, and part of the eastern contact is distinctly defined even in this map.

A regional increase of the radiation intensity has been registered to the north-east of the granite.



Fig. 11. Total gamma-radiation map of the investigated area.

THE STAVSJÖ IGNEOUS SUITE

As previously mentioned, the Stavsjö suite is differentiated from norite to granite. The rocks have been extensively described by Asklund (1925). The major and principally important difference between his publication and the present paper implies that the oldest prekinematic (primorogenic) granitoids have been

distinguished in the latter. Although the porphyritic members of both the prekinematic rocks and the Stavsjö suite in part have a very similar appearance, this age difference must be taken in account. When Asklund found some of the granites now classed as late-kinematic (serotogenic) to cut some of the porphyritic granites, he concluded that the former were younger than the postkinematic (postorogenic) Småland granites. This opinion reappears in several of his later publications.

Other discrepancies between Asklund (*op.cit.*) and Wikström (map of 1979, simplified in the present paper) are less important.

Also in other parts of Sweden, where the two groups meet, one can notice a petrographical resemblance between the oldest prekinematic plutonics (urgranite) and the postkinematic granites. In the Västervik area, for instance, these phenomena have complicated the interpretation (Elbers 1971).

Coarse-porphyritic Stavsjö granite

The coarse-porphyritic Stavsjö granite generally contains perthitic microcline megacrysts (Fig. 12) oriented northwest. Outcrops with megacrysts lacking preferred orientations occur at places, however. In sections the width/length ratio is normally 1:4, and the average length 3—4 cm. Preferred orientations of the

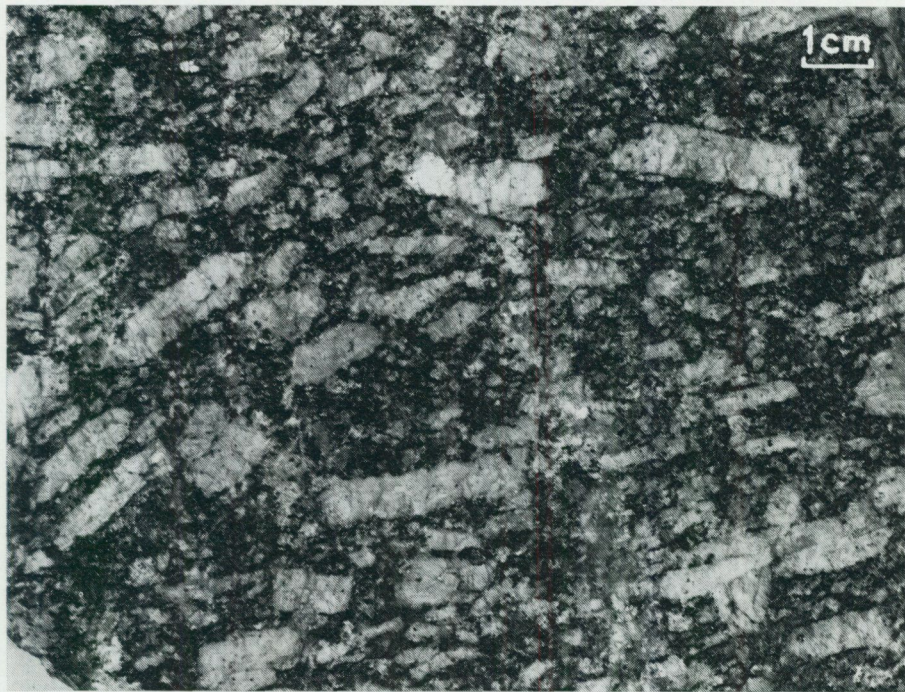


Fig. 12. Typical Stavsjö granite with rectangular, mostly oriented, perthitic microcline megacrysts. 750 m east of Klocktjärnen. 650975/153355.

feldspar megacrysts is a rule not only in the main massif but also in the smaller massifs and dykes outside this. In some cases their orientations in the latter seem to have been more influenced by the general northwest direction than by the elongations of the local granite bodies, but about 700 m northwest of Böksjö (1g) both dyke and megacrysts are oriented north—south. A very weak concentric arrangement of the small massifs in relation to the major Graversfors massif may possibly exist (Fig. 3). Available data are, however, not sufficient to evaluate if the small massifs are members of a ring dyke system or some similar structure. The small massifs of Stavsjö granite are older than the radially arranged Graversfors dykes, as can be seen to the north of lake Skrålen (2f; Fig. 18).

In the main Stavsjö massif the most typical porphyritic rocks are found in the eastern part. They contain accessory muscovite (generally less than 1%), which led Asklund (*op.cit.*) to call this type two-mica granite (in both map and description).

Hornblende-bearing Stavsjö granite

In the western part, around the norite, hornblende appears as a subordinate mineral in the porphyritic granite. The rectangular megacrysts gradually become reduced in size and distinctive character, and close to the norite the rock is only slightly porphyritic (Fig. 13).

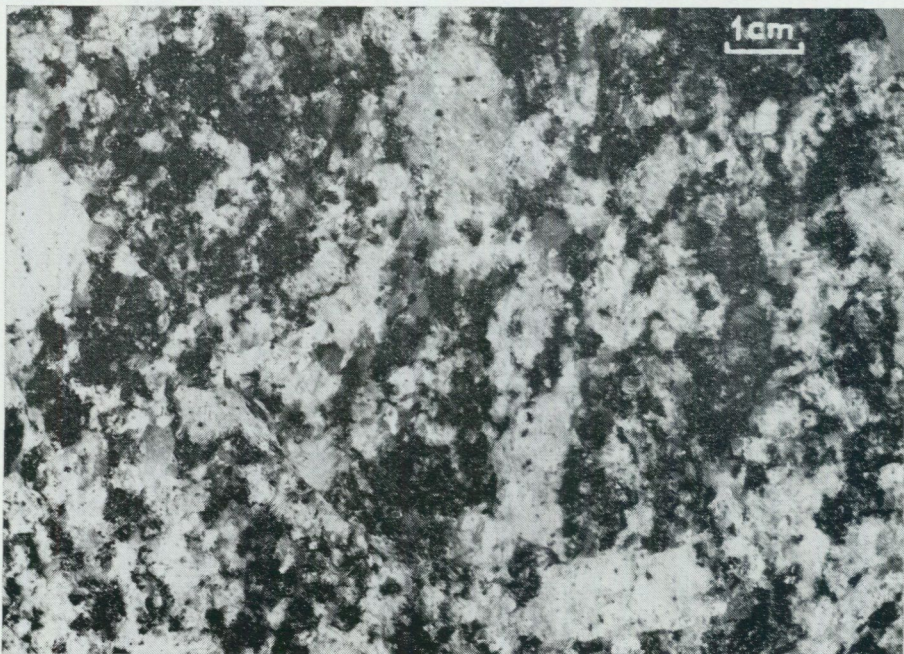


Fig. 13. Slightly porphyritic hornblende granite with pinkish feldspar. 400 m east of Hagen. 651275/153313.



Fig. 14. Helsinkite. 300 m south of Aspetorp. 651355/153310. See also Asklund 1923, p. 41, tab. 5.

Helsinkite

South of lake Björnsjön (2g) Asklund (op.cit.) distinguished a helsinkite rock (Fig. 14) as a member of the differentiated Stavsjö suite. The locality is situated close to a major tectonic zone with epidote-filled veins and breccias. The rock in itself is astonishingly fresh both in outcrop and under the microscope. The genesis of this rock type as interpreted by Mellis (1932) seems to be applicable to the present occurrence. In main his explanation implies that the crystallized but still hot rock was disintegrated by tectonic forces. A porous structure with angular voids was developed. In the voids epidote and quartz crystallized at the expense of hornblende, anorthite and biotite. Thus, the brittle breaking of the rock should have occurred in very close connection with the final stages of crystallization.

Small-porphyrific granite

To the northwest of the main Stavsjö granite a small-porphyrific granite dominates a heterogeneous area with abundant xenoliths of older rocks. It is medium-grained and grey with white microcline megacrysts, often developed as Karlsbad twins. The megacrysts are mostly square-shaped in section, and their size is generally less than 1 cm. To and fro one can discern a faint grain orientation, mostly of biotites. About 2 km to the west of Virå (3h) occurs a minor plug

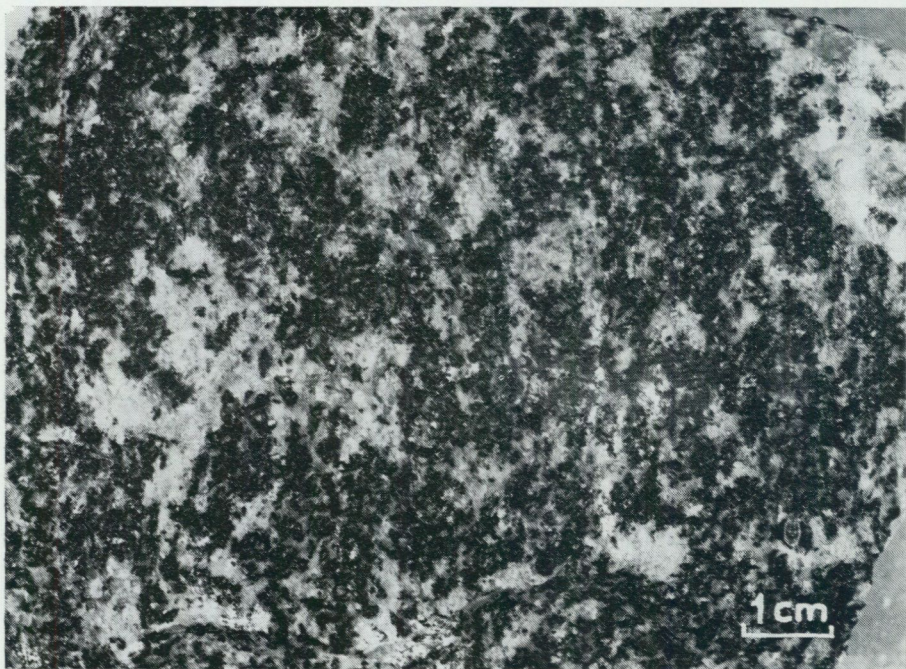


Fig. 15. Granodiorite with irregular pink patches of microcline. Border-zone between the norite and the hornblende-granite. 350 m north of Smedsbygget. 651195/153340.

of the coarse-grained Stavsjö granite showing that this rock is younger than the small-porphyrific type. Gradual contacts towards intermediate, sometimes hornblende-carrying and non-porphyrific types have been observed. The major impression is that these constitute partly resorbed large xenoliths of the intermediate rocks.

Intermediate rocks

Within the Stavsjö suite granodioritic, tonalitic and monzodioritic compositions are distinguished. All these rocks display medium grain-sizes and colours covering different shades of grey. Their exact compositions cannot always be determined in the field, and during the mapping they have been grouped together. In many cases they show a hybrid character. A late, in some types extensive microcline growth of a probably metasomatic origin (Fig. 17) is locally observed.

A massive, hornblende-carrying granodiorite around Skogsby probably belongs to this group. It has been more extensively described by Asklund (*op.cit.*) under the name of quartz-syenite.

Norite

This rock appears in one major and a few minor bodies within the Stavsjö area. Its central parts are generally fresh, fine- to medium-grained and partly dolerite-

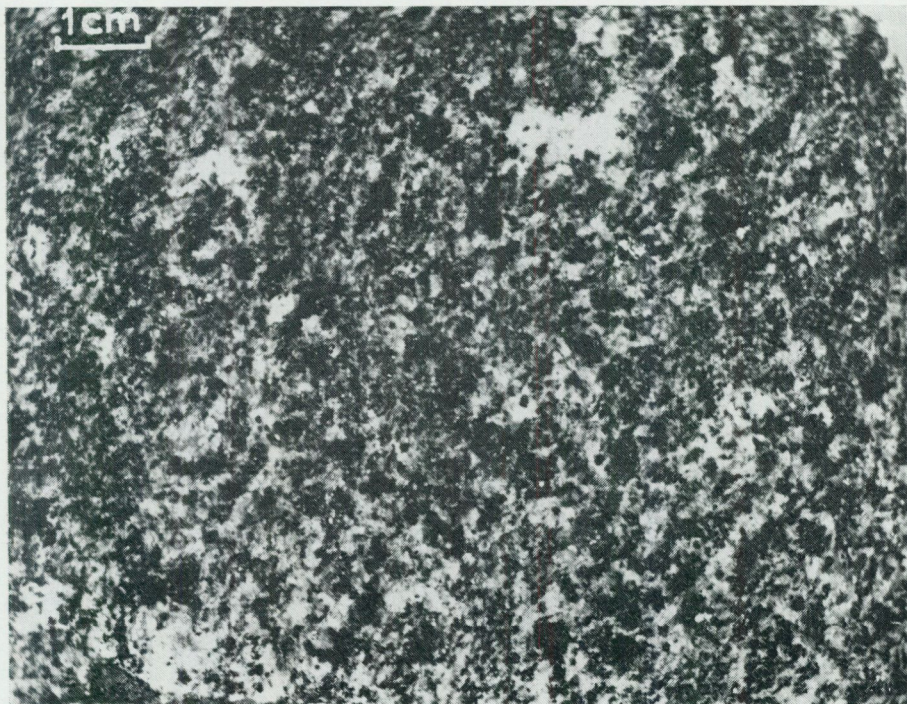


Fig. 16. Quartz-diorite containing minor amounts of both orthorhombic and monoclinic pyroxenes. 1 km northeast of Peterslund. 651115/153265.

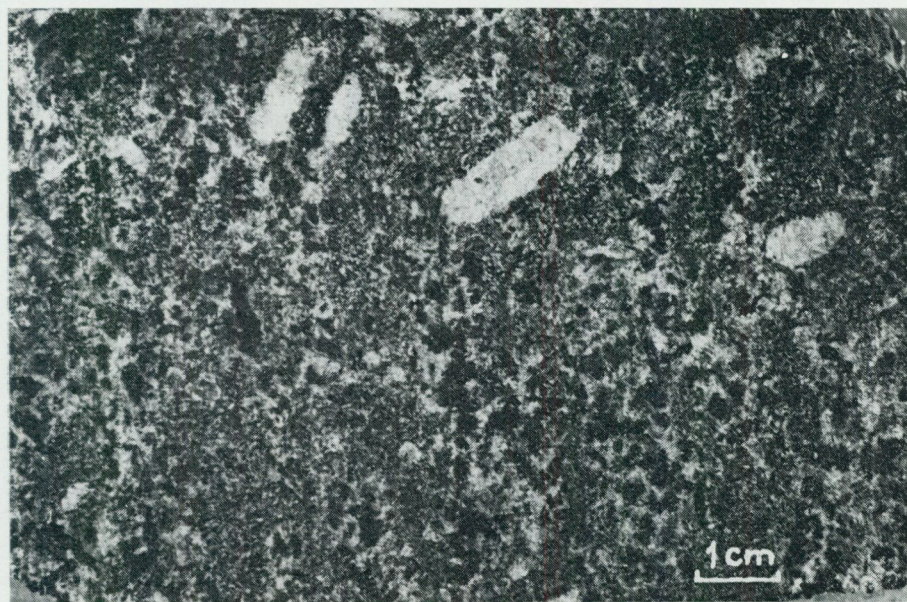


Fig. 17. Quartz-diorite with scattered late feldspar megacrysts of Stavsjö type. Locality as Fig. 16.

looking. Towards the margins of the rock both clino- and orthopyroxene have been gradually replaced by hornblende and the rock has become darker. The contact towards the acid members are generally distinct while those towards the intermediate members are more often irregular and gradual.

A more detailed petrographic description of the different Stavsjö rocks is found in Asklund's work (op.cit.)

GENERAL DISCUSSION

In the present area a magmatic evolution starting with the Stavsjö igneous suite and ending with the intrusion of the Graversfors granite has been established during the final stages of the Svecokarelian orogeny.

As stated earlier, the intrusion of the Graversfors granite is related to a local folding of the surrounding rocks and also probably to a remelting of some of the country rocks. All heat energy required for such a process could probably not have been delivered by the granite as the magma of this rock has intruded into a more or less cold crust. The crust ought thus to have been fairly hot already during the first stages of this evolution. Åberg (1978) received a Rb/Sr whole rock age of 1 920 Ma for the oldest prekinematic granitoids 10—15 km to the southeast. Minerals separated from two rocks gave individual parallel Rb/Sr isochrons of 1 570 Ma, indicating that the mineral systems had remained open for a considerable time due to slow cooling. K/Ar dating of separated

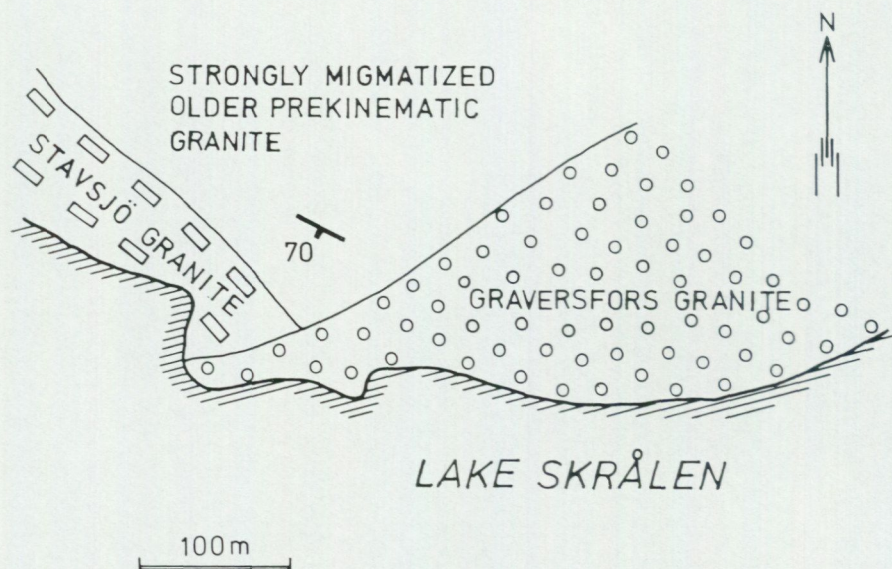


Fig. 18. Contact between dykes of a Stavsjö and a Graversfors granite outside the main massifs. The latter is found to be the youngest. Lake Skrålen. 651340/152750.

biotite gave still lower ages, viz. about 1 545 Ma. The original age figures have been recalculated by Åberg (pers. comm. 1979) according to a newly accepted decay constant (Steiger and Jäger 1977). Several data thus indicate that the crust has remained hot during a fairly long time after the main orogenic development.

Similar problems are also met with further north. The Revsund granite occupies vast areas in the north central parts of Sweden. In various respects it shows features similar to some rocks studied in this paper and, geochemically, also to certain Finnish rapakivi granite (Persson 1978). The Revsund granite has earlier mostly been classed as serorogenic and genetically associated with abundant migmatization (Gavelin 1955). Lundqvist (1973, 1979) has denominated it as "ser- to postorogenic", a term also used by Gavelin (op.cit.), and principally not responsible for the migmatization in Västernorrland county. Strong contact metamorphism resulting in the development of hornfelses in the neighbouring metasedimentary rocks (Lundqvist, pers. comm. 1974) together with the chemical composition of the granite are major arguments for a post-orogenic age. However, no distinctive events seem to separate the ser- and postorogenic units of that area.

In other areas the distinctions between orogenic and later events are more obvious.

Vorma (1975) has suggested that a cratonization and a denudation of the uppermost 10 km of crust took place between the ser- and postorogenic activities.

In southern Sweden several examples of erosion events prior to the main postorogenic evolution have been found. Hjelmqvist (1969) and Lars Persson in Uppsala, (pers. comm.) for instance, have described conglomerates interlayered with arkosic and volcanic material and older than the major Småland granite types. The locality described by Persson is situated only 90 km to the southwest of the Graversfors granite. In that area the older Svecokarelian supracrustal xenoliths show no sign of serorogenic migmatization (Lars Persson, pers. comm.). One may therefore speculate if not most of the heat that caused abundant serorogenic migmatization in the northern Östergötland—Sörmland district (where the Graversfors—Stavsjö rocks are situated) may have remained in this area (which should then represent a deep section) until the later magmatism started.

Accepting a postorogenic character of the Revsund granite, the Swedish bedrock contains a huge belt stretching north—south and characterized by post-orogenic granites of different ages with translations into anorogenic types. This magmatic evolution finally ended with a strong uplift of the crust followed by erosion (Jotnian sandstones) and rifting (dolerites).

At least in the southern part of the belt transverse structures striking east—west are also important. Contacts between intrusion of different ages in this heterogeneous area can often be found in that direction in central Småland

(Magnusson et al. 1959). Furthermore, the same direction is found in western Östergötland (Lars Persson, pers. comm.) and southern Värmland (Lundegårdh 1977) and is also manifested by the previously mentioned, approximately east—west extension of the Stavsjö, Graversfors and Roxen Massifs. The character of the last-mentioned rocks also changes eastwards.

In spite of its rather variable composition, the texture of the Graversfors granite is remarkably homogeneous. On the other hand, the Stavsjö suite shows a range of different rocks within approximately the same compositional gap (Fig. 5), if the restricted basic members are neglected.

The differences in the crystallization history of the two rock groups cannot wholly be explained at present. As to the Graversfors granite one could probably expect a deep "reaction-melting" process in the sense of Barker et al. (1975), where the lowest part of the crust has reacted with primary basic magma. Before the intrusion, pyroxene and olivine precipitated, and there occurred an increase in the magma of silica, alkalis and the iron/magnesium ratio.

The somewhat more heterogeneous nature of the western (upper) half of the Graversfors granite could probably be explained both by an uneven temperature distribution and by a chemical influence from the enclosed xenoliths.

In the Graversfors massif the general impression is that the magma remained liquid during very long time and that the crystallization proceeded slowly. This is also in accordance with the structural observations discussed on page 19. The special character of the differentiated Stavsjö suite probably depends on its spatial situation deep in the orogenic complex, although similar trends have been locally recognized within the main Småland granitoids (Lundegårdh 1950).

The Stavsjö suite shows a weak calc-alkaline character which is in general uncommon among postorogenic rocks. On the other hand its chemistry differs clearly from the igneous suites within the main orogenic complex. The previously mentioned indications implying that heat remained in the area long after the main orogeny could probably have contributed to this development. Although rocks of the suite cut fold structures of the orogenic suite distinctly, the elongated feldspars in the coarse granite (Fig. 12), most of which are oriented in the same direction, indicate a directed stress field to have been active during the final stages of crystallization or that extensive flow has taken place. The consequence of this, regarding the differentiation process, is an open question, however. Another observation, which concerns the size variations of the feldspar megacrysts, should be mentioned. In Stavsjö their maximum length is about 5 cm, while in the eastern part of the Jönåker massif it is about 1 cm (Lundström 1974, Wikström 1979). The latter is situated 15—25 km to the ENE of the Stavsjö massif and displays essentially the same character, although the most basic rocks are missing. The reduction in size of the megacrysts over this distance is gradual and may indicate that the cooling was faster in the east.

The Stavsjö suite has only been touched upon here. A radiometric dating of the suite together with more detailed investigations are necessary in order to solve the problems associated with its evolution.

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II. GRAVIMETRICAL AND PETROPHYSICAL INVESTIGATION

By

SVEN AARO AND MATS LAGMANSSON

GRAVITY MEASUREMENTS

The investigated area was measured in 1974, using a Worden Prospector gravity meter. In all 265 stations were measured, which makes a station density of 0.3 stations/km².

As far as possible levelled bench marks and profiles of the railroad have been used as height references but also lake surfaces and elevation lines from topographical maps on a scale of 1: 50 000.

The gravity net, which was composed of six carefully measured base stations, was connected to the European calibration system 1962 at Lunda Church (Pettersson 1967).

The error in height over sea level was estimated to one metre or less for 203 stations and up to five metres for the remaining 62 stations (Johansson and Krosse 1964). A one metre difference in height corresponds to 0.2 mgal in Bouguer anomaly value.

THE BOUGUER ANOMALY MAP

The result of the measurements has been represented in a Bouguer anomaly map where the gravity stations are indicated with dots (Fig. 19). The map has been contoured at a one mgal spacing. The gravity values have not been corrected for the effects of terrain since the influence of topography is almost negligible in this area.

The map shows a rather low positive anomaly over the Graversfors massif, but the anomaly curves connect well to the surface extension of the granite. This similarity and the corresponding density indicate that the Graversfors granite is the disturbing body. The anomaly indicates that the granite has a thick eastern part which decreases towards the west. In the western part of the map there is a gravity minimum, down to -6 mgal. This minimum is accounted for by the density measurements which implies a mass deficit in the area considered.

In the eastern part of the map there is a distinct positive anomaly of +6 mgal which coincides with the Stavsjö igneous suite.

PETROPHYSICAL MEASUREMENTS

In order to get an improved basis for interpretation of the gravity anomalies and earlier measured aeromagnetic anomaly map, density and *in situ* magnetic

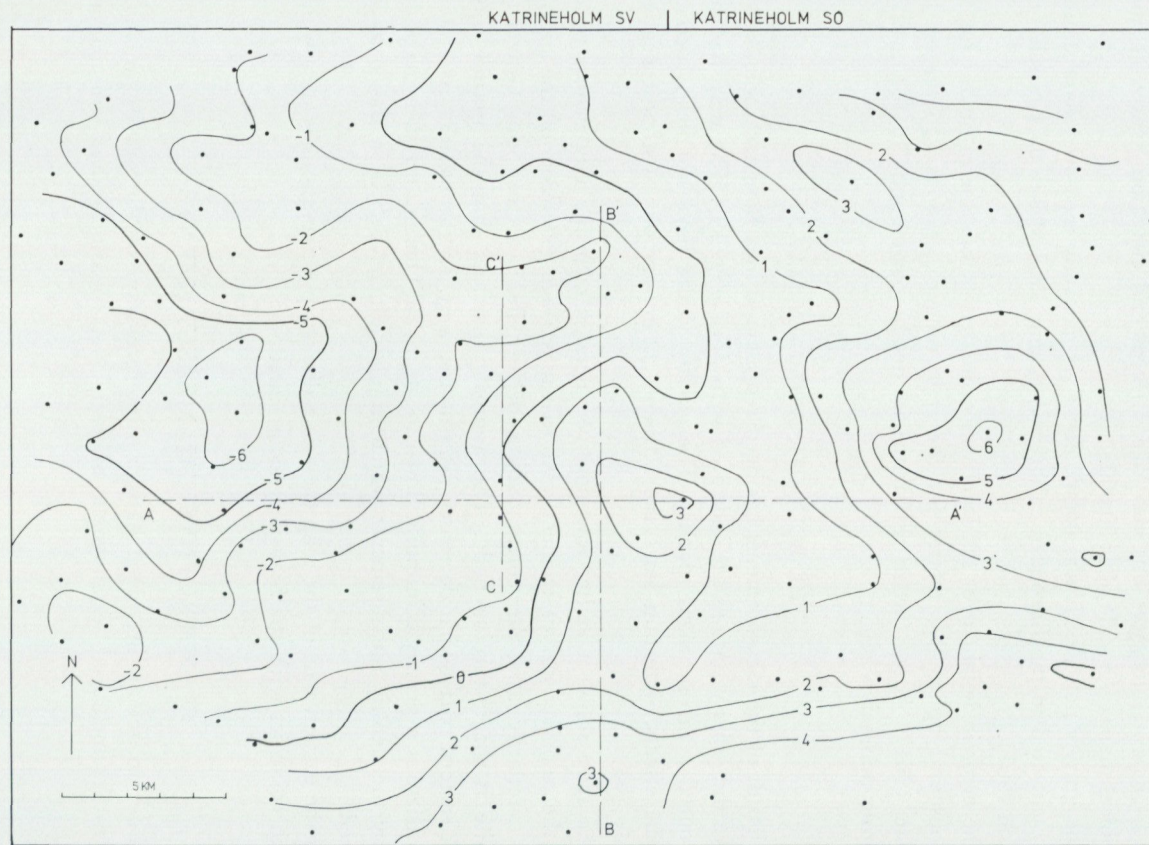


Fig. 19. Bouguer anomaly map of the investigated area. Profiles used for the model calculation indicated.

GRAVITY, VERTICAL COMPONENT

Measurements with gravity meter during 1974

Mean station spacing 1.7 km

MEASUREMENTS

- Position of measurement
- Terrain corrections not applied
- Mean error approximately 0.2 mgal

ISO-GRAVITY LINES WITH INTERVALS OF:

- 5 mgal
- 1 mgal

REFERENCE SYSTEM

European calibration system
ECS 62

Elevation system 1970

International formula of normal
gravity 1930

Bouguer density 2.67 g/cm³

— Calculation profile,
see text

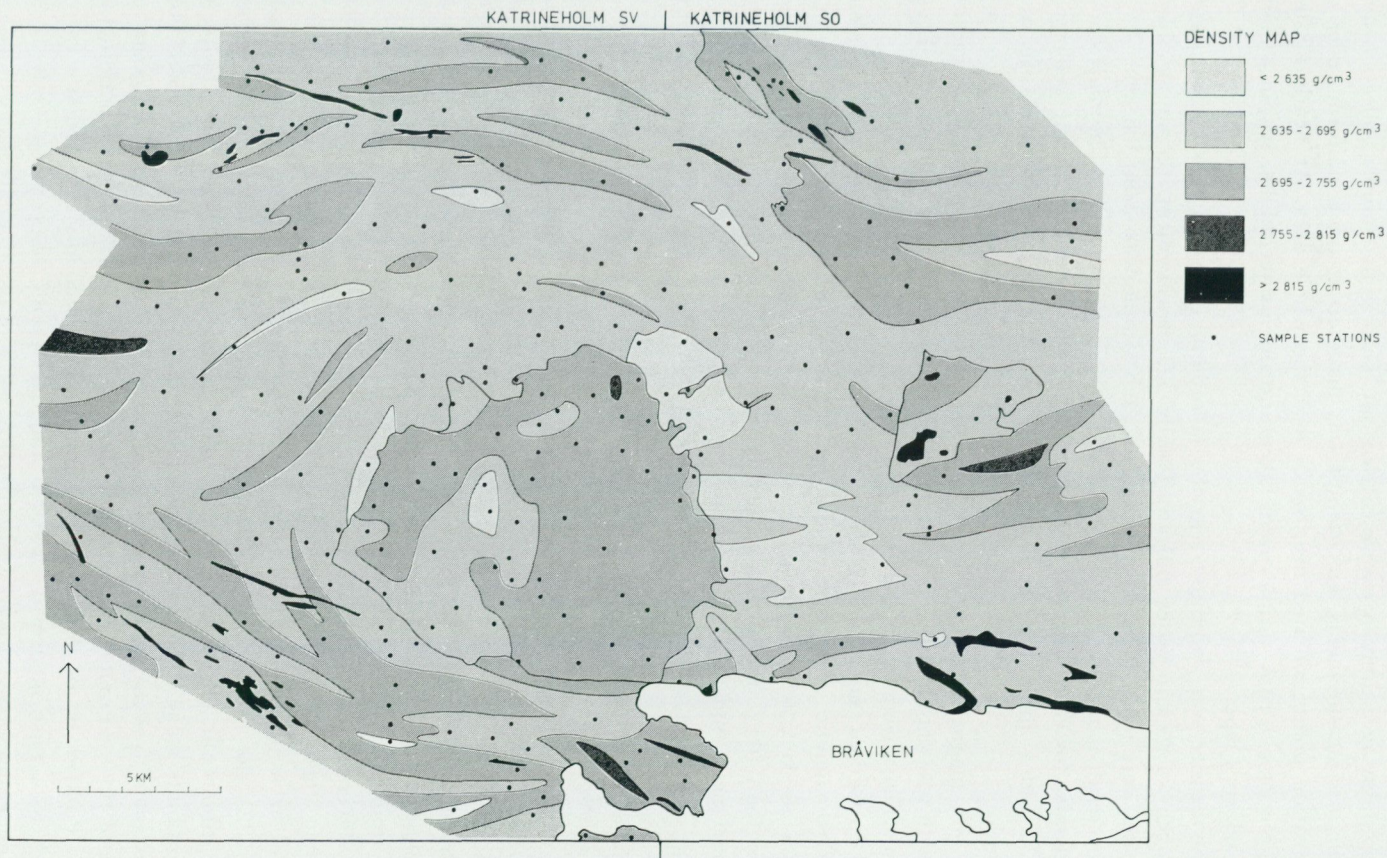


Fig. 20. Density map of the investigated area. Some of the rock-contacts are also indicated.

susceptibility measurements were carried out. During the sample collection and the *in situ* measurements, an attempt was made to attain a uniform cover of observation points, situated near roads over the whole area. At nearly all the sites, one or two rock samples were taken and three susceptibility readings made for each rock type.

The density was determined in the laboratory by weighing water-saturated specimens of rock in water and air. Totally 505 measurements on samples from 315 sites were made. The mean weight of each sample was about 0.8 kg.

The result is presented in Table 10 and as a map in Fig. 20. The map shows the density for each observation point which gives, together with the geological map, an idea about the density distribution in the different rock massifs and formations.

In situ magnetic susceptibility measurements on rock exposures were carried out with a susceptibility meter equipped with an external coil attachment. These measurements were made at 280 sites.

The magnetic susceptibility of the rocks is mainly dependent on the content of ferromagnetic and paramagnetic minerals. Acid and basic rocks, which completely lack ferromagnetic minerals, generally have a susceptibility value of less than 10^{-5} and 10^{-4} cgs units respectively (Chernyuk 1971). Among the ferromagnetic minerals magnetite and pyrrhotite are the most common.

Fig. 21 gives a summary of the *in situ* susceptibility values of each rock type.

PETROPHYSICAL CHARACTER OF THE GRAVERSFORS GRANITE AND ITS SURROUNDINGS

The mean density of the Graversfors granite is 2.70 g/cm^3 and the standard deviation 0.03 g/cm^3 (Table 10). At every place in the massif, however, the variation in density is generally very small. Sites where two samples were taken showed at 90 % of these sites a density difference between the two samples of less than 0.01 g/cm^3 . From the density distribution in Fig. 22 and from the density map (Fig. 20) it appears that the western part of the Graversfors granite has a lower density than the eastern part. The border between these two areas concur with a fault line which cuts the granite massif in a north—south direction. The *in situ* susceptibility measurements (Fig. 22) do also show a difference between the two areas with a higher susceptibility in the western part of the granite massif. The most frequent susceptibility value for the whole massif (Fig. 22) is around 10^{-3} cgs units. This corresponds to a magnetite content of about 0.3 % by vol., and the maximum value of 10^{-2} cgs units to a content of about 3 % by vol. (Balsley and Buddington 1958; Puranen et al. 1968). An addition of these amounts of magnetite corresponds to a raise in density of 0.006 and 0.06 g/cm^3 respectively. Only 12 % of the measurements showed a susceptibility value of less than 10^{-4} cgs units, i.e. a susceptibility which can be caused by paramagnetic minerals.

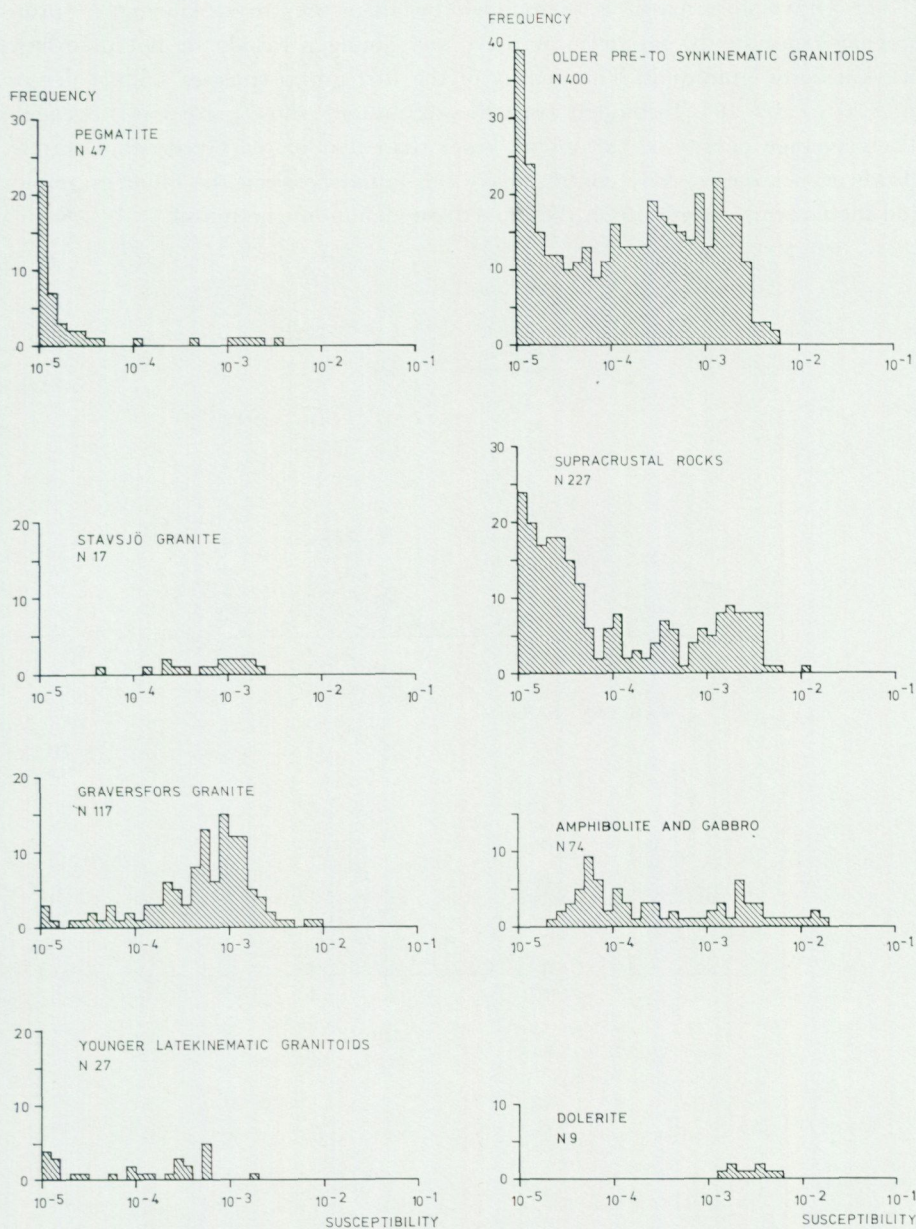


Fig. 21. Results of the *in situ* magnetic susceptibility measurements for the different rock types. N denotes number of measurements.

The density of the supracrustal rocks has, with a wide distribution, an average density of 2.70 g/cm^3 . From Fig. 21 it can be seen that the susceptibility of the supracrustal rocks mainly falls within two groups, one with low and the other with relatively high susceptibility. The supracrustal rocks situated south of the Graversfors massif mainly enter into the group with low susceptibility.

The younger late-kinematic granitoid, situated immediately north of the Graversfors granite, has a comparatively low susceptibility and an average density of 2.65 g/cm^3 with a standard deviation of only 0.022.

Other types of rocks in the area are of secondary importance to the gravity interpretation and are only shown in tables and figures.

THE AEROMAGNETIC ANOMALY MAP

The magnitude of magnetic anomalies produced by rocks depends on induced and remanent magnetization, size, and shape of the disturbing body. For granitoid rocks the remanent magnetization is normally small and directed parallel to the present geomagnetic field (Werner, Aaro and Lagmanson 1977, Lindroos and Henkel 1978), which means that most of the rocks studied here should show a good correlation between susceptibility and magnetic anomaly.

The magnetic anomalies over the Graversfors massif (Fig. 23) are characterized by an irregular pattern of moderately higher and lower areas. The north—south striking fault (Wikström, this paper), which separates the Graversfors granite into an eastern and a western part, is clearly indicated on the map, as well as the rock contacts following the dip-slip faults along the north side of the Bråviken bay.

The western part of the Graversfors granite has, relatively seen, a greater area with moderately high magnetic anomalies than the eastern part. This discrepancy between the two areas is well reflected by the susceptibility distributions in Fig. 22.

The anomaly pattern outside the Graversfors massif is in the east radially arranged and in other places banded conformable to the contact. Other moderately high magnetic anomalies are, as the susceptibility distributions indicate, caused mainly by the older granitoids and the supracrustal rocks. The highest magnetic anomalies are found over the norite in the Stavsjö area.

INTERPRETATION OF THE STRUCTURE OF THE GRAVERSFORS GRANITE

Three-dimensional models for the calculations were used according to the method given by Talwani and Ewing (1960). The method was simplified so that the interpretation model was only allowed to have right angular corners.

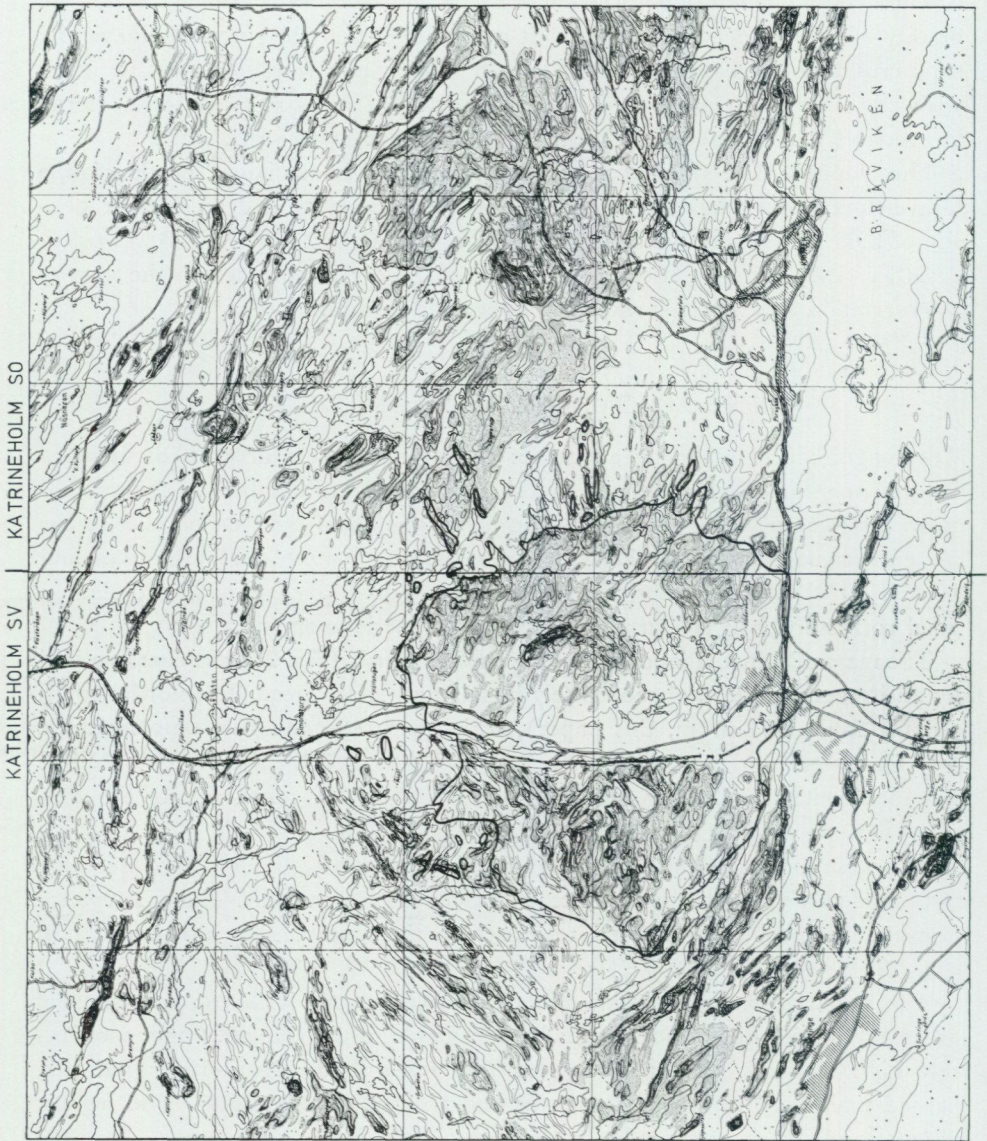
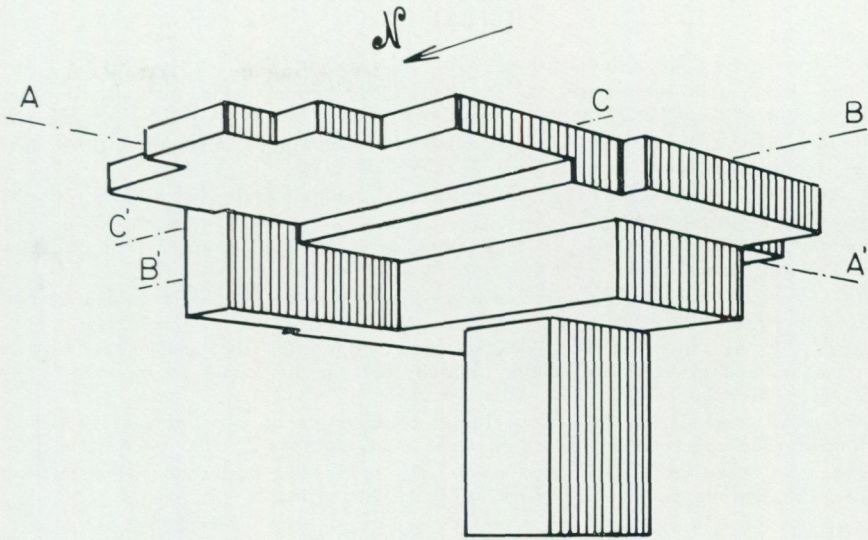


Fig. 23. Aeromagnetic anomaly map of the investigated area.

Calculations have been carried out along three different profiles, the location of which is shown in the Bouguer anomaly map (Fig. 19). One model revealing correspondance with these profiles is shown in Fig. 24. It consists of a horizontal disk of varying thickness, 0.5—2 km, and a vertical prism to a depth of 5 km.



VIEW FROM SOUTH-WEST

Fig. 24. Perspective drawing of the Graversfors massif based on gravity interpretation.

However, it should be noted that this is a mathematical model and that minor variations in the starting values will change the details and the thickness of the model.

The density values for the model calculation are the mean for each rock type concerned. As regards the Graversfors granite, however, the western part has been given a density of 2.69 g/cm^3 and the eastern part a density of 2.71 g/cm^3 . The calculation has been carried out under the assumption that the Graversfors granite is underlain by rocks with a mean density of 2.66 g/cm^3 , corresponding to the older pre- to synkinematic granitoids and the younger late-kinematic granitoids.

The regional field has been approximated with a westerly dipping plane with the gradient 0.3 mgal/km . It can thus be concluded that the Graversfors granite has got its greatest thickness towards the north and the east. The anomaly maximum in the eastern part of the massif indicate that the granite has its greatest depth here.

ACKNOWLEDGEMENTS

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TABLE 1. Chemical analyses of the Graversfors granite

Field No.	GR 2	GR 3	GR 4	GR 5	GR 6	GR 7	GR 8	GR 9	GR 10	GR 11	GR 12
SGU Lab. No. 010-92-	61	62	63	64	65	66	67	68	69	70	71
SiO ₂	68.0	70.5	66.2	65.0	68.3	67.9	67.2	77.7	77.2	65.9	69.6
TiO ₂	0.71	0.44	0.90	1.1	0.74	0.79	0.92	0.16	0.09	0.91	0.61
Al ₂ O ₃	14.7	14.4	15.2	14.9	14.3	14.6	14.4	11.5	11.7	15.3	14.3
Fe ₂ O ₃	0.7	0.7	1.1	2.0	0.6	0.6	1.2	0.1	0.1	1.2	1.0
FeO	3.1	1.9	3.5	4.0	3.4	3.2	3.4	0.8	0.8	3.8	2.3
MnO	0.07	0.06	0.09	0.10	0.08	0.07	0.09	0.01	0.02	0.10	0.06
CaO	2.2	1.7	2.6	2.8	2.1	2.2	2.7	0.5	0.8	2.6	1.9
MgO	0.77	0.50	0.98	1.0	0.84	0.82	0.92	0.14	0.12	1.0	0.69
Na ₂ O	3.0	2.8	2.9	2.9	2.8	2.9	2.9	2.5	2.9	3.1	2.8
K ₂ O	5.4	5.7	5.1	4.9	5.5	5.5	4.9	5.3	5.2	4.8	5.4
BaO	0.14	0.12	0.19	0.16	0.15	0.17	0.17	0.02	0.01	0.16	0.14
Total	98.79	98.82	98.76	98.86	98.81	98.75	98.80	98.73	98.84	98.87	98.80
N-co-or 65-	0760	0775	0900	1040	1095	1157	1130	1097	1015	0560	0722
E-co-or 15-	1662	1625	1645	1614	1658	1763	1872	1964	1980	2466	1880
Type	N	N	Np	Np	Np	Np	D	A	A	N	N
Colour (K-feldspar)	RB	RB	DRB	DRB	RB	GR	GB	R	R	GV	PR

Explanation of abbreviations to Tables 1—6

Type, Graversfors granite, Tables 1—5

- N Normal, coarse-grained, slightly porphyritic with irregular, somewhat rounded feldspar megacrysts
 Np Normal, as above, but somewhat more distinctly porphyritic
 A Acid, medium-grained, non-porphyritic
 D Dark, coarse-grained, bluish quartz with a comparatively even grey or greyish black colour

Type, Stavsjö suite, Table 6

- C Coarse-grained, marginal type
 Cp Coarse-grained granite, rectangular perthitic megacrysts longer than 2 cm
 Mp Medium-grained granite, rectangular perthitic megacrysts less than 2 cm long
 M Medium-grained granite, scattered small megacrysts, locally a weak foliation
 Mgd Medium-grained granodiorite, scattered small megacrysts, locally weak foliation
 Mmd Medium-grained monzodiorite
 Mn Medium-grained norite

Colour

- R Red
 RB Reddish brown
 DRB Dark reddish brown
 GR Greyish red
 G Grey
 GV Greyish violet
 GB Greyish black

TABLE 2. Chemical analyses of the Graversfors granite. For explanation of symbols see p. 43

Field No.	GR 13	GR 14	GR 15	GR 16	GR 17	GR 18	GR 19	GR 20	GR 21	GR 22	GR 23
SGU Lab. No. 010-92-	72	73	74	75	76	77	78	79	80	81	82
SiO ₂	70.0	69.6	68.0	66.6	65.3	64.9	66.0	66.0	64.7	65.0	63.5
TiO ₂	0.60	0.61	0.63	0.92	1.1	1.1	0.97	0.95	1.2	0.94	0.93
Al ₂ O ₃	13.8	14.0	15.1	15.3	14.9	15.4	14.8	15.2	14.9	15.7	16.7
Fe ₂ O ₃	0.4	0.6	1.2	1.1	1.4	1.1	1.0	0.9	1.3	1.6	1.2
FeO	2.6	2.5	2.7	3.6	4.3	4.2	3.9	3.8	4.7	3.3	3.7
MnO	0.05	0.07	0.07	0.06	0.10	0.11	0.10	0.09	0.13	0.08	0.09
CaO	1.8	1.8	1.9	2.5	2.8	3.2	2.8	2.8	3.1	2.7	2.7
MgO	0.63	0.76	0.57	0.95	1.1	1.0	1.0	0.91	1.0	1.1	1.2
Na ₂ O	2.7	2.8	2.9	3.2	3.0	3.0	3.0	3.1	2.9	2.9	3.3
K ₂ O	5.8	5.4	5.5	4.4	4.6	4.6	5.0	4.9	4.7	5.3	5.3
BaO	0.14	0.15	0.18	0.13	0.18	0.18	0.20	0.18	0.18	0.22	0.19
Total	98.52	98.29	98.75	98.76	98.78	98.79	98.77	98.83	98.81	98.84	98.81
N-co-or 65-	0657	0892	1343	1252	0843	0696	0578	0710	0610	0805	0745
E-co-or 15-	1810	1810	1856	1996	1999	2204	2257	2465	2360	2155	2137
Type	N	N	N	N	N	Np	Np	Np	Np	Np	Np
Colour (K-feldspar)	PR	PR	PR	GV	G	R	R	R	R	R	R

TABLE 3. Chemical analyses of the Graversfors granite. For explanation of symbols see p. 43

Field No.	GR 24	GR 26	GR 27	GR 28	GR 29	GR 30	GR 31	GR 32	GR 33	GR 34	GR 35
SGU Lab. No. 010-92-	83	85	86	87	88	89	90	91	92	93	94
SiO ₂	66.1	66.3	64.9	66.2	65.7	65.0	64.5	65.6	64.1	67.7	64.1
TiO ₂	0.83	0.91	1.1	1.1	1.2	0.92	1.2	0.87	1.3	0.87	1.2
Al ₂ O ₃	15.6	14.9	15.1	14.4	15.0	15.9	15.1	15.6	14.9	14.5	15.3
Fe ₂ O ₃	0.7	1.4	1.6	1.5	0.8	1.5	1.1	0.7	1.6	0.9	1.7
FeO	3.4	3.4	3.8	3.9	4.2	3.2	4.8	3.5	4.6	3.3	4.2
MnO	0.09	0.13	0.10	0.11	0.11	0.09	0.11	0.09	0.12	0.09	0.10
CaO	2.4	2.5	2.7	2.7	2.9	2.6	2.9	3.1	3.4	2.4	3.2
MgO	1.0	1.0	1.1	1.0	1.1	1.0	1.1	0.96	1.1	1.0	1.0
Na ₂ O	3.1	3.0	2.9	2.8	2.8	3.0	2.9	3.2	3.1	3.0	3.0
K ₂ O	5.3	5.1	5.3	4.9	4.8	5.4	4.9	4.9	4.4	4.8	4.8
BaO	0.19	0.17	0.19	0.14	0.20	0.21	0.19	0.20	0.17	0.16	0.19
Total	98.71	98.81	98.79	98.75	98.81	98.82	98.80	98.72	98.79	98.72	98.79
N-co-or 65-	1222	1294	1380	1340	1150	1142	1048	0902	0750	0993	0985
E-co-or 15-	2245	2468	2590	2767	2562	2468	2554	2332	2387	2212	2082
Type	Np	N	Np	Np	Np	Np	Np	Np	Np	Nr	N
Colour (K-feldspar)	R	R	GR	R	R	R	R	R	GR	R	G

TABLE 4. Chemical analyses of the Graversfors granite. For explanation of symbols see p. 43

Field No.	C 03	C 04	C 05	C 06	C 07	C 08	C 09	C 10	C 11	C 14	C 38
SGU Lab. No. 010-9-	295	296	297	298	299	300	301	302	303	304	305
SiO ₂	62.6	69.0	66.0	70.7	68.7	69.0	66.0	66.7	68.0	64.6	65.8
TiO ₂	0.52	0.64	0.89	0.53	0.55	0.57	0.89	0.85	0.61	0.87	0.60
Al ₂ O ₃	19.2	14.4	15.1	13.6	14.3	14.3	14.5	14.4	14.9	15.5	16.2
Fe ₂ O ₃	0.5	0.7	2.8	1.3	1.2	0.6	1.6	1.8	1.3	1.1	2.0
FeO	2.6	2.6	2.6	2.1	2.2	2.7	3.8	3.3	2.5	4.2	2.0
MnO	0.08	0.06	0.08	0.07	0.07	0.08	0.10	0.10	0.07	0.11	0.07
CaO	3.3	1.9	2.8	2.4	1.7	2.4	2.8	2.7	2.2	3.3	3.0
MgO	0.86	0.63	0.88	0.68	0.71	0.82	1.1	1.1	0.74	1.0	0.70
Na ₂ O	4.9	2.7	3.3	2.9	2.9	3.0	2.7	2.5	2.9	3.3	3.5
K ₂ O	4.0	5.9	4.1	4.4	6.0	4.7	5.1	5.2	5.3	4.7	4.7
BaO	0.12	0.19	0.22	0.16	0.18	0.17	0.16	0.14	0.16	0.18	0.19
Total	98.68	98.72	98.77	98.84	98.51	98.34	98.75	98.79	98.68	98.86	98.76
N-co-or 65-	0552	0665	0730	0810	0867	0980	1111	1193	1280	1365	1325
E-co-or 15-	2065	1994	2015	2045	2037	2057	2105	2220	2127	2130	2170
Type	N	N	N	N	N	N	N	N	N	N	N
Colour (K-feldspar)	RB	R	R	R	R	R	R	R	R	R	R

TABLE 5. Chemical analyses of the Graversfors granite. For explanation of symbols see p. 43

Field No.	C 39	C 40	C 41	C 42	C 103	C 106	C 116	C 300	C 304	C 420
SGU Lab. No. 010-93-	05	06	07	08	09	10	11	12	13	14
SiO ₂	64.6	66.3	64.5	66.4	65.4	66.2	67.9	72.1	65.6	68.0
TiO ₂	0.92	0.87	0.71	0.79	0.87	0.90	0.56	0.42	0.94	0.78
Al ₂ O ₃	15.1	14.4	16.6	14.8	15.4	14.2	14.7	13.0	15.0	14.2
Fe ₂ O ₃	1.2	1.3	1.1	1.7	3.2	1.2	1.9	0.9	1.2	1.3
FeO	4.3	3.9	3.2	3.6	2.9	4.3	2.4	1.9	3.8	3.5
MnO	0.12	0.11	0.10	0.11	0.14	0.10	0.06	0.07	0.12	0.09
CaO	3.0	2.8	3.3	2.5	2.6	2.8	1.9	1.4	2.2	2.4
MgO	1.1	1.1	1.0	0.98	1.0	0.99	0.91	0.44	0.93	0.85
Na ₂ O	3.0	3.0	3.9	2.9	3.3	2.9	3.0	2.4	2.8	3.0
K ₂ O	5.3	4.8	4.2	4.8	3.4	5.0	5.3	6.0	6.0	4.6
BaO	0.20	0.18	0.17	0.19	0.21	0.18	0.18	0.15	0.21	0.12
Total	98.84	98.76	98.78	98.77	98.42	98.77	98.81	98.78	98.80	98.84
N-co-or 65-	1370	1305	1200	1415	1420	1140	0933	1380	1120	0750
E-co-or 15-	2285	2380	2382	2425	2050	1807	1600	2515	2607	2772
Type	N	N	N	N	N	N	N	N	N	N
Colour (K-feldspar)	R	R	R	R	R	G	R	R	GR	RB

TABLE 6. Chemical analyses of rocks of the Stavsjö igneous suite. For explanation of symbols see p. 43

SGU Lab. No. 75940-	26	15	69	32	A 59 ^{x)}	28	58	27	57	55	31	70	A 19 ^{x)}
SiO ₂	71.9	67.9	66.1	65.5	64.8	70.2	69.5	63.8	62.0	61.5	61.0	58.7	52.8
TiO ₂	0.35	0.58	0.92	1.0	0.60	0.51	0.68	1.1	1.5	1.3	1.4	1.8	1.12
Al ₂ O ₃	13.0	13.4	13.3	14.2	17.2	13.4	13.2	14.9	14.1	15.3	14.9	14.4	13.8
Fe ₂ O ₃	1.0	1.0	1.5	1.3	1.3	0.8	1.7	2.5	1.9	2.3	2.8	2.5	1.9
FeO	0.9	2.0	3.2	3.6	3.6	1.9	2.0	3.5	5.2	4.5	4.8	6.0	8.1
MnO	0.04	0.05	0.08	0.08	0.04	0.04	0.07	0.08	0.12	0.12	0.14	0.13	0.09
CaO	1.1	1.8	2.3	2.6	2.1	1.7	1.9	3.0	3.8	4.0	3.9	4.9	8.8
MgO	0.61	0.81	1.2	1.4	1.0	0.81	1.1	1.5	1.7	1.7	1.8	2.4	8.3
Na ₂ O	2.8	2.7	3.1	2.9	3.1	2.7	3.6	3.3	2.7	3.1	3.0	2.8	3.1
K ₂ O	5.9	5.7	4.6	4.9	6.0	5.8	3.5	4.1	4.6	4.0	3.8	3.6	1.5
BaO	0.08	0.11	0.11	0.13	-	0.12	0.09	0.13	0.16	0.16	0.19	0.15	-
Total	97.68	96.05	96.41	97.61	99.74	97.78	97.34	97.91	97.78	97.98	97.73	97.38	99.51
N-co-or 65-	1168	0963	1817	1233	1325	1537	1705	1460	1805	1845	1265	1817	1200
E-co-or 15-	3218	3327	4822	3442	3525	3055	3100	3132	3045	2970	3397	4805	3304
Type	C	Cp	Mp	Mp	Cp	M	M	Mgd	Mgd	Mgd	Mgd	Mnd	Mn
Colour	R	GR	GR	R	GR	R	R	G	G	G	R	G	GB

x) From Asklund 1925, position of localities uncertain.

TABLE 7. Micro-probe analyses of biotites and hornblendes from a quartz-diorite of the Stavsjö suite and a Graversfors granite

Sample No.	J 7426 (co-or: 651176/153307)		GR 23 (co-or: 650747/152137)	
	biotite	hornblende	biotite	hornblende
SiO ₂	35.9	41.0	35.6	41.1
TiO ₂	2.8	1.5	2.7	1.2
Al ₂ O ₃	14.4	10.1	14.8	9.9
FeO	23.6	21.8	27.3	25.9
MnO	0.3	0.5	0.4	0.7
MgO	9.5	7.5	6.3	5.1
CaO		11.8		11.5
Na ₂ O		1.2		1.2
K ₂ O	9.0	1.5	9.2	1.5
	95.5	96.9	96.2	98.1

TABLE 8. Partial micro-probe analyses of iron and magnesium in biotites

Sample No.	<u>Stavsjö rocks</u>			
	Granodiorite W 7555	Quartz-diorite J 7415	Quartz-diorite J 7426	Norite J 7417
FeO (tot)	23.4	21.0	21.8	12.2
MgO	7.2	7.8	7.5	14.9
Fe (atomic)	7.6	7.1	7.0	3.4
Mg	4.2	4.5	4.3	7.4
$\frac{Mg}{Mg+Fe_{tot}}$	0.36	0.39	0.38	0.69

Co-ordinates: See Tab. 9

Sample No.	<u>Graversfors granites</u>											
	Gr 3	Gr 5	Gr 6	Gr 7	Gr 8	Gr 11	Gr 16	Gr 23	Gr 26	Gr 28	Gr 34	
Fe _{tot}	25.7	24.7	23.9	25.7	23.5	24.9	22.2	27.3	24.3	24.2	28.6	
MgO	4.6	5.7	4.4	6.1	6.5	5.7	7.1	6.3	6.2	6.3	7.0	
Fe (atomic)	8.5	8.1	7.7	8.5	7.7	7.8	7.2	8.6	8.0	7.9	9.6	
Mg	2.7	3.3	2.6	3.6	3.8	3.2	4.1	3.0	3.6	3.7	4.2	
$\frac{Mg}{Mg+Fe_{tot}}$	0.24	0.29	0.25	0.30	0.33	0.29	0.36	0.26	0.31	0.32	0.30	

Co-ordinates: See Tabs 1—3

TABLE 9. Partial micro-probe analyses of iron and magnesium in hornblendes

Sample No.	<u>Stavsjö rocks</u>							
	J 7440	W 7515	W 7532	W 7555	H 7403	J 7426	J 7415	J 7417
FeO (tot)	22.8	21.7	23.3	22.5	24.3	23.6	23.0	19.9
MgO	8.6	8.6	8.8	9.8	8.7	9.5	9.3	13.2
Fe (atomic)	7.3	6.9	7.5	7.2	7.9	7.6	7.4	5.8
Mg	4.9	4.9	5.0	5.6	5.1	5.4	5.3	6.9
$\frac{Mg}{Mg+Fe_{tot}}$	0.40	0.42	0.40	0.44	0.39	0.42	0.42	0.54
N-co-or 65-	1073	0963	1233	1845	1549	1176	1146	1186
E-co-or 15-	3290	3327	3442	2970	3238	3307	3234	3246

Sample No.	<u>Graversfors granite</u>										
	Gr 3	Gr 5	Gr 6	Gr 7	Gr 11	Gr 16	Gr 23	Gr 26	Gr 28	Gr 34	
FeO (tot)	27.0	25.5	28.0	27.1	25.9	24.2	27.3	25.6	25.9	28.6	
MgO	5.6	6.7	6.4	6.6	6.8	7.6	6.3	7.3	6.8	7.0	
Fe (atomic)	8.9	8.3	9.3	9.0	8.5	7.8	9.0	8.4	8.5	9.6	
Mg	3.3	3.9	3.8	3.9	3.9	4.4	3.7	4.3	3.9	4.2	
$\frac{Mg}{Mg+Fe_{tot}}$	0.37	0.32	0.29	0.30	0.31	0.36	0.29	0.34	0.35	0.30	

Co-ordinates: See Tabs 1—3

TABLE 10. Summary of density measurements

Rock type	No. of obs.	Mean density (g/cm ³)	Standard deviation (g/cm ³)	Density range (g/cm ³)
Pegmatite	5	2.608	0.022	2.58-2.64
Stavsjö granite	6	2.687	0.032	2.66-2.76
Graversfors granite	54	2.702	0.029	2.62-2.76
Younger late-kinematic granitoids	10	2.645	0.022	2.62-2.69
Older pre- to syn-kinematic granitoids	153	2.675	0.035	2.62-2.80
Supracrustal rocks	105	2.697	0.045	2.62-2.83
Amphibolite and gabbro	23	3.00	0.10	2.83-3.18
Dolerite	3	2.987	0.035	2.94-3.03

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