SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 813 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 80 NR 2

ANDERS WIKSTRÖM AND SVEN AARO

THE FINSPÅNG AUGEN GNEISS MASSIF

GEOLOGY, GEOPHYSICS AND RELATIONSHIP TO POSTOROGENIC GRANITES

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ABSTRACT

The Finspång augen gneiss massif in southeastern Sweden has been investigated in various aspects.

Chemical analyses show no systematic differences between foliated, lineated and isotropic parts of the massif. A typical coarse-porphyritic post-Svecokarelian Småland granite with the local name Roxen granite in the western part of the investigated area deviates somewhat in chemistry from the majority of the Finspång samples. However, they lie within the range of values for the Finspång samples.

Aeromagnetic and gravimetric information has demonstrated a limited depth of the massif. This is in accordance with an earlier hypothesis that the Finspång massif represents the lower part of a cap to a diapir of the post-Svecokarelian granites.

A kinematic model is presented where the fabrics and structures within the Finspång massif are related to the intrusion of the younger granitoids. The consequence of this model is that many of the structures and much of the metamorphism of the surrounding region are due to the emplacement of these intrusions.

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INTRODUCTION

Augen gneisses occur along the eastern margin of the Småland-Värmland granite belt in central Sweden. These augen gneisses are generally folded conformably with the surrounding rocks but in several areas they seem to pass transitionally into the otherwise cross-cutting coarse-porphyritic Småland granites (Fig. 1). It was suggested by Wikström (1984) that these augen gneisses could be interpreted as early crystallized 'skins' of the Småland granites which were later distorted and folded due to magmatic inflation by the younger intrusions. This would mean that a large-scale tectono-metamorphic event was superimposed on the Svecokarelian rocks in the area surrounding the Småland granites. That paper also reviewed the different hypotheses about these rocks which have been proposed in the past.

The present paper describes investigations in and around the Finspång massif in order to collect more data on this subject.

The essential features of Fig. 1 were already shown on Törnebohm's map from 1880. Törnebohm made a description of the lithologies seen along some traverses over the Finspång massif (1880, map-sheet 8, pp. 22–25). In the map he separated the massif from the 'Filipstad' granites, although he noted in the description that this later granite along its northern margin merged into an augen gneiss, similar to the augen gneiss in the Finspång massif.

He also made the remark that it is only by regional mapping one can be convinced that these rocks are related to each other; in outcrop and hand specimen this is not always obvious.

Magnusson (1957) classified the Finspång massif as 'Gothian' and claimed (Magnusson *et al.* 1960) that the augen gneisses represented path-ways of Småland granite magmas through an already folded bedrock. Magnusson's opinion that there were no regional deformations at this evolutionary stage and that the so-called postorogenic granites crosscut the regional structures has been adhered to by most subsequent geologists. Wikström (1976), following this tradition, mapped the eastern part of the Finspång massif as Svecokarelian on structural grounds. Although it was recognized at that time that important regional deformations younger than the Svecokarelian deformations had affected the region (Wikström 1974), no mechanism was understood how the structures of the Finspång massif could be incorporated in these deformations. After mapping on the Finspång SO map-sheet during 1980 in the region around Hällestad the original observations and conclusions of Törnebohm were accepted. How should then the structures on the map and section of Fig. 1 be explained? The idea of 'ballooning' granitoids appeared in several papers at the end of the 1970's. In the main these theories originated with Cloos (1925) who described the deformation in the marginal parts of a granite massif in Riesengebirge. He regarded the deformation to be caused by 'Aufblähung des Massivs' (inflation of the massif) and the marginal parts behaved 'wie die Haut der Seifenblase' (like the skin of a

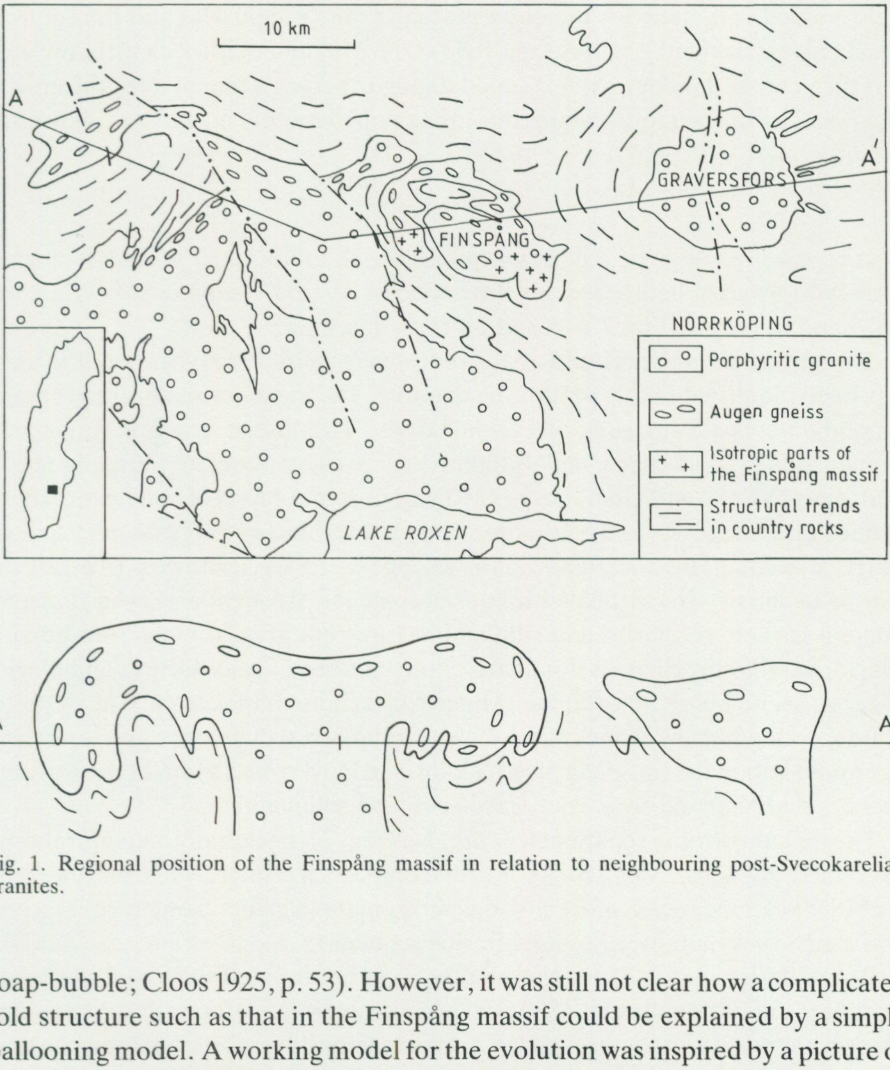


Fig. 1. Regional position of the Finspång massif in relation to neighbouring post-Svecokarelian granites.

soap-bubble; Cloos 1925, p. 53). However, it was still not clear how a complicated fold structure such as that in the Finspång massif could be explained by a simple ballooning model. A working model for the evolution was inspired by a picture of a model published by Ramberg (1967). Pendant lobes of the cap of this model diapir were conformably folded together with the surrounding material while the trunk had discordant contacts. The analogy to the structure in the Finspång area was obvious (Wikström 1984). A test of this hypothesis is not simple. In theory the 'skin' or boundary shell should be older than the central part of the intrusion. Certainly the rocks of the Finspång massif differ in fabric and have slightly different chemistry from the Roxen granite (a local variety of the Småland-Värmland granites).

A radiometric dating of rocks from the Finspång massif yielded ages of 1819 or 1840 Ma (Åberg and Wikström 1985), the two alternatives depending upon whether two points are included in the diagram or not. The magnitude of this deformation is in between the older plutonics (1850–1900 Ma) and the younger Småland – Värmland granites (age 1650–1760 Ma) and neither confirm nor rule out the proposed model. An extended dating program is planned for the area to the west, with its more continuous transition between massif and deformed granites.

GEOLOGY

The regional geology of the area is presented in more detail in the Geological Survey of Sweden bedrock maps Katrineholm SV and Finspång SO (Wikström 1976 and in prep.). Fig. 2 is based on these maps.

The supracrustal rocks build up the oldest map-units and no basement to them has been identified in this part of the country. The metasediments are generally amphibolite facies gneisses of various kinds. The lowest grade is found in a sequence of layered pelitic and psammitic gneisses between the Finspång massif and lakes Dovern and Glan. Large (2–3 cm) porphyroblasts of andalusite can be found here; muscovite and cordierite seem to be stable. Scattered quartz veins are fairly common. This rock association disappears to the northwest (west of the Finspång massif) where the pelitic beds become less frequent and, when present, contain garnet, cordierite and sillimanite. Layered, grey, often garnet-bearing plagioclase-biotite gneisses dominate, intercalations of calc-silicates and plagioclase quartzite being subordinate. Migmatitic veining is moderate. The opposite is true for the narrow stripes of strongly migmatized sedimentary gneisses which are found within the Finspång massif along lake Dovern and south of the Lövlund massif, characterized by garnet, cordierite and sillimanite.

The mixed volcanic-sedimentary complex (Fig. 2) is generally metamorphosed to veined gneisses. Most rocks in this complex are interpreted as reworked (tuffitic) volcanic rocks, more homogeneous metavolcanics being rare. Marbles and skarn rocks are locally found in this sequence.

Rocks designated as 'gneissic granites, undifferentiated' in Fig. 2 are problematical. Traditionally the 1850–1900 Ma granitoids, deformed together with the supracrustal rocks, are called 'primorogenic Svecokarelian' or labelled 'urgraniter' using the old Swedish term. Normally this calc-alcaline igneous suite is differentiated from gabbro to granite. Some of the youngest members in this suite can be rather felsic. This is true also for one of the younger members of the 1650–1750 Ma Småland – Värmland igneous suite. The felsic granite belonging to the later suite is described below under the local name Sonstorp. The younger suite is generally supposed to cross-cut the regional fold-pattern while the older doesn't. The deformation history outlined in this paper with parts of the younger granitoids deformed within the regional pattern makes the above criterion not valid for distinguishing between the two granite groups. A detailed structural or petrochemical investigation could possibly separate between the two suites of different ages. Gneissic, even-grained, red granites have been grouped together

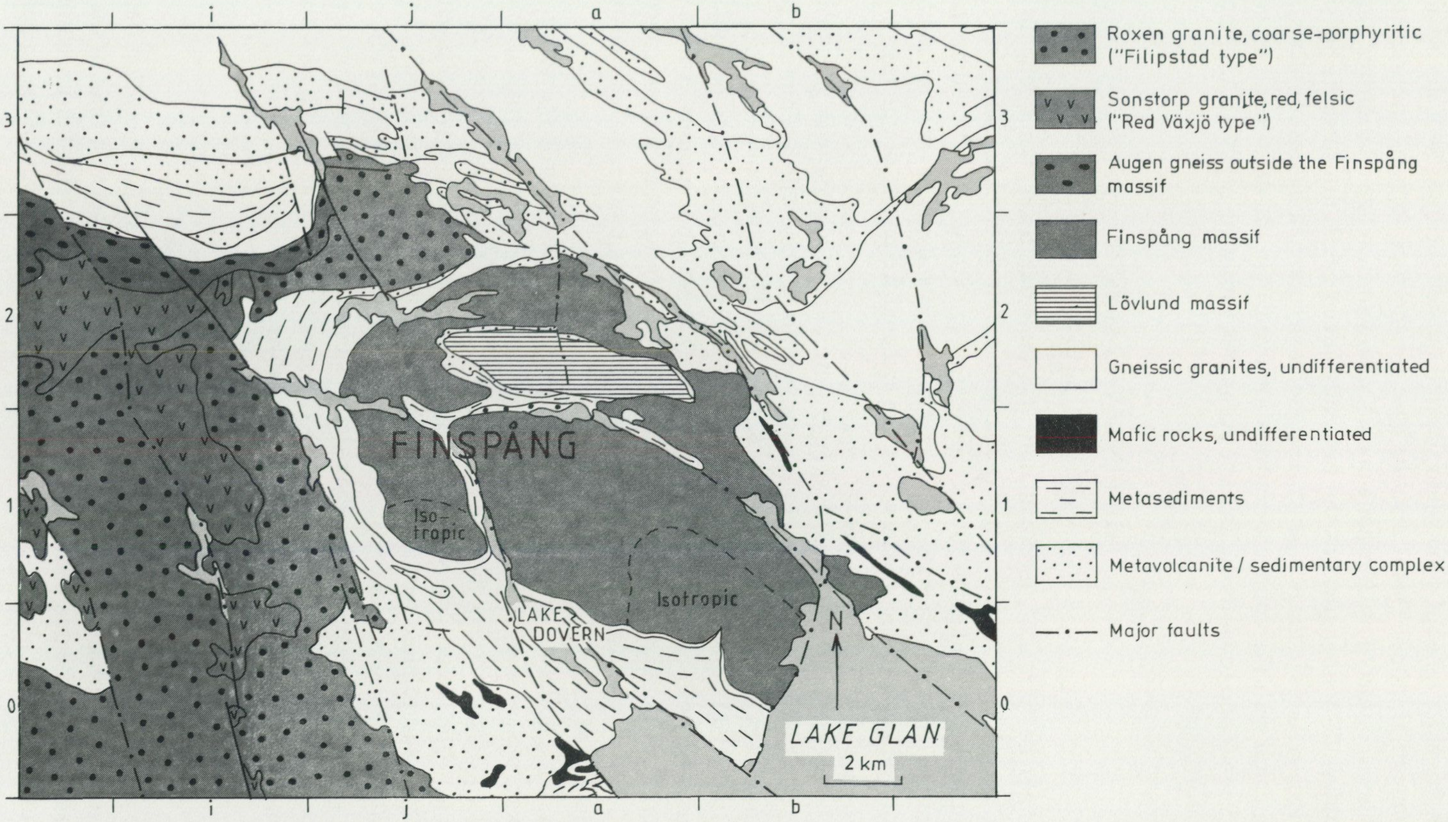


Fig. 2. Hard-rock geology of the Finspång area.

with the older igneous suite when situated outside the massifs of the Småland – Värmland granites. This is also the case for the rock forming the western and northern contact of the Finspång massif, where no clear age relationship has been established, neither towards the Finspång augen gneiss nor towards the similar gneissic granites in the northeast. The gneiss-structure along this contact is clearly connected with the youngest deformation event. On the other hand no contact has been found towards the gneissic granitoids within the regional fold pattern in the northeast.

THE FINSPÅNG MASSIF

THE EASTERN ISOTROPIC AREA

This part of the massif, approximately 3×4 km in size, is very homogeneous. Only two xenoliths of sedimentary gneiss and a few pegmatite dikes have been recorded. A second generation of microcline growth has been noted in only one outcrop. The area is more or less continuously exposed in contrast to the deformed parts of the massif where the size and frequence of outcrops is much less.

The rock is a grey to pinkish grey granite to granodiorite with grey or bluish grey quartz (Fig. 3:5). Under the microscope plagioclase with a composition An_{25} – An_{30} can be seen to dominate over K-feldspar. The K-feldspar is untwinned and has abundant minute muscovite flakes along cleavage planes. Myrmekite is occasionally present. Biotite is the only dark mineral and amounts to some 10–15 volume per cent. Muscovite, rarely recognizable in hand specimen, constitutes 5–10 % and is mostly associated with and replacing biotite, K-feldspar and to some extent plagioclase.

A slight foliation parallel to the southern contact towards the supracrustal rocks can be seen some hundred meters into the massif. In the north, the foliation in the gneissic parts is running parallel to the transition line between deformed and isotropic areas. The western contact is more complicated with a mixture of lineated and foliated tectonites. The dips and plunges of these fabrics are commonly gentle towards the east and beneath the isotropic part. However, also in this generally gneissic area, along the western contact, some outcrops are isotropic. The isotropic granodiorite in the southeast appears to lie in a shallow asymmetric bowl outlined by a gneissic fabric.

THE WESTERN ISOTROPIC AREA

The general impression gained in the field work is that the transition between isotropic and foliated/lineated parts is less distinct in the west than in the east. This may partly be due to the difficulty in recognizing flat-lying fabrics in subhorizontal outcrops. This part is somewhat more salic than the rest of the massif (Fig.

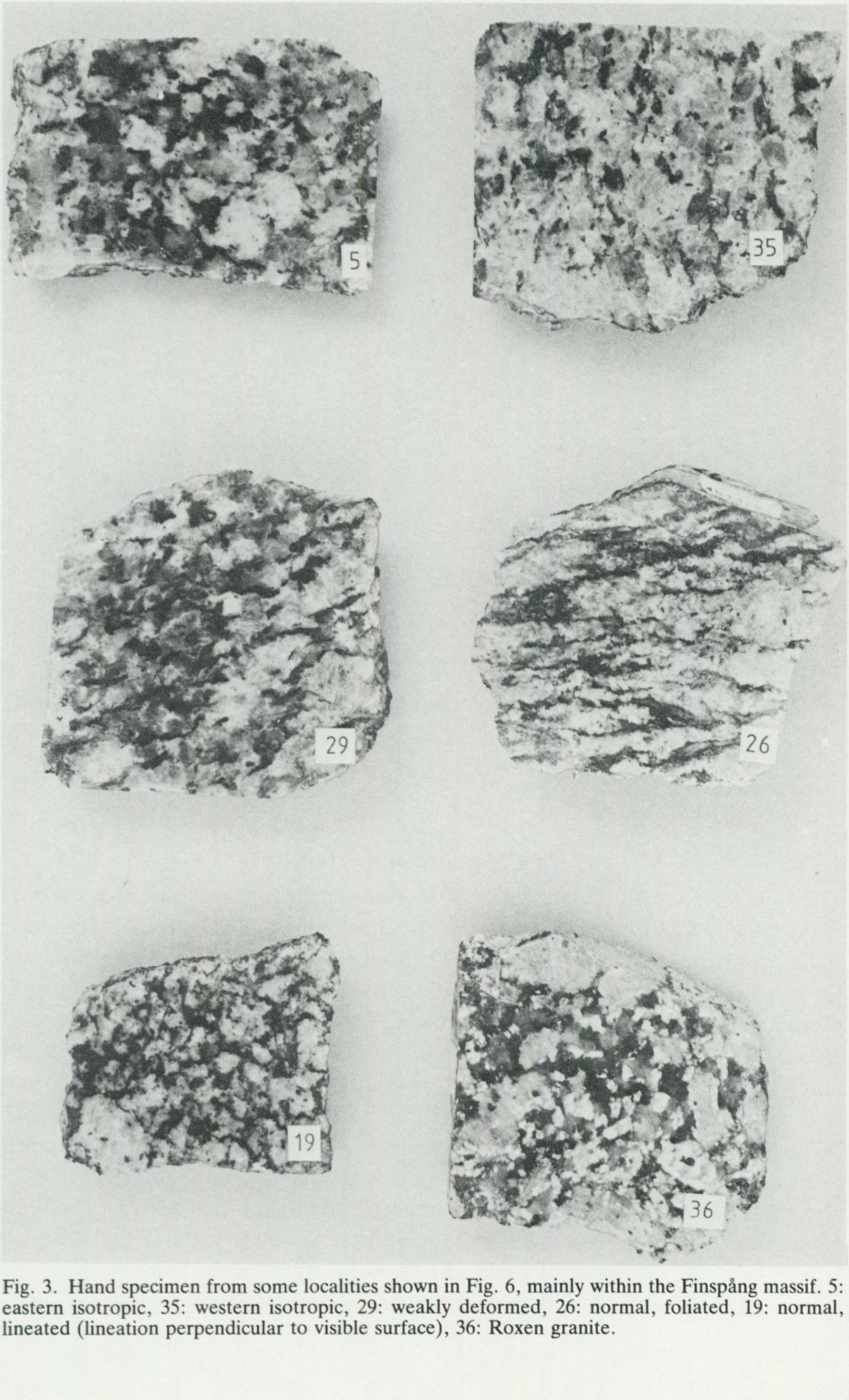


Fig. 3. Hand specimen from some localities shown in Fig. 6, mainly within the Finspång massif. 5: eastern isotropic, 35: western isotropic, 29: weakly deformed, 26: normal, foliated, 19: normal, lineated (lineation perpendicular to visible surface), 36: Roxen granite.

Fig. 4. Discordant contact between Finspång augen gneiss and pelitic veined gneiss. Finspång town. Nat. coord. 651030/149720.

7). The feldspar megacrysts are less well developed and the content of biotite is somewhat lower than in the rest of the massif. Under the microscope a slightly perthitic microcline with well-developed cross-hatching predominates. Some minor amounts of strongly altered cordierite have been observed.

THE AUGEN GNEISS AREA

The augen gneisses making up most of the Finspång massif are somewhat variable (Törnebohm 1880) in both fabric and chemistry (Figs. 3, 7 to 9). Most of these rocks are strongly deformed (Fig. 3:26) although the intensity decreases towards the isotropic areas. Within such transition zones a later generation of K-feldspar megacrysts can be seen partly overgrowing the foliation. However, this second generation can also sometimes be seen to have been deformed and the process of recrystallization repeated. There was apparently an interplay between deformation and recrystallization processes and the classification of the megacrysts into definite generations is difficult. The shape of the megacrysts varies between elliptical to elongated angular with a length of up to 3 or 4 cm. In this deformation process the oldest megacrysts seem to merge into migmatitic veins. The amount of discrete pegmatite leucosomes, segregations or dikes is fairly limited on a larger scale. Only along the contact with the supracrustal rocks along the highway between Finspång and Norrköping has a strong migmatization been recognized.

This is probably because the abundant xenoliths supplied extra water here. Young tectonic movements along this zone have also contributed to the observed structures. The external contact of the Finspång massif is generally conformable and steep as shown in Fig. 16. The only exception to this is a single outcrop where the original contact was locally discordant although both the augen gneiss and the metasediment share the same youngest deformation event (Fig. 4). Between lakes Dovern and Glan the porphyritic character is less well developed in a narrow zone along the southern contact. This rock seems to be somewhat more transitional to the megacrystic variety than the marginal gneiss-granite along the western and northern contacts.

No amphibolite dikes have been found in the massif.

THE LÖVLUND MASSIF

This massif is a brachyantiformal structure in the central part of the area. Lineations plunge towards the east in the eastern part and towards the west in the western part. The massif is surrounded by a thin (1–500 m), strongly migmatized supracrustal envelope and, outside that, the Finspång augen gneiss (Fig. 19). The predominating rock in the massif is a reddish grey, medium-grained granodiorite gneiss. The grain-shape fabric is commonly well-developed with transitions between S- and L- tectonites. Migmatitic veining is common with stromatic structures predominating (sometimes the veins are at low angles to the foliation). Some scattered thin amphibolite dikes are conformable to the foliation. Also common in the massif is a red, fine- to medium-grained granite gneiss with gradual transitions into the predominating granodiorite gneiss. These rocks share the same deformation fabric. Along the eastern margin of the massif the transition is also gradual between this granite gneiss and some recrystallized acid metavolcanics. As can be seen on the aeromagnetic map (Fig. 13), the rocks of the Lövlund massif can be distinguished from the other gneissic plutonics by their higher magnetic susceptibility values. Nevertheless they have the general appearance of the older plutonics and probably belong to this group. Under the microscope a slight mortar texture has been found in several thin sections. The microcline is weakly perthitic and myrmekite is common. Biotite pleochroism varies from light green to greenish black and is clearly different from that of the biotites in all the other rocks in the area, which have brownish tints.

THE ROXEN GRANITE

This local variety of the Småland – Värmland granite suite was named by Gorbatschev (1976). Parts of this massif were described by Kornfält (1975) and the rock seems to be identical with the Graversfors granite investigated by Wikström

Fig. 5. Weakly foliated Roxen granite, in outcrop similar to some Finspång varieties. 1 km W Bårsjön. 651400/159900.

et al. (1980). The Roxen granite is a coarse-grained, porphyritic granitoid with rounded, sometimes plagioclase-mantled microcline megacrysts between 2 and 4 cm in diameter (Fig. 3:36). Its composition is generally in the borderzone between granite, granodiorite, monzonite and monzodiorite. The colour of the microcline megacrysts varies between pinkish red, light grey and brownish violet. The colour of the quartz varies between light grey and blue. The dark minerals are dominated by biotite and hornblende with subordinate magnetite, chlorite and sphene. Darker varieties outside the area considered here (Fig. 2) contain some orthopyroxene and accessory fayalite. The magnetic susceptibility values of the Roxen granite are fairly high in the area of Fig. 2 unlike in the same massif further west where this property is highly variable. A slight foliation can be seen in the southern part of the northeast protruding bulge of the Roxen granite north of the Finspång massif (Figs. 5 and 16). There is a striking similarity with the Finspång augen gneiss in outcrops here. Minor occurrences of deformed augen gneiss with abundant strongly migmatized supracrustal xenoliths have been observed outside the eastern contact of this bulge.

THE SONSTORP GRANITE

This granite is red, medium-grained and felsic. Dikes of it penetrate the Roxen granite in some places and apart from some minor fine-grained granites, aplites

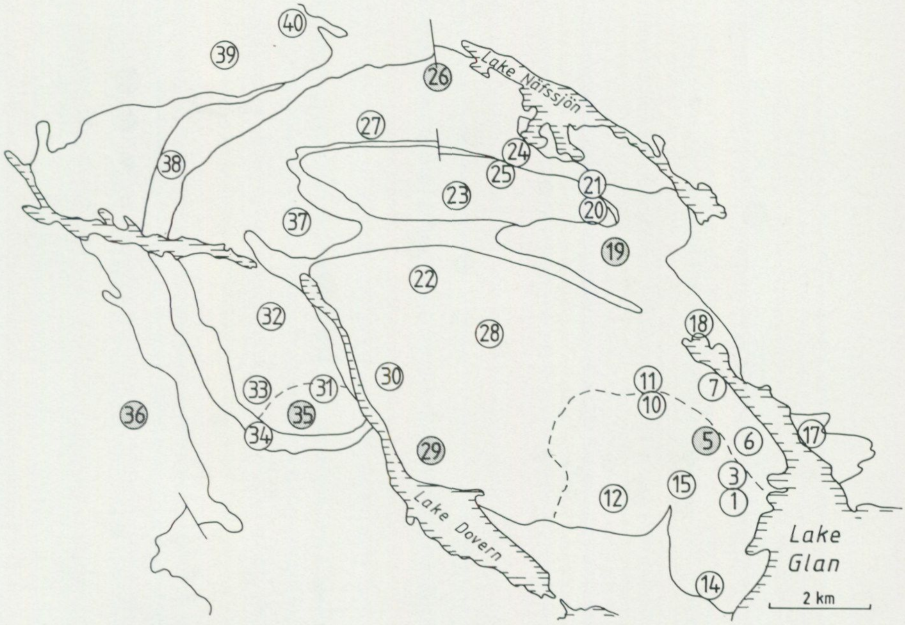


Fig. 6. Localities for chemically analysed samples. Coordinates are given in Tables 1–3. The last two figures in the sample numbers of these tables correspond to the numbers in the figure. Shaded numbers refer to samples shown in Fig. 3.

and dolerites, this rock is the youngest in the area. Nevertheless the northern margin of even the Sonstorp granite complex is foliated and suggests that the Roxen and later Sonstorp granites are fairly close in time and that the intrusions in the central part have continued also after the marginal parts have crystallized.

CHEMICAL INVESTIGATION

Wet chemical analyses have been made on rocks both from the Finspång massif and its surroundings (Fig. 6). The results are given in Tables 1–3 and in Figs. 7 to 9. These analyses show no obvious systematic variation in chemistry between deformed and isotropic parts of the Finspång massif. Field observations suggest that the southern tips of both isotropic areas seem to be more acid than the rest of the massif and this is somewhat sustained by the analyses in these areas. The three analysed samples of the Roxen granite differ from the majority of the Finspång samples although their values are within the general spread of points, as shown in Figs. 7 to 9.

TRICLINICITY MEASUREMENTS OF K-FELDSPAR

The triclinicity ($\triangle = 12.5(d_{131}-d_{1\bar{3}1})$) has been measured on some K-feldspar megacrysts. It has been maintained in a number of papers (e.g. Laves 1950,

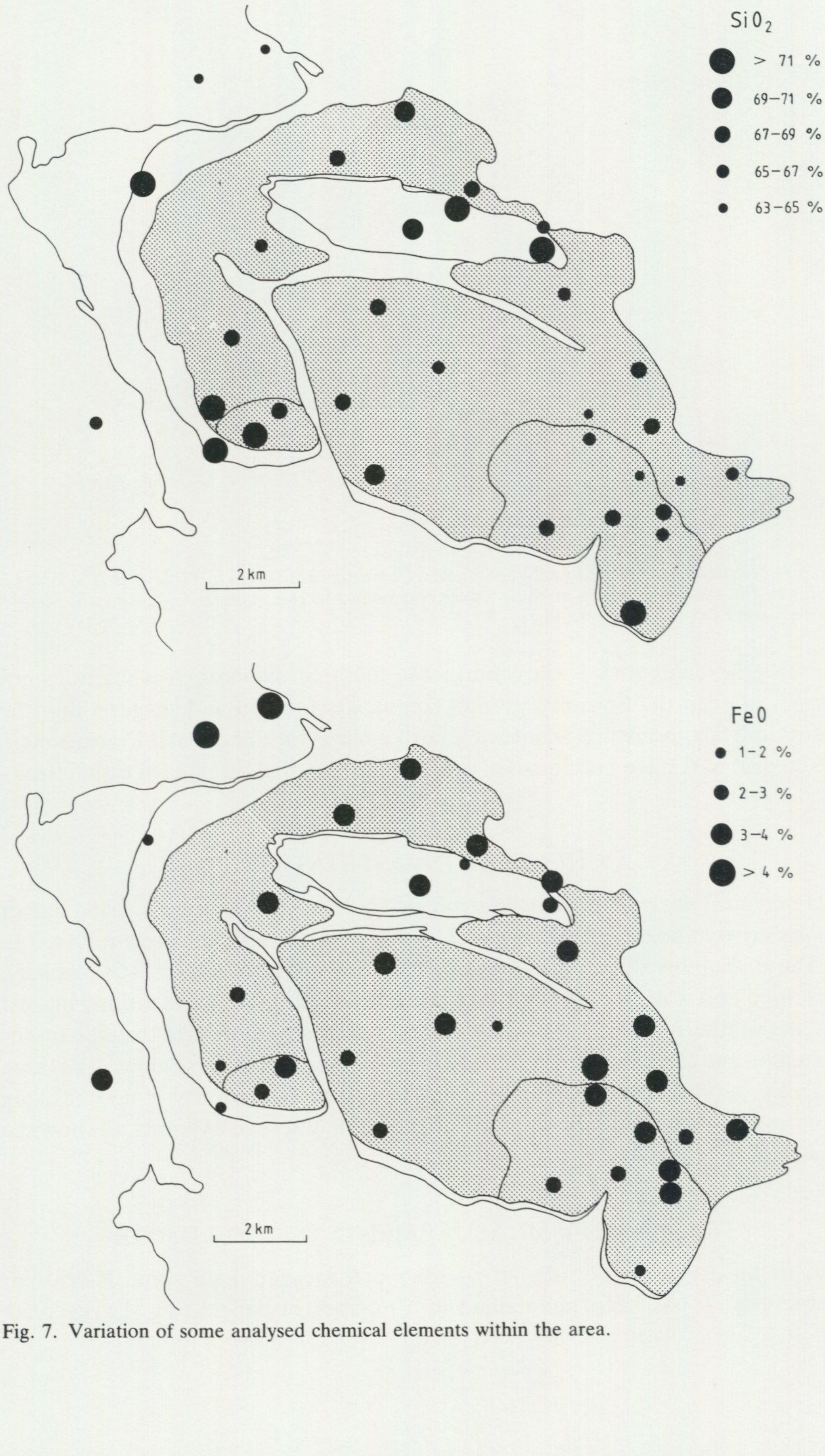


Fig. 7. Variation of some analysed chemical elements within the area.

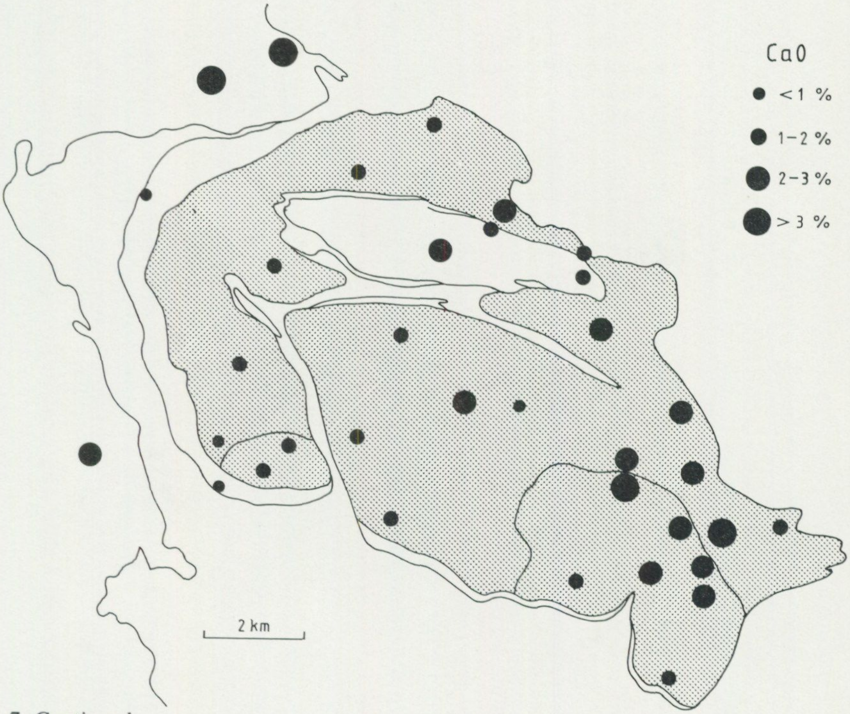


Fig. 7. Continued.

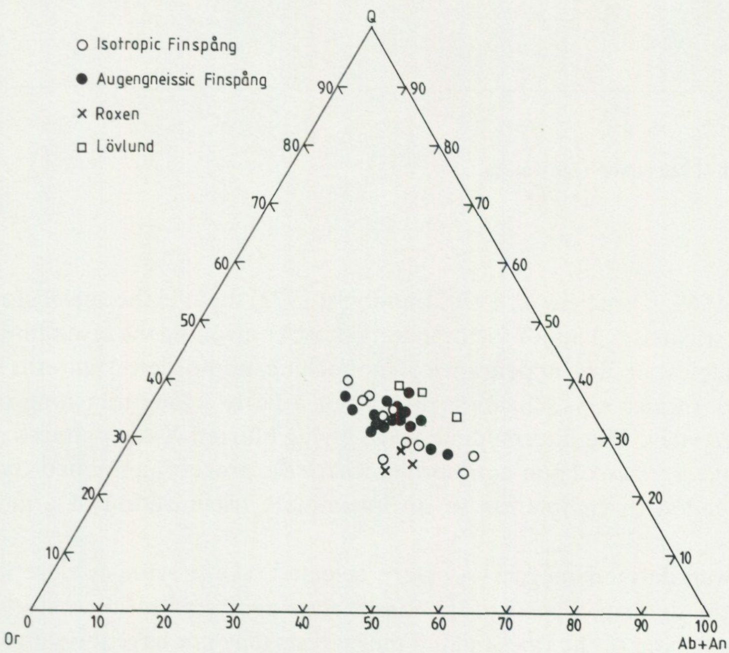


Fig. 8. Plot of normative Q-Or-(Ab+An)-values.

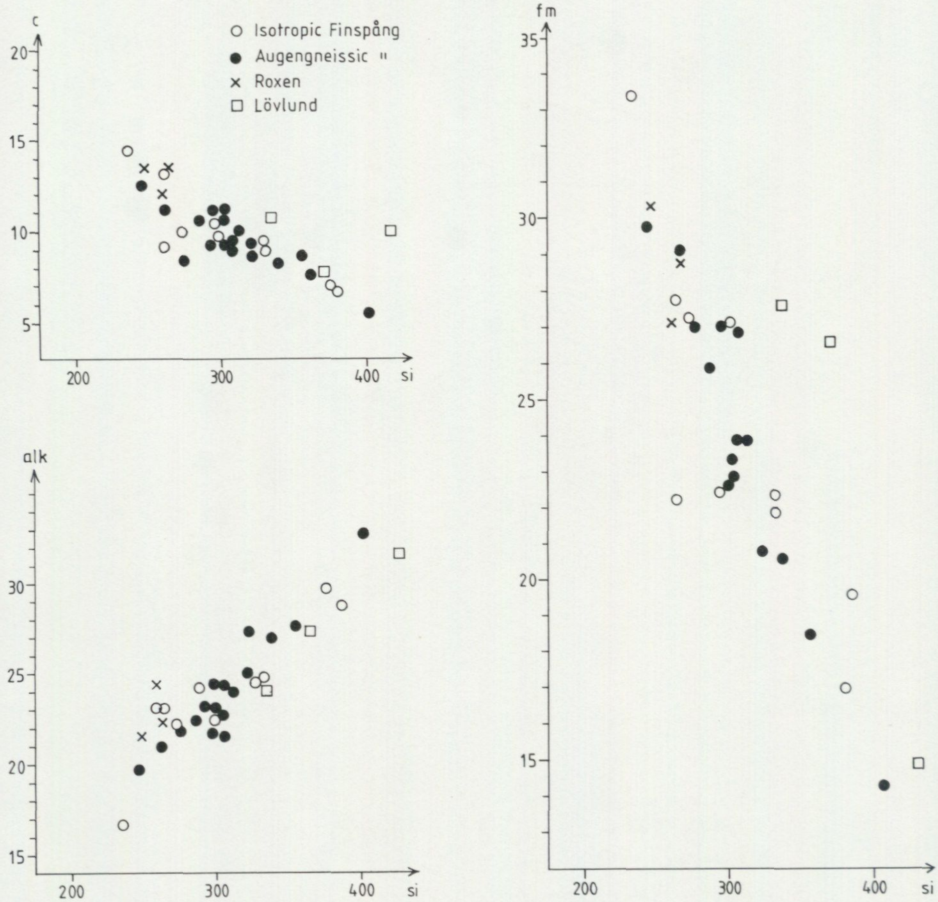


Fig. 9. Plot of selected Niggli-values.

Kornfält 1969, Christie *et al.* 1970, Lundqvist 1973) that the thermal history of the rock investigated 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 process mentioned above have not proceeded to completion or an incomplete triclinization of a monoclinic feldspar.

Only well-defined megacrysts were selected. As previously described, the rocks in the deformed parts of the massif show recrystallization textures, which means that some of the investigated megacrysts may not have the same age. All

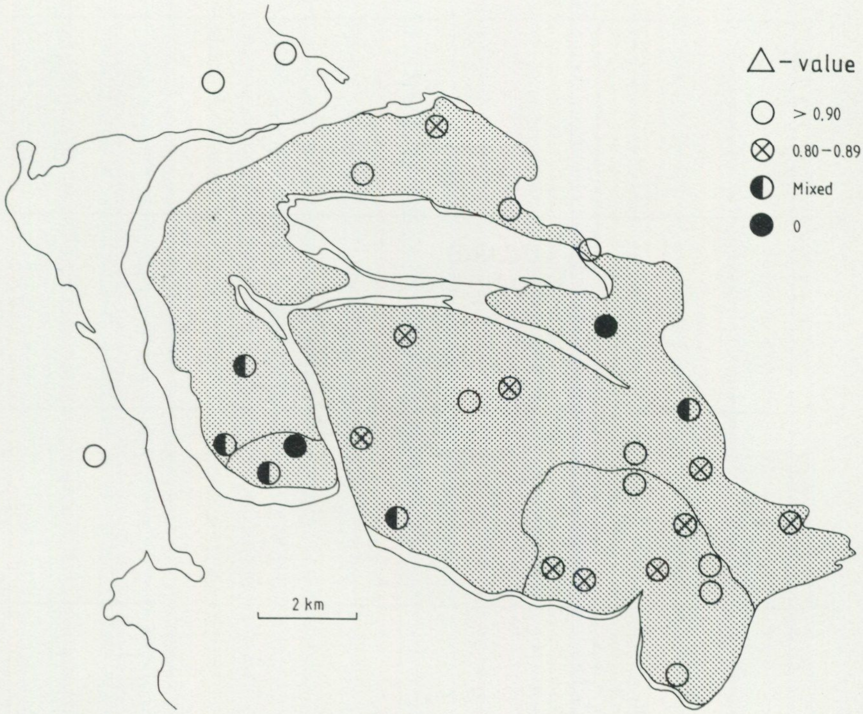


Fig. 10. Triclinicity measurements on K-feldspar.

the megacrysts show microcline crosshatching with the exception of those from the eastern isotropic area, where such twinning is almost absent.

The southwestern part of the massif, which deviates from the rest of the massif in being somewhat more felsic, also deviates in triclinicity and shows high-termal or disturbed X-ray patterns. Within this area, which has a weakly developed fabric, no recrystallization of the feldspars has been recognized. Two samples along the eastern contact are also disturbed, although this area is of the average augen gneiss type.

The structural evolution outlined in Fig. 20 assumes a Roxen granite on top of the Finspång massif. Variations in heat flow from this granite might be the reason for the observed values.

PETROPHYSICAL PROPERTIES OF INVESTIGATED ROCKS

In order to get an improved basis for the interpretation of the gravity anomalies and also of the aeromagnetic anomalies, petrophysical measurements were carried out on representative 0.7 kg samples. The density was determined on 162 rock samples and the magnetic properties, susceptibility and q-value, were measured on 73 samples.

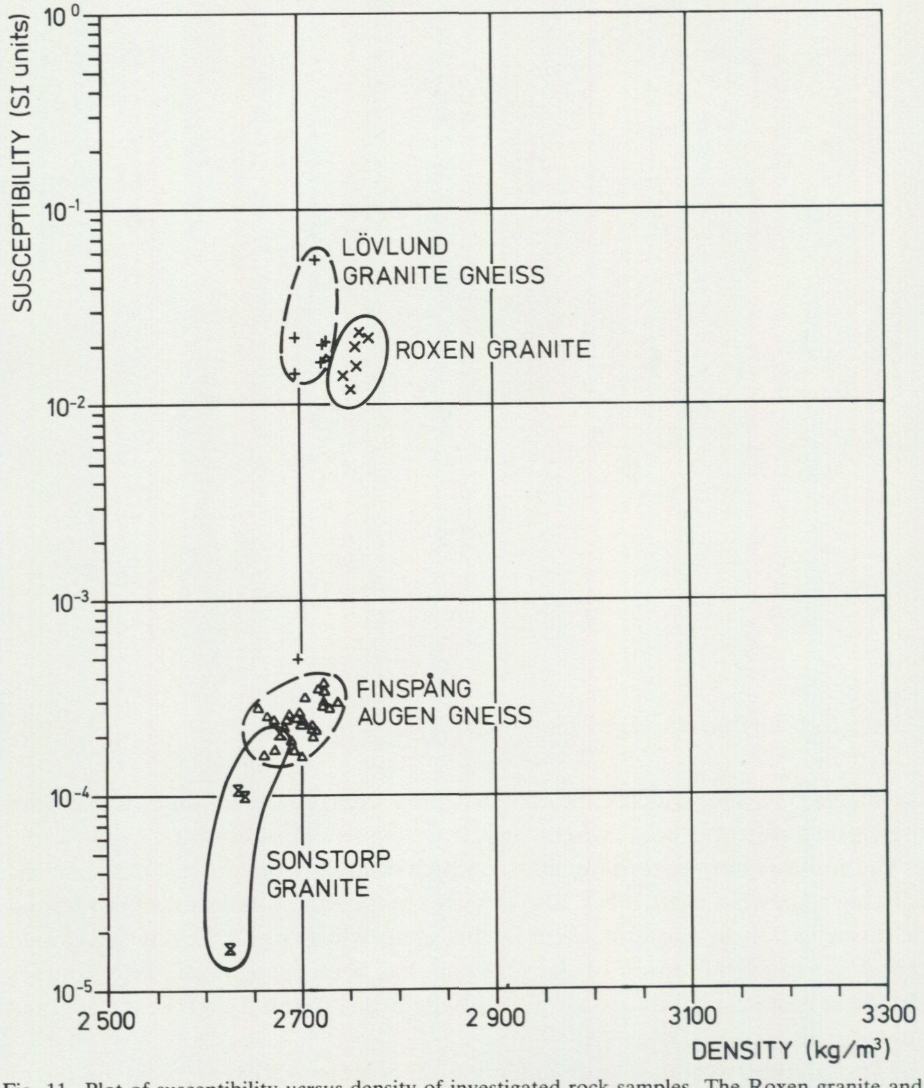


Fig. 11. Plot of susceptibility *versus* density of investigated rock samples. The Roxen granite and Lövlund granite gneiss have susceptibility values which indicate a magnetite content of 0.2–1 % by volume.

The results of the density determinations are presented in Table 4 and they are plotted together with the susceptibility in Fig. 11. The susceptibility *versus* q-value (ratio of remanent to induced magnetization in the ambient earth's field) is shown in Fig. 12. The mean density of all the measured samples, which are uniformly distributed in the investigated area, is 2711 kg/m^3. As can be seen from Table 4, the Finspång and Lövlund gneisses have densities which do not differ significantly from the mean for the whole area. The Roxen and Sonstorp granites

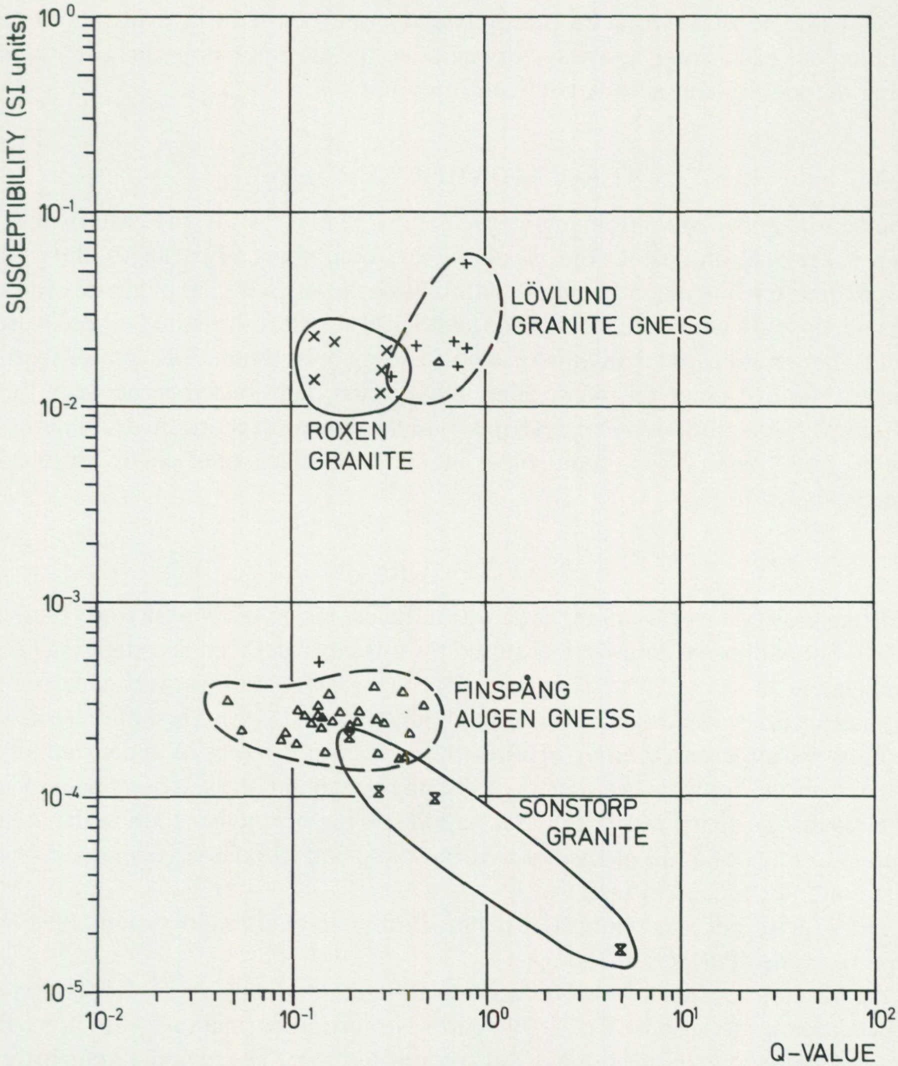


Fig. 12. Plot of susceptibility *versus* q-value (ratio of remanent and induced magnetization) of investigated rock samples. Note the relatively high q-value of the Lövlund granite gneiss.

as well as the undifferentiated gneissic granites have densities which are distinctly higher and lower, respectively, than the mean for the whole area. The Finspång gneiss and the Sonstorp granite have low ferromagnetic mineral contents while the Roxen granite and Lövlund granite gneiss have a magnetic susceptibility about 500 times greater, which indicates a magnetite content of 0.2–1.0% by volume (Puranen *et al.* 1968). The influence of remanent magnetization, indicated by the susceptibility *versus* q-value plot (Fig. 12), is low for all the rocks investigated except for the Lövlund granite gneiss.

Fig. 11 demonstrates that the petrophysical properties of the investigated rocks supplement each other in a way very suitable for discriminating the granitoids using the gravity and aeromagnetic information.

AEROMAGNETIC SURVEY

The aeromagnetic measurements in the area were made 1970 (the eastern part, map sheet 9G) and 1979 (the western part, map sheet 9F) using a fluxgate magnetometer flown at a height of 30 m above the surface. The flight direction was north-south which means that the geological structures oriented east to west will be better indicated than those in a north-south orientation. This is a consequence of the five times greater spacing between the flightlines than between the readings. For a more detailed description of these aeromagnetic measurements, see Werner (1963). The aeromagnetic anomaly contour map of the investigated area is shown in Fig. 13.

GRAVITY SURVEY

Existing gravity coverage in the area was sufficient for a preliminary study (Aaro 1983), but additional data were required for this more detailed investigation. To supplement the preexisting coverage, 196 new gravity stations were measured with an accuracy in Bouguer gravity of about 0.2 mgal (2 gu). Most of these new stations were measured along profiles with a station distance of approximately 200 m over the contacts between the Finspång massif and the surrounding rocks. The resulting gravity data base has a station spacing of roughly 1 km in the area within a radius of 5 km of the town of Finspång and less dense coverage in the surroundings.

The gravity net was connected to the European calibration system 1962 at Örebro castle (Pettersson 1967).

All observations have been reduced to Bouguer anomaly values by standard procedures using a density of 2670 kg/m^3. No terrain corrections were applied because of the low surface relief of the investigated area. The regional trend in the area was estimated by visual graphical smoothing of regional Bouguer anomalies (Wideland 1946) with a station spacing of roughly 20 km. The estimated regional trend is a smooth third degree trend surface with a western dip of 0.2 mgal/km. The residual component of the Bouguer gravity in the investigated area is shown in Fig. 14.

INTERPRETATION OF THE GEOPHYSICAL DATA

Two and a half-dimensional models for the calculations were used according to the method given by Rasmussen and Pedersen (1979). The computer program used was primarily written by Enmark (1982).

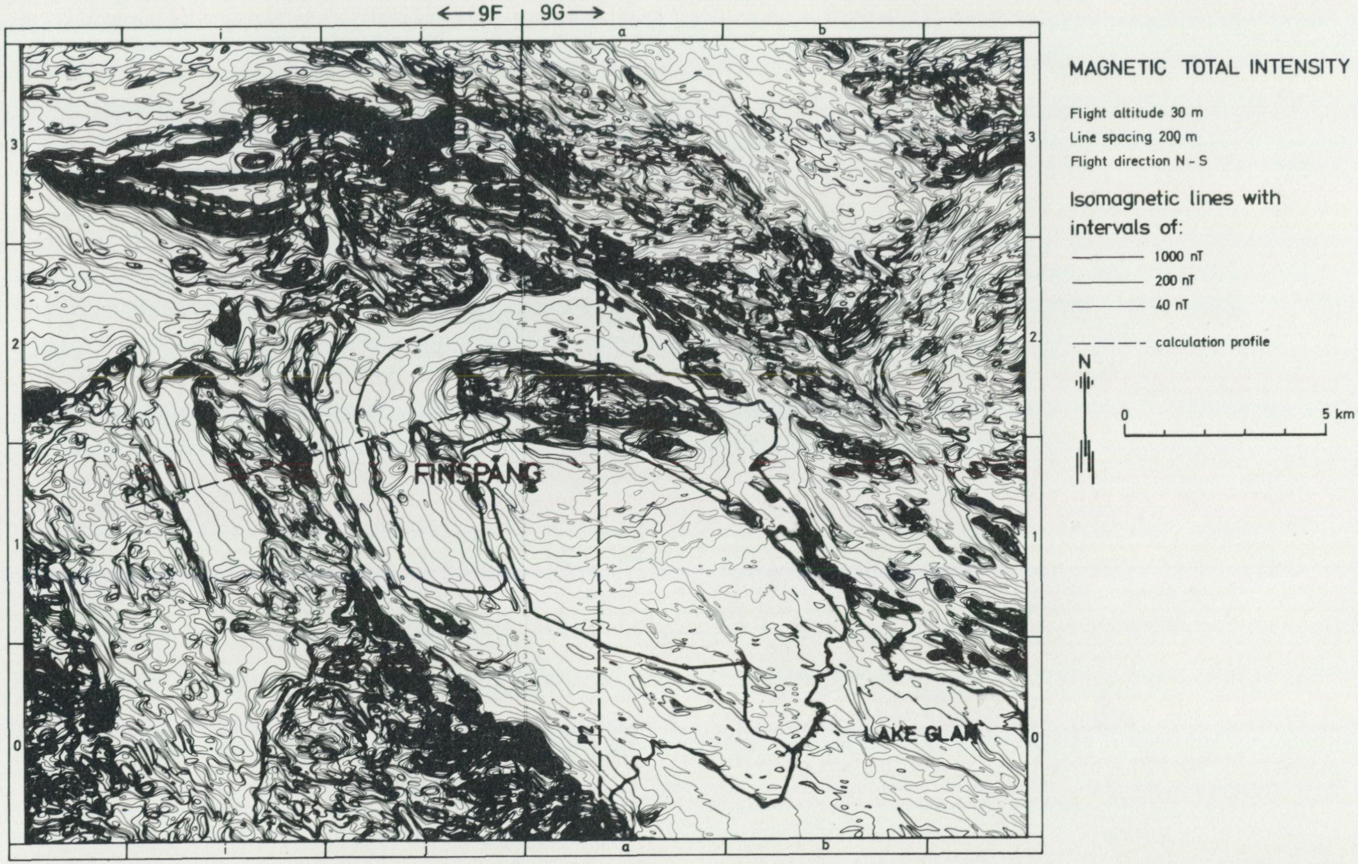


Fig. 13. Aeromagnetic anomaly contour map of the investigated area. The Finspång massif as well as model calculation profiles are indicated.

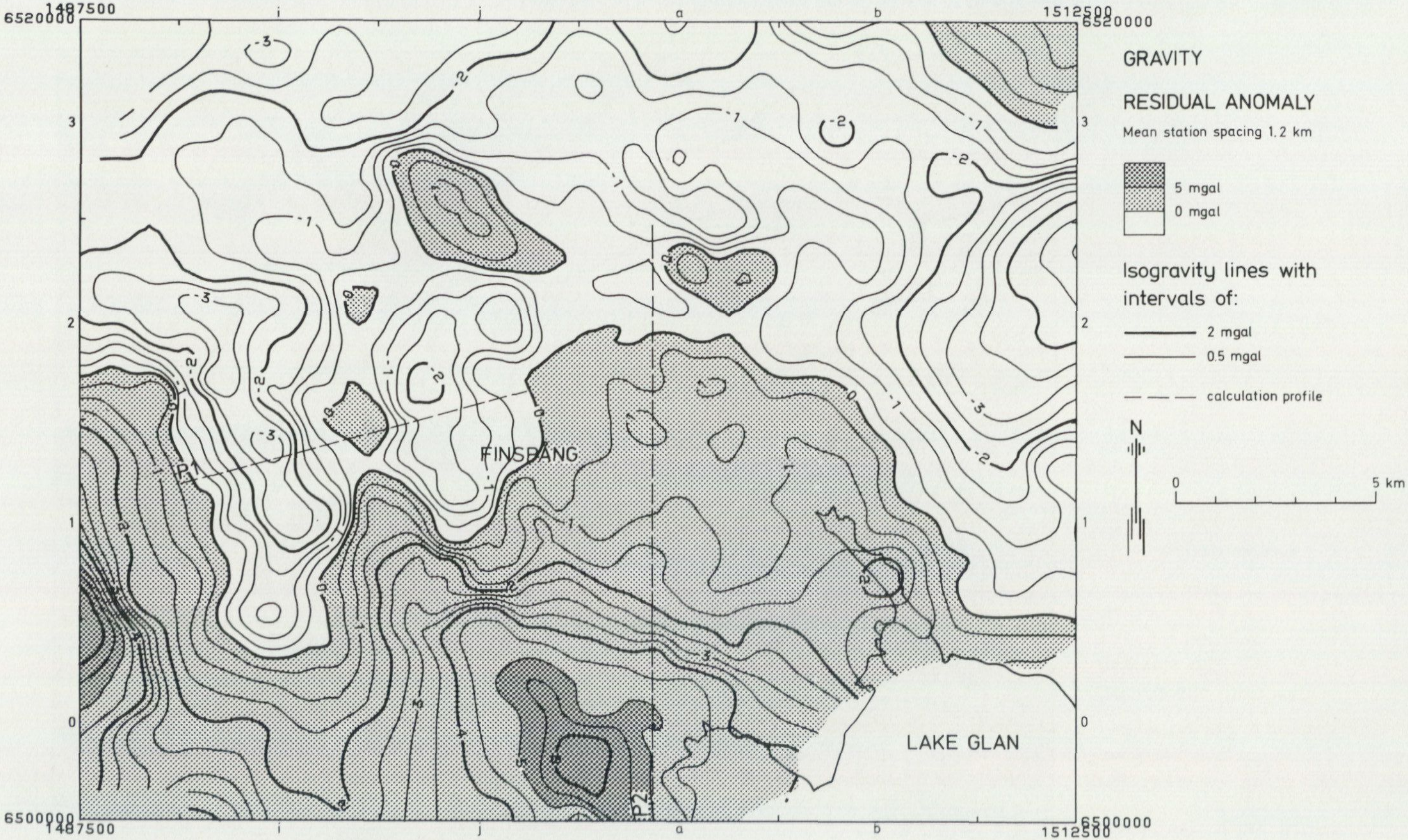


Fig. 14. Graphically separated residual component of the Bouguer gravity field. Contour interval is 0.5 mgal (5 gu). The locations of calculation profiles are indicated.

Model calculations have been carried out along two profiles shown in Figs. 13 and 14. The results of the model calculations are shown in Fig. 15. The density and magnetic properties used for the model calculations are approximatively the measured values for each rock unit concerned (see Table 4 and Figs. 11, 12 and 15). The remanent magnetization is assumed to be parallel to the present geomagnetic field, as indicated by the results obtained by Werner *et al*. (1977).

The aeromagnetic data have mainly been used to calculate the dips of the rock-contacts of the Roxen granite (Profile P1, Fig. 15) and to establish the antiformal structure of the Lövlund massif (Profile P2, Fig. 15). Both of these rock units have magnetizations which are clearly distinguishable from adjacent rocks (Figs. 11 and 12). With the good geological control available, the result of modelling is that the Finspång massif, which is the principal object of this study, has a limited thickness. The gravity and magnetic studies indicate that the thickness of the massif probably does not exceed 3 km.

The three-dimensional geological configuration of the area shown in Fig. 19 is based on the integration of both qualitative and quantitative interpretation of all the geological and geophysical data currently available.

STRUCTURAL SYNTHESIS AND DISCUSSION

The horizontal plan of minor folds in the foliation of the Finspång augen gneiss is illustrated in Fig. 17. By conventional structural methods one can distinguish a minimum of two phases of deformations: one responsible for the early foliation and at least one other connected with the folding and cross folding of the massif (Fig. 18). These deformations are here believed to indicate the structural development shown in Fig. 20 and are thus associated with the emplacement of the younger granitoids and later than the major Svecokarelian structures. The early foliation within the augen gneiss could have formed as a result of 'ballooning' (Fig. 20, II and III) while the subsequent folding and cross folding could be related to the final emplacement of the granite (Fig. 20, IV).

The major syn- and antiforms in the area, interpreted both from geophysical data and structural measurements in outcrops, are shown in Fig. 18. Two interfering directions can be distinguished, one mainly N–S and one E–W. The major recumbent folding with a vergence towards the east and a part of the granite cap moving down in the pocket to the north of the Finspång massif could be responsible for these crossing structures. Eventually could deeper fold structures with axial planes at right angles to the diapir (Ramberg 1967, Fig. 76) have some importance at these higher levels. Also the lighter granite (?) below the Lövlund massif deduced by the gravimetrical survey could have moved somewhat during this development (Fig. 19).

Some of the foliations and lineations observed in the area are shown in Fig. 16. A compilation of some of these structures in the eastern part of the massif situated

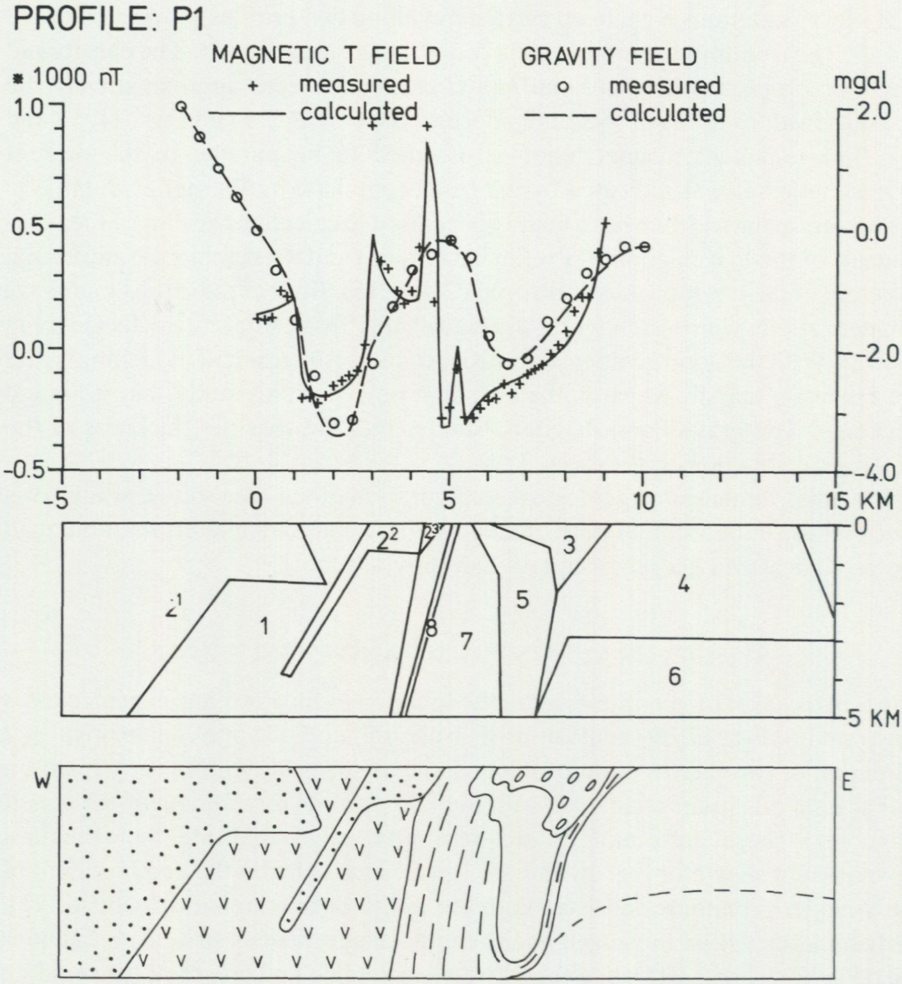
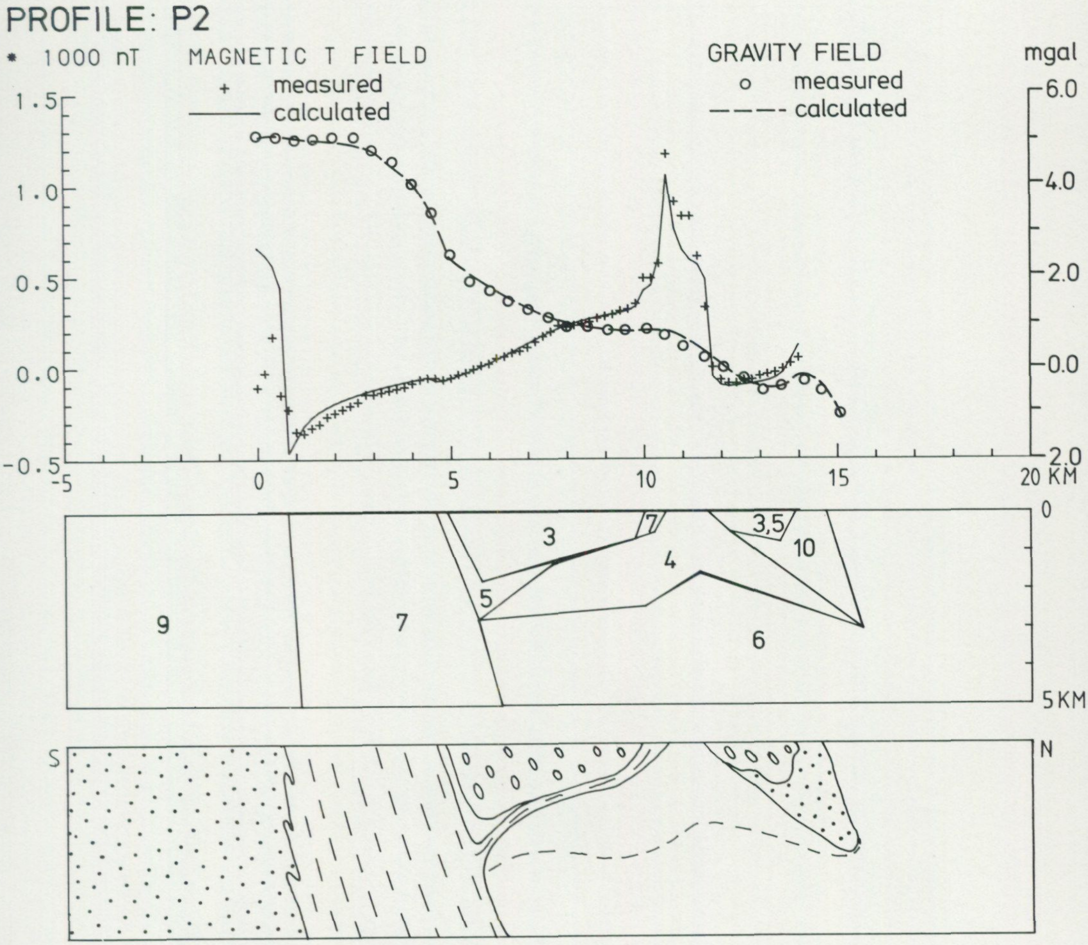


Fig. 15. Profiles P1 and P2 showing the interpretation of the residual gravity and total magnetic anomaly fields. For location of profiles see Figs. 13 or 14. The bottom picture shows a geological interpretation with a legend according to Fig. 2. See also Fig. 19.



Density and magnetic property values used:

Unit	kg/m^3	$\times 10^{-5}$ SI-units	assumed rock unit
1	2640	20	Sonstorp granite
2^1	2746	2200	Roxen granite
2^2	2746	3500	Roxen granite
2^3	2765	8000	Roxen granite
3	2701	30	Finspång augen gneiss
4	2712	4100	Lövlund granite gneiss
5	2644	0	Gneissic granites, marginal to Finspång massif
6	2674	0	Gneissic granites, undifferentiated
7	2728	200	Metasedimentary rocks
8	2750	2500	Metasedimentary rocks
9	2751	5000	Metavolcanic and mafic rocks, southwestern area
10	2717	900	Metavolcanic and mafic rocks, northeastern area

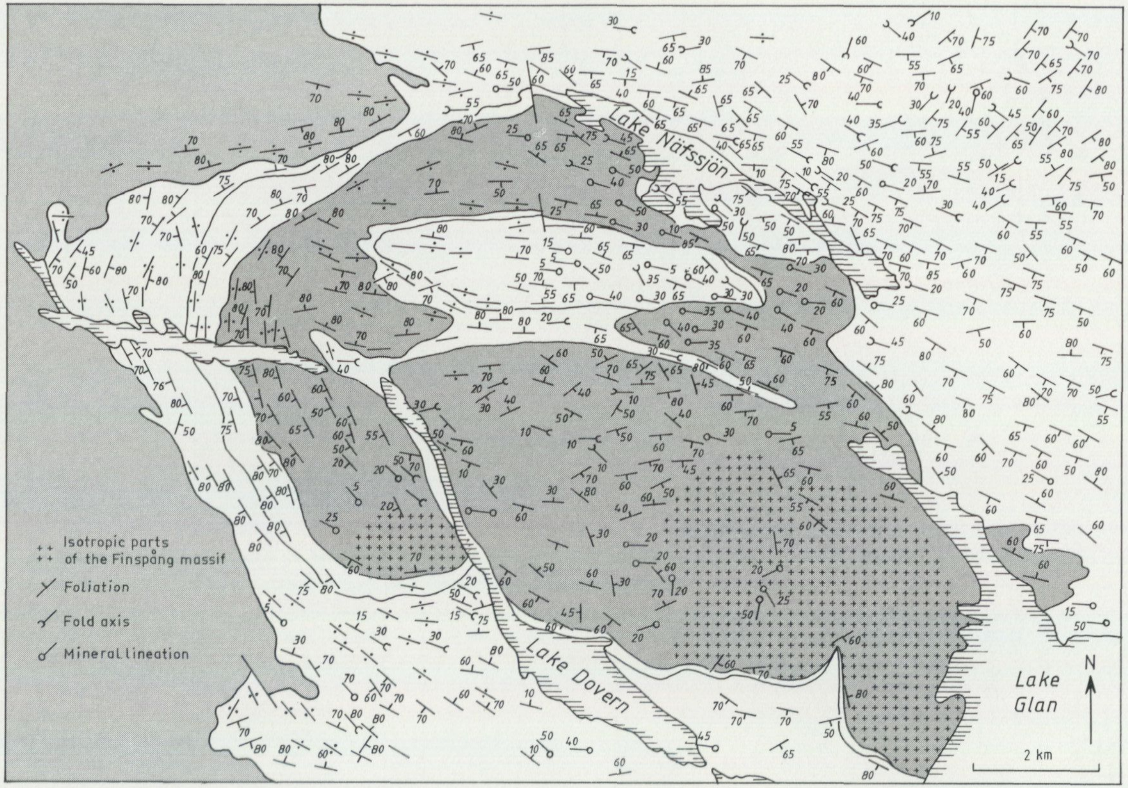


Fig. 16. Selected structural elements measured at outcrops.

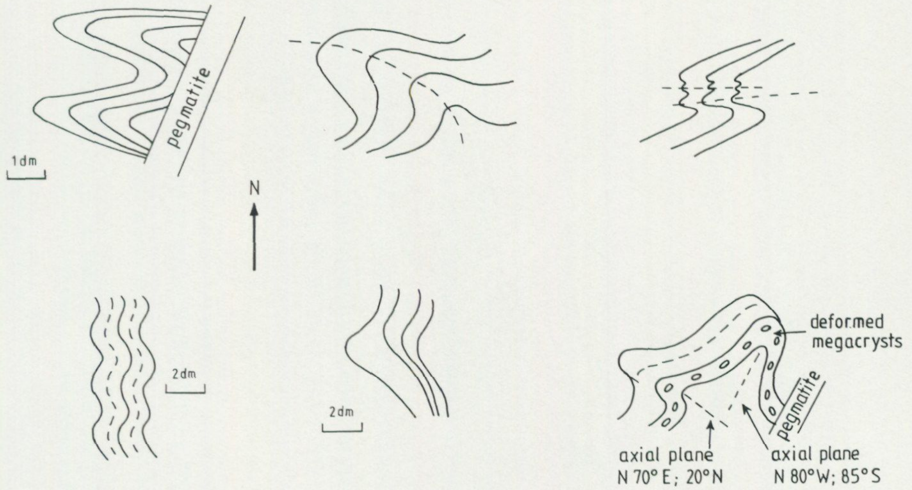


Fig. 17. Fold-structures in outcrops within the Finspång augen gneiss. (Original drawings by K. Röshoff.)

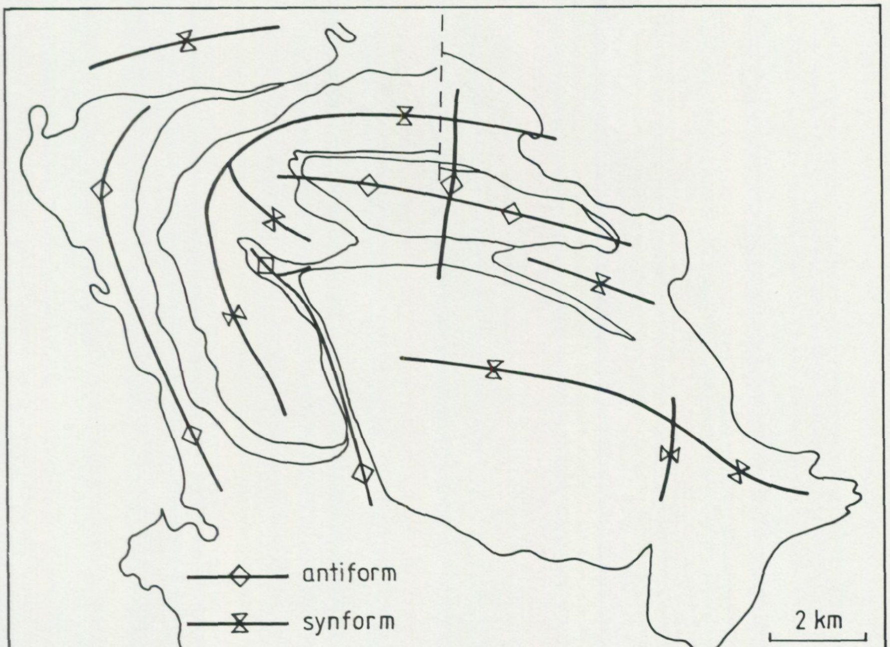


Fig. 18. Predominating anti- and synforms in the area.

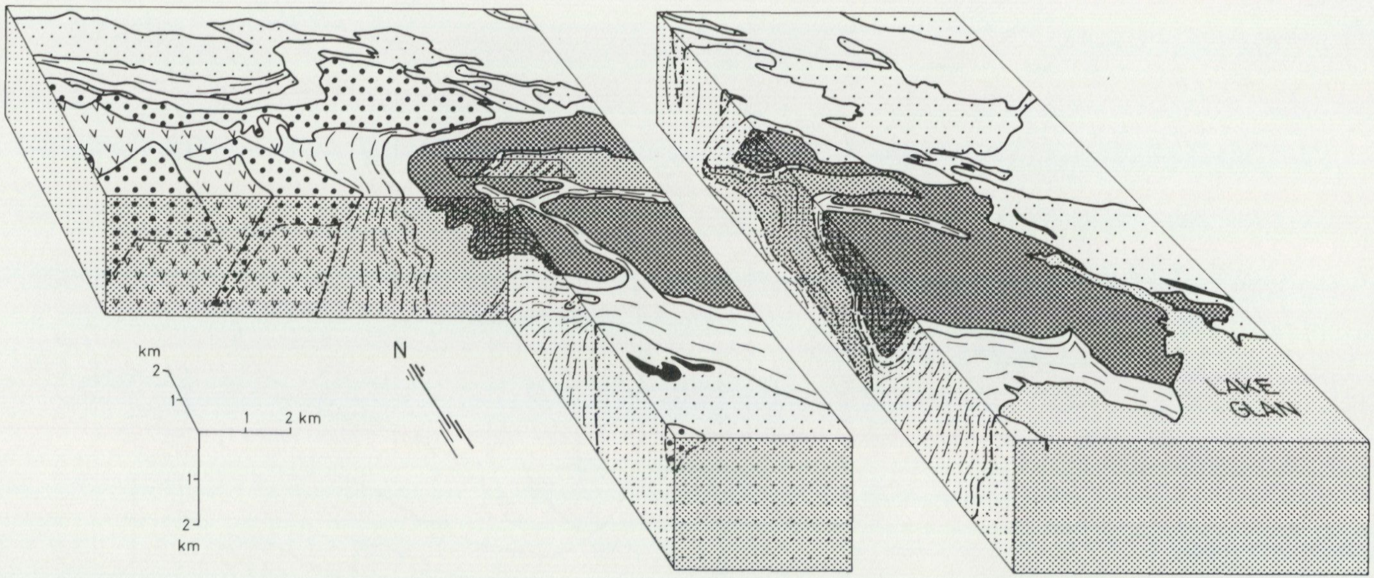


Fig. 19. Three-dimensional structural diagram of the investigated area based on geological and geophysical information. Geological signature according to Fig. 2.

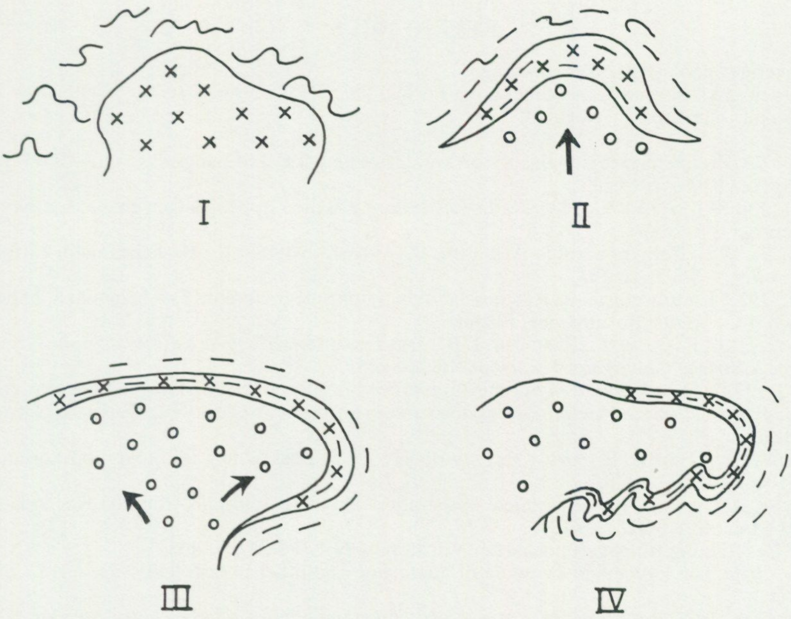


Fig. 20. Hypothetical development of the observed structures. I. A first pulse of the younger granites intrudes into a folded bedrock. II, III. A second intrusion inflates the older rocks. IV. Recumbent folding in the 'skin' below a cap of the younger granites.

on the Katrineholm SV map-sheet (Wikström 1976) shows that the orientations could be interpreted as similar to the structural pattern in the surrounding region. This has led to the conclusion that the Finspång massif belongs to the older plutonics. A consequence of these observations (Fig. 16) and the ideas presented here, is that the structural pattern in the surrounding region is due to the emplacement of these younger intrusions to a much larger extent than so far recognized. No clear border towards the east and north for these structures have been seen, although the fairly monotonous regional orientations i.e. some 25 km to the northeast and further eastwards in the counties of Södermanland and Östergötland (Stålhös 1976, Wikström 1979, 1983) most probably have nothing to do with these structures. The younger granites of the Småland type are missing in the coastal areas of these counties, although Asklund (1923) claimed that a Småland granite is present on some skerries far out in the Baltic.

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GFF = Geologiska Föreningens i Stockholm Förhandlingar
RAK = Rikets allmänna kartverk

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TABLE 1. Chemical analyses of isotropic Finspång granite. Eastern area.

	WAB79001	WAB79003	WAB79005	WAB79010	WAB79012	WAB79014	WAB79015
SIO2	65.40	67.50	64.30	65.30	68.60	71.80	67.00
TIO2	0.64	0.61	0.66	0.52	0.47	0.30	0.50
AL2O3	16.50	15.40	16.50	17.30	15.30	14.80	16.70
FE2O3	0.90	0.90	1.10	0.90	0.60	0.60	0.80
FEO	3.70	3.50	3.70	3.00	2.70	1.80	2.90
MNO	0.04	0.04	0.04	0.03	0.02	0.02	0.03
CAO	2.20	2.00	2.00	3.00	1.80	1.20	2.20
MGO	1.83	1.64	1.87	1.50	1.22	0.83	1.42
NA2O	2.70	2.30	2.60	3.50	2.60	2.60	3.00
K2O	4.20	4.40	4.90	3.60	4.10	4.90	4.20
H2O	1.30	1.10	1.20	0.90	1.00	1.00	1.10
BAO	0.17	0.19	0.20	0.12	0.13	0.13	0.16
TOTAL	99.58	99.58	99.07	99.67	98.54	99.98	100.01
NORMATIVE MINERALS							
Q	23.839	28.360	21.174	20.670	30.762	32.950	24.745
C	3.414	3.104	3.179	2.118	3.274	2.952	3.112
OR	24.924	26.110	29.227	21.344	24.587	28.961	24.816
AB	22.943	19.544	22.207	29.714	22.326	22.005	25.383
AN	11.270	10.310	10.381	15.151	9.301	6.190	11.203
EN	4.577	4.102	4.701	3.748	3.083	2.068	3.536
FS	5.090	4.771	4.916	3.976	3.779	2.352	3.894
MT	1.310	1.310	1.610	1.309	0.883	0.870	1.160
IL	1.221	1.163	1.265	0.991	0.906	0.570	0.950
TOTAL	98.587	98.775	98.661	99.021	98.902	98.918	98.799
SALIC	86.389	87.429	86.169	88.997	90.251	93.058	89.259
FEMIC	12.198	11.346	12.492	10.024	8.651	5.859	9.540
NIGGLI VALUES							
AL*	40.55	40.49	39.96	41.45	43.61	46.11	42.76
FM*	27.25	27.14	27.71	22.15	21.98	16.98	22.46
C*	10.11	9.89	9.13	13.26	9.57	7.07	10.51
ALK*	22.09	22.47	23.20	23.13	24.84	29.85	24.27
SI	272.77	301.19	264.24	265.53	331.78	379.59	291.08
RI	2.01	2.05	2.04	1.59	1.71	1.19	1.63
H	18.08	16.37	16.45	12.21	16.13	17.63	15.94
K	0.51	0.56	0.55	0.40	0.51	0.55	0.48
MG	0.42	0.40	0.41	0.41	0.40	0.39	0.41
SI′	188.36	189.89	192.81	192.54	199.35	219.39	197.09
QZ	84.41	111.30	71.44	72.99	132.43	160.20	93.99
N-COORD	650445	650495	650567	650650	650460	650275	650480
E-COORD	150495	150700	150640	150535	150440	150635	150587

TABLE 1. (cont.) Chemical analyses of isotropic Finspång granite. Western area.

	QAW81031	QAW81035
SIO2	68.80	73.20
TIO2	0.47	0.36
AL2O3	15.50	14.40
FE2O3	0.40	0.30
FEO	3.00	2.60
MNO	0.03	0.02
CAO	1.70	1.20
MGO	1.23	0.88
NA2O	2.30	2.30
K2O	4.50	5.10
H2O	1.10	1.00
P2O5	0.14	0.14
CO2	0.01	0.05
F	0.10	0.09
S	0.01	0.01
BAO	0.15	0.07
TOTAL	99.40	101.68
NORMATIVE MINERALS		
Q	31.475	34.760
C	4.274	3.469
OR	26.753	29.639
AB	19.580	19.140
AN	7.130	4.211
EN	3.082	2.155
FS	4.464	3.883
MT	0.583	0.428
IL	0.898	0.672
AP	0.334	0.326
FR	0.181	0.157
PR	0.019	0.018
CC	0.023	0.112
TOTAL	98.795	98.971
SALIC	89.211	91.219
FEMIC	9.584	7.752
NIGGLI VALUES		
AL*	43.95	44.64
FM*	22.46	19.61
C*	9.05	6.91
ALK*	24.54	28.84
SI	331.04	385.06
RI	1.70	1.42
P	0.29	0.31
H	17.65	17.54
K	0.56	0.59
MG	0.39	0.35
SI′	198.16	215.36
QZ	132.89	169.69
N-COORD	650731	650660
E-COORD	149875	149820

TABLE 2. Chemical analyses of augengneissic Finspång granite.

	WAB79006	WAB79007	WAB79011	QAW81017	QAW81018	QAW81021	QAW81022
SIO2	63.20	67.10	64.90	65.30	67.40	66.80	67.40
TIO2	0.73	0.59	0.70	0.70	0.59	0.62	0.53
AL2O3	16.50	15.30	16.10	17.00	16.60	15.50	16.50
FE2O3	2.50	0.80	0.70	0.40	0.40	0.50	0.40
FEO	2.90	3.40	4.30	4.00	3.20	3.60	3.10
MNO	0.05	0.04	0.04	0.03	0.03	0.03	0.03
CAO	3.00	2.30	2.50	1.80	2.20	1.90	1.90
MGO	2.20	1.72	2.00	1.85	1.39	1.63	1.45
NA2O	2.90	2.40	2.80	2.40	2.90	2.50	2.60
K2O	3.50	4.00	3.80	4.60	3.70	3.50	4.60
H2O	1.20	1.20	1.30	1.50	1.00	1.20	1.30
P2O5				0.06	0.06	0.04	0.06
CO2				0.10	0.04	0.05	0.12
F				0.10	0.10	0.10	0.09
S				0.01	0.01	0.02	0.01
BAO	0.18	0.20	0.18	0.22	0.16	0.13	0.20
TOTAL	98.86	99.05	99.32	100.03	99.74	98.08	100.25
NORMATIVE MINERALS							
Q	22.366	28.320	22.908	25.000	28.014	31.050	26.921
C	2.394	2.734	2.734	5.282	4.220	4.617	4.294
OR	20.921	23.864	22.609	27.175	21.922	21.088	27.114
AB	24.822	20.503	23.855	20.302	24.603	21.569	21.945
AN	15.385	11.886	12.816	7.610	9.893	8.542	7.998
EN	5.542	4.325	5.015	4.606	3.471	4.139	3.602
FS	2.172	4.728	6.279	5.892	4.619	5.290	4.511
MT	3.667	1.171	1.022	0.580	0.581	0.739	0.579
IL	1.402	1.131	1.339	1.329	1.123	1.201	1.004
AP				0.142	0.142	0.097	0.142
FR				0.194	0.195	0.202	0.173
PR				0.019	0.019	0.038	0.019
CC				0.227	0.091	0.116	0.272
TOTAL	98.671	98.661	98.577	98.359	98.893	98.688	98.575
SALIC	85.888	87.306	84.922	85.369	88.651	86.866	88.273
FEMIC	12.783	11.355	13.655	12.990	10.242	11.822	10.302
NIGGLI VALUES							
AL*	37.86	40.11	38.70	42.23	43.58	42.06	43.46
FM*	29.70	26.88	29.12	27.10	22.61	26.90	22.71
C*	12.79	11.31	11.22	8.49	10.78	9.61	9.45
ALK*	19.64	21.70	20.96	22.18	23.04	21.44	24.38
SI	246.11	298.49	264.76	275.27	300.25	307.57	301.27
RI	2.14	1.97	2.15	2.22	1.98	2.15	1.78
P				0.11	0.11	0.08	0.11
H	15.59	17.80	17.69	21.09	14.86	18.43	19.38
K	0.44	0.52	0.47	0.56	0.46	0.48	0.54
MG	0.43	0.42	0.42	0.43	0.41	0.42	0.43
SI´	178.56	186.80	183.85	188.70	192.15	185.75	197.52
QZ	67.54	111.69	80.92	86.56	108.10	121.82	103.74
N-COORD	650540	650680	650690	650575	650790	651105	650930
E-COORD	150790	150660	150530	150875	150675	150455	150100

TABLE 2. (cont.) Chemical analyses of augengneissic Finspång granite.

	QAW81024	QAW81026	QAW81027	QAW81028	QAW81029	QAW81030	QAW81032
SIO2	68.90	69.50	67.10	66.30	70.80	68.20	68.20
TIO2	0.55	0.53	0.62	0.52	0.36	0.43	0.42
AL2O3	15.70	16.00	15.80	16.00	15.20	15.50	15.10
FE2O3	0.40	0.50	0.40	0.30	0.40	0.30	0.30
FEO	3.40	3.00	3.30	3.30	2.40	2.90	2.80
MNO	0.03	0.03	0.03	0.03	0.03	0.02	0.02
CAO	2.00	1.80	1.80	2.20	1.60	1.70	1.50
MGO	1.40	1.30	1.43	1.43	0.90	1.15	1.04
NA2O	2.70	2.90	2.50	2.50	2.80	2.80	2.30
K2O	4.20	4.10	4.50	4.00	4.40	4.80	5.00
H2O	0.70	1.00	1.20	1.20	0.80	0.90	1.10
P2O5	0.09	0.09	0.11	0.06	0.07	0.13	0.12
CO2	0.07	0.03	0.12	0.30	0.03	0.09	0.11
F	0.10	0.06	0.09	0.10	0.06	0.09	0.08
S	0.01	0.02	0.01	0.01	0.01	0.01	0.01
BAO	0.15	0.15	0.18	0.19	0.10	0.14	0.12
TOTAL	100.36	100.98	99.15	98.40	99.93	99.12	98.19
NORMATIVE MINERALS							
Q	28.969	29.312	28.179	28.936	31.695	27.180	30.316
C	3.588	3.806	4.217	4.598	3.239	3.273	3.896
OR	24.730	23.992	26.819	24.022	26.018	28.616	30.092
AB	22.765	24.300	21.335	21.499	23.708	23.903	19.821
AN	8.460	7.965	7.254	8.412	7.083	6.755	5.777
EN	3.474	3.206	3.592	3.619	2.243	2.889	2.638
FS	5.022	4.194	4.781	5.070	3.520	4.423	4.295
MT	0.578	0.718	0.585	0.442	0.580	0.439	0.443
IL	1.041	0.997	1.188	1.004	0.684	0.824	0.812
AP	0.212	0.211	0.263	0.144	0.166	0.311	0.289
FR	0.188	0.106	0.166	0.198	0.111	0.163	0.145
PR	0.019	0.037	0.019	0.019	0.019	0.019	0.019
CC	0.159	0.068	0.275	0.693	0.068	0.206	0.255
TOTAL	99.205	98.911	98.672	98.656	99.134	99.000	98.800
SALIC	88.512	89.375	87.804	87.466	91.743	89.727	89.903
FEMIC	10.693	9.536	10.869	11.189	7.391	9.273	8.896
NIGGLI VALUES							
AL*	42.04	43.47	42.67	42.90	45.00	43.15	44.26
FM*	23.89	22.35	23.91	23.40	18.46	20.70	20.56
C*	10.00	9.16	9.16	11.06	8.81	8.86	8.23
ALK*	24.07	25.02	24.26	22.64	27.73	27.29	26.95
SI	313.09	320.41	307.50	301.67	355.66	322.18	339.21
RI	1.88	1.84	2.14	1.78	1.36	1.53	1.57
P	0.17	0.18	0.21	0.12	0.15	0.26	0.25
H	10.61	15.38	18.34	18.21	13.40	14.18	18.25
K	0.51	0.48	0.54	0.51	0.51	0.53	0.59
MG	0.40	0.40	0.41	0.41	0.37	0.39	0.37
SI′	196.27	200.07	197.04	190.54	210.94	209.14	207.81
QZ	116.82	120.35	110.46	111.13	144.73	113.04	131.40
N-COORD	651185	651350	651350	650805	650560	650715	650870
E-COORD	150295	150135	150135	150225	150070	150001	149760

TABLE 2. (cont.) Chemical analyses of augengneissic Finspång granite.

	QAW81033	QAW81037
SIO2	72.70	66.50
TIO2	0.23	0.59
AL2O3	14.40	16.50
FE2O3	0.40	0.40
FEO	1.80	3.60
MNO	0.02	0.03
CAO	0.90	1.90
MGO	0.50	1.47
NA2O	2.60	2.70
K2O	5.30	4.10
H2O	0.70	1.20
P2O5	0.13	0.11
CO2	0.03	0.17
F	0.04	0.09
S	0.01	0.01
BAO	0.05	0.16
TOTAL	99.79	99.49
NORMATIVE MINERALS		
Q	34.001	27.452
C	3.180	4.957
OR	31.384	24.352
AB	22.046	22.963
AN	3.316	7.373
EN	1.248	3.680
FS	2.617	5.368
MT	0.581	0.583
IL	0.438	1.126
AP	0.309	0.262
FR	0.058	0.166
PR	0.019	0.019
CC	0.068	0.389
TOTAL	99.264	98.690
SALIC	93.927	87.097
FEMIC	5.338	11.592
NIGGLI VALUES		
AL*	47.30	43.06
FM*	14.32	24.48
C*	5.48	9.29
ALK*	32.89	23.17
SI	405.26	294.48
RI	0.96	1.96
P	0.31	0.21
H	13.01	17.72
K	0.57	0.50
MG	0.29	0.40
SI′	231.58	192.68
QZ	173.68	101.79
N-COORD	650725	651055
E-COORD	149735	149830

TABLE 3. Chemical analyses of marginal rocks to the Finspång massif. Central Lövlund massif.

	QAW81020	QAW81023	QAW81025
SIO2	71.90	70.50	73.80
TIO2	0.61	0.54	0.33
AL2O3	12.80	13.30	12.70
FE2O3	1.70	1.30	0.50
FEO	2.50	3.70	1.90
MNO	0.03	0.06	0.04
CAO	1.40	2.00	1.50
MGO	1.25	1.02	0.42
NA2O	2.90	2.90	2.90
K2O	4.10	3.30	4.10
H2O	0.70	0.60	0.60
P2O5	0.14	0.08	0.02
CO2	0.08	0.07	0.07
F	0.07	0.08	0.03
S	0.01	0.01	0.01
BAO	0.15	0.07	0.12
TOTAL	100.31	99.50	99.03
NORMATIVE MINERALS			
Q	34.042	33.719	36.825
C	1.616	1.833	0.980
OR	24.153	19.599	24.466
AB	24.463	24.663	24.780
AN	5.359	8.594	6.947
EN	3.104	2.553	1.056
FS	2.207	4.945	2.610
MT	2.457	1.894	0.732
IL	1.155	1.031	0.633
AP	0.331	0.190	0.048
FR	0.118	0.150	0.059
PR	0.019	0.019	0.019
CC	0.181	0.160	0.161
TOTAL	99.205	99.350	99.315
SALIC	89.634	88.408	93.998
FEMIC	9.571	10.943	5.317
NIGGLI VALUES			
AL*	38.12	38.11	43.54
FM*	26.58	27.44	15.27
C*	7.88	10.55	9.62
ALK*	27.42	23.90	31.57
SI	363.38	342.77	429.33
RI	2.32	1.97	1.44
P	0.30	0.16	0.05
H	11.80	9.73	11.64
K	0.48	0.43	0.48
MG	0.35	0.27	0.24
SI′	209.70	195.61	226.27
QZ	153.68	147.16	203.06
N-COORD	651065	651105	651160
E-COORD	150450	150160	150220

TABLE 3. (cont.) Chemical analyses of marginal rocks to the Finspång massif. Marginal even-grained gneissgranite.

	QAW81034	QAW81038
SIO2	74.50	74.10
TIO2	0.04	0.11
AL2O3	14.10	13.40
FE2O3	0.20	0.10
FEO	1.90	1.50
MNO	0.04	0.04
CAO	0.50	0.80
MGO	0.09	0.29
NA2O	2.50	2.90
K2O	4.20	4.60
H2O	1.10	0.50
P2O5	0.37	0.14
CO2	0.12	0.02
F	0.16	0.03
S	0.01	0.01
BAO	0.01	0.02
TOTAL	99.77	98.55
NORMATIVE MINERALS		
Q	42.503	37.355
C	5.454	2.650
OR	24.875	27.583
AB	21.202	24.901
AN		2.878
EN		0.733
FS	3.254	2.582
MT	0.291	0.147
IL	0.076	0.212
AP	0.878	0.336
FR	0.023	0.037
PR	0.019	0.019
CC		0.046
MG	0.189	
SD	0.057	
TOTAL	98.822	99.478
SALIC	94.035	95.366
FEMIC	4.786	4.112
NIGGLI VALUES		
AL*	52.39	48.44
FM*	12.03	11.02
C*	3.40	5.31
ALK*	32.17	35.24
SI	469.78	454.53
RI	0.19	0.51
P	0.99	0.36
H	23.13	10.23
K	0.53	0.51
MG	0.07	0.24
SI′	228.70	240.97
QZ	241.08	213.56
N-COORD	650625	651205
E-COORD	149720	149570

TABLE 3. (cont.) Chemical analyses of marginal rocks to the Finspång massif. Roxen granite.

	QAW81036	QAW81039	QAW81040
SIO2	65.10	63.70	64.70
TIO2	0.96	1.09	1.01
AL2O3	15.20	14.80	14.50
FE2O3	1.50	1.60	1.30
FEO	3.80	4.60	4.20
MNO	0.09	0.11	0.10
CAO	2.70	3.20	3.00
MGO	1.53	1.75	1.61
NA2O	2.80	2.80	2.70
K2O	5.20	4.40	4.40
H2O	1.10	1.10	0.70
P2O5	0.34	0.40	0.36
CO2	0.08	0.07	0.17
F	0.17	0.18	0.17
S	0.04	0.05	0.05
BAO	0.16	0.15	0.16
TOTAL	100.70	99.92	99.06
NORMATIVE MINERALS			
Q	20.270	20.312	23.034
C	1.315	1.021	1.374
OR	30.515	26.020	26.248
AB	23.528	23.711	23.064
AN	9.866	12.044	10.839
EN	3.784	4.362	4.048
FS	4.209	5.431	5.102
MT	2.160	2.322	1.903
IL	1.811	2.072	1.936
AP	0.800	0.948	0.861
FR	0.285	0.297	0.286
PR	0.074	0.094	0.094
CC	0.181	0.159	0.390
TOTAL	98.798	98.793	99.179
SALIC	85.495	83.109	84.559
FEMIC	13.303	15.684	14.620
NIGGLI VALUES			
AL*	36.40	34.23	35.28
FM*	27.08	30.42	28.80
C*	12.01	13.69	13.53
ALK*	24.51	21.67	22.39
SI	264.56	249.98	267.13
RI	2.93	3.22	3.14
P	0.58	0.66	0.63
H	14.91	14.40	9.64
K	0.55	0.51	0.52
MG	0.34	0.34	0.34
SI′	198.04	186.66	189.57
QZ	66.52	63.32	77.55
N-COORD	650609	651430	651485
E-COORD	149490	149695	149835

TABLE 4. Summary of density determinations made on rock-samples from the investigated area.

Rock type	N	m (kg/m^3)	s (kg/m^3)
Sonstorp granite	8	2640	18
Roxen granite	8	2746	29
Finspång augen gneiss and granite	32	2701	21
Lövlund granite gneiss	7	2712	15
Gneissic granites, marginal to Finspång massif	3	2644	18
Gneissic granites, undifferentiated	17	2674	31
Metasedimentary rocks	17	2728	27
Metavolcanic and mafic rocks, southwestern are	13	2751	126
Metavolcanic and mafic rocks, northeastern area	26	2717	110

N = number of samples
m = mean
s = standard deviation

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