SVERIGES GEOLOGISKA UNDERSÖKNING
BERGGRUNDSGEOLOGISKA OCH GEOFYSISKA KARTBLAD
SKALA 1:50 000
Serie Af · Nr 21—24

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PAJALA NV, NO, SV, SO

DESCRIPTION OF THE GEOLOGICAL MAPS PAJALA NV, NO, SV, SO

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GEOPHYSICAL INVESTIGATIONS BY HERBERT HENKEL

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Geologisk översikt

Pajalafältet har varit föremål för undersökningar från SGU:s sida vid flera tillfällen. De föreliggande tryckta berggrundskartbladen (Pajala NV, NO, SV, SO) med beskrivning är en sammanställning av dessa undersökningar och av arbeten utförda åren 1962—1970. Under den senare arbetsfasen har man haft tillgång till flygbilder med höjdkurvor i skala 1:20 000, nya topografiska blad i skala 1:50 000, flygmagnetiska mätkartor i skala 1:50 000 samt tyngdkraftskartor. Detta material har gjort det möjligt att ge en bättre sammanställning av geologin än tidigare. Över vissa delar av fältet har utförts magnetiska och gravimetriska markmätningar, som har kommit den geologiska kartbilden till godo.

Tyngdpunkten i arbetet har lagts på en närmare studie av de så kallade suprakrustala bergarterna, som huvudsakligen består av skiktade metasediment, och intrusiva gabbroida kroppar. Granit och besläktade bergarter som utgör resten av bladet har ägnats mindre uppmärksamhet. Trots detta och viss tidsbrist när det gäller utförandet av petrologiska studier är områdets uppbyggnad och geologiska utveckling i stora drag nu relativt klar. Därmed har möjligheterna för att kunna värdera malmer och råvaror starkt förbättrats. I detta sammanhang är det viktigt att poängtera att mindre än 1 % av områdets areal är blottad. Följaktligen kvarstår många frågetecken när det gäller berggrunden och dess geologiska uppbyggnad.

Parallellt med den rutinmässiga geologiska fältkarteringen har mer intensiva studier bedrivits över järnmalmsstråken och andra magnetiska drag. Resultaten från dessa undersökningar redovisas i olika SGU-publikationer och rapporter (se litteraturlista) och behandlas icke närmare här.

Stratigrafi

Inom de suprakrustala områdena har mycket arbete nedlagts på detaljundersökningar av lagerföljden och fastställande av lagrens upp- eller nedförhållanden. Följande lagerserie har etablerats. I stort sett överensstämmer den med de stratigrafiska förhållandena på närliggande kartblad.

Yngst	Kuusivaara- (Mäntyvaara-) kvartsit
	Konglomerat vid Palovaara
	Porfyrer tillhörande Porfyrgruppen
	Pahakurkkiogruppen (se Padget 1970)
	Käymäjärvigruppen
Äldst	Suorsagrönstenar och Kolarigrönstenar

De äldsta suprakrustala bergarterna *(Suorsa- och Kolarigrönstenarna)* samt *Käymäjärvigruppen* är av vulkanisk karaktär och består av tuffer med basisk sammansättning. De uppvisar skiktning på många ställen och karakteristisk för den övre delen av Käymäjärvigruppen är magnetiska drag och stratabundna järnmalmer (Kaunisvaara- och Käymäjärvistråken).

Pahakurkkiogruppens metasediment representerar en total förändring i sedimentationsmiljö med kvartsiter och glimmerförande skiffrar som huvudkomponenter (fig. 3). Dessa är särskilt väl blottade vid sjön Käymäjärvi.

Porfyrgruppen har liten utbredning på Pajalabladet jämfört med Vittangi- och Kirunabladen men har trots detta ett stort intresse ur geologisk synpunkt. Bergarterna kan mycket väl vara av tuffitiskt ursprung och representera sur vulkanism av explosiv kontinental typ. En liten apatitförande järnmalm av obetydliga dimensioner, som förekommer vid älvstranden nära Peräjävaara, understryker bergarternas släktskap med Kirunafältets vulkaniter.

Palovaarakonglomeratet. På berget Palovaara finns osorterade polymikta konglomerat (fig. 4) jämförbara med Haukkalakikonglomeratet på Tärendöbladet (Padget 1970, s. 29—31). Det tolkas som en relativt lokal avsättning utan större utbredning och med begränsat korrelationsvärde.

Kuusivaaragruppen består övervägande av kvartsiter med skiffriga inslag. I denna beskrivning tolkas de som yngst i lagerföljden jämförbara med bergarter av Vakkotyp på andra ställen i Norrbotten även om de i viss grad liknar Pahakurkkiogruppens bergarter. En annan möjlighet är att gruppen motsvarar Tjärokvartsiten på Vittangibladet (Eriksson och Hallgren 1975) men detta kräver i så fall en radikal omtolkning av tektoniken.

Djupbergarter av basisk till intermediär sammansättning utgör en relativt liten men signifikant del av bladets geologi. De stora kropparna framträder väl på de flygmagnetiska bladen, trots att bergarterna i fast klyft vanligtvis konstateras vara starkt påverkade av yngre kaligranit. Som exempel kan nämnas Saalovuomagabbron. I Sattajärvigabbron finns däremot en antydning till inre struktur (fig. 6), som framträder tack vare en parallellorientering av ljusa fragment (xenoliter). Ett fåtal kända diabasgångar har troligtvis bildats i samband med eller kort efter gabbrons intrusion. Frekvensen är betydligt större i Kaunisvaaraområdet (borrhålsdata, geofysiska tolkningar). Andesitporfyren vid Palovaara tillhör en distinkt intrusiv fas klart yngre än omgivande grönstenar. Den är jämförbar med basaltandesitporfyren på Vittangibladet (Eriksson och Hallgren 1975).

Områdets regionala tektonik framgår tydligt av kartorna. En förbättrad kännedom om den stratigrafiska följden har gjort det möjligt att tolka veckningstektoniken på ett säkrare sätt och i överensstämmelse med flyg- och markmagnetiska data samt med tyngdkraftsmätningarna. Detta gäller särskilt Käymäjärviområdet, som framgår av bifogade profiler. De kraftigt överstjälpta vecken med axelriktning mot nordväst är äldst och kan betecknas som en F_1-fas. Förkastningar framkommer i riklig mängd. Många av de brottlinjer som finns markerade på bladen har bestämts med hjälp av magnetiska data. Den typ av bergartsbrecciering, som man vanligtvis förknippar med förkastningstektonik, har observerats vid enbart några få tillfällen (fig. 7). En säkrare och mer rättvis bild av förkastningsmönstret kan möjligtvis åstadkommas med en mer inträngande tolkning av geofysiska data (se appendix).

Bergarternas petrologi och metamorfa karaktär är ännu delvis ofullständigt undersökta. De generella intrycken är att bergarterna har utsatts för relativt hög temperatur och tryck, kanske i förbindelse med veckning i flera faser och sist i samband med granitbergarternas uppkomst. Kvarts-sillimanitbollar på berget Nivanlehto nordost om Pajala (6f) (fig. 10) är av intresse även om flera liknande bildningar numera är kända från andra områden.

Granit och besläktade bergarter utgör över hälften av bladets areal. Den dominerande typen är kalirik och uppträder oftast diskordant mot andra bergarter och är sålunda av yngre ålder. Östra delen av fältet, mot finska gränsen, domineras av migmatitiska bergarter med basiska inslag. Pegmatiter förekommer ganska allmänt såväl tillsammans med graniter som med migmatiter. Det finns få bevis för att Haparandasviten är representerad inom området, men kvartsdioriten i nordväst torde höra hemma här. Tyvärr är den inte blottad på Pajalabladet.

Bladets geologiska uveckling är följande: Avsättning sker av de suprakrustala bergarterna med början i en fas av basisk vulkanism. Därefter uppkommer intrusioner av gabbro och basiska gångar. Något senare inträffar veckning i två eller flera faser. Porfyrgruppens uppkomst i förhållande till gabbrointrusionerna och till veckningen är inte helt klar. Kaligraniterna är klart yngre än samtliga suprakrustala bergarter och veckningsstrukturer. En del förkastningar och förskjutningar i förbindelse med blockrörelser har troligtvis berört området vid senare tillfällen. Efter detta har skett ett långt erosionsintervall fram till kvartärtid då isen lämnade efter sig ett utbrett, delvis tjockt täcke av morän och sediment.

Fyndigheter av eventuellt ekonomiskt intresse begränsar sig till de tidigare kända järnmalmsstråken vid Kaunisvaara, Käymäjärvi och Erkheikki. Dessa har närmare undersökts genom geofysiska markmätningar och på enskilda lokaler med diamantborrning. Vissa rapporter om dessa undersökningar är publicerade i SGU:s serie C (se litteraturförteckning). Käymäjärvigruppen innehåller de viktigaste järnmalmskoncentrationerna vid Stora Sahavaara, Ruutijärvi, Tapuli och Palotieva (Lundberg 1967, Lindroos 1974) och i Pellivuoma. Närmare redovisning av dessa finns i olika SGU-rapporter (Lindroos 1971, 1972; Lindroos m. fl. 1972 a, 1972 b). Andra metaller än järn är ytterst sällsynta. Grönstenarna visar ibland mycket svaga kopparkis-svavelkis-impregnationer, dock utan att någon signifikant mineralisering har framkommit.

Introduction

The village of Pajala is located on the Torneälv in northernmost Sweden, close to the Finnish border (Fig. 1). The area covered by the map-sheet is one of low relief, drained by a few larger rivers but otherwise heavily forested (Fig. 2). Outcrops are rather rare, probably less than 1 % of the total area of the map-sheet, due to the extensive vegetational and moraine cover. Despite this, the geology has long been the subject of interest due to the presence of iron-ore deposits at several places and the occurrence of layered metasedimentary and volcanic rocks in a terrain otherwise dominated by granite and granitic gneiss. (Fredholm 1886, Geijer 1925, Tanner 1918.) During 1945—1949 T. Eriksson carried out detailed mapping and documentation of all available data for the whole Pajala field summarizing his

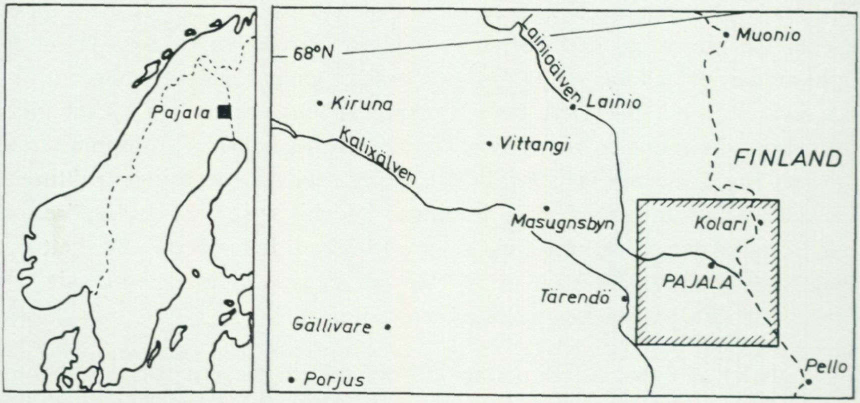

Fig. 1. Location of the map-sheet Pajala.
Pajalabladets läge.

conclusions in an important publication from 1954, the main results of which are incorporated in Ödman's (1957) geological map of Norrbotten.

In 1962 aeromagnetic maps and topographic maps became available for the whole of the Pajala sheet and indicated the necessity for a re-evaluation of certain features of the geology. Field-work was carried out sporadically in the years 1962—1970. The present maps and description also include information from diamond drilling carried out by the Geological Survey of Sweden (SGU) in connection with a more widespread investigation of the iron-ores of Norrbotten. More detailed reports on specific iron-ores are to be found in the archives of the Survey or in preparation and will not be further discussed here.

The Pajala sheet and the adjacent Tärendö sheet (Padget 1970) together cover most of the large supracrustal fragment, referred to as the Pajala field (Pajalafältet) in Swedish geological literature.

The author wishes to thank a number of assistants who have helped in the field-work and in particular Mr. Axel Theolin whose knowledge of the area from earlier investigations was of the greatest value.

Author's note. The field-work involved in mapping the Pajala sheet was complete in 1970 but study of the material only just begun when the author left Sweden in 1971. No systematic study of the rock samples was therefore possible and the present description is inadequate in many respects, not least as regards the petrology. Nevertheless it gives a general picture of the

Fig. 2. Torneälv at Pajala (1963).
Vy över Torneälv vid Pajala (1963).

geology as understood at the end of the 60's and correlations can be made with adjacent map-sheets. In the absence of the author from SGU the responsibility of seeing the maps and manuscript into print was entrusted to Dr. Bo Eriksson to whom a special word of thanks is due.

Stratigraphy

Rocks of so-called supracrustal character form less than 50 per cent of the Pajala sheet. Their distribution and relation to the surrounding granitic rocks is now much better known thanks to comprehensive aeromagnetic surveys carried out by the Geological Survey of Sweden in the early 60's. The stratigraphic succession for the map-sheet as a whole has been pieced together from what is known for each supracrustal relict, and from the relatively few, often scattered exposures. The greatest attention has been paid to evidence of 'way-up' in the rocks and to other established litho-stratigraphic sequences outside the map-sheet in order to establish the correct order of succession. The stratigraphic succession as presented here resembles most closely that of the adjacent Tärendö sheet (Padget 1970) and to some extent is complementary to it. Together they cover the Pajala field, a recognized unit of the Precambrian geology of north Sweden.

The succession arrived at for the Pajala sheet is shown in the legend to the maps and will be further described according to the following subdivision:

Youngest	Kuusivaara group
	Conglomerate at Palovaara
	Porphyry group
	Pahakurkkio group
	Käymäjärvi group
Oldest	Suorsa greenstone group and Kolari greenstone

Suorsa greenstone group (1a)

The oldest rocks on the map-sheet are believed to be greenstones of varying character exposed in the vicinity of Suorsa (Pajala SV) and in particular on the hill Suorsapakka (cf. Geijer 1931, p. 70). They include both metamorphosed and less metamorphosed types and show distinct evidence of layering, a feature which is clearly evident on the aeromagnetic maps. Most of the rocks seem to be tuffs of basaltic composition with water-lain members showing evidence of graded- and cross-bedding. Other types are more difficult to classify due to metamorphic and tectonic effects. One exception is a characteristic andesitic porphyry which seems to occur high in the group. This is evident in a profile drawn across Suorsapakka (profile IV, on the map-sheet Pajala SV) where it occurs on both flanks of an anticlinal structure.

At the same time it seems to be in part discordant to other rocks in the group and could possibly be of a somewhat later date than these. No satisfactory base to the group has been found. The rocks as a whole resemble the middle and lower portions of the Veikkavaara greenstone group on the Tärendö sheet (Padget 1970, pp. 12—15).

Rather similar rocks to those at Suorsa occur in a north-easterly direction extending from the Torneälv to Suksivaara and north-eastwards on to the Huuki sheet. This is evident from the few outcrops and from aeromagnetic maps, but emerged with greater clarity when gravimetric data became available.

The most interesting outcrops are those on the hill Suksivaara where a series of well banded tuffitic greenstones are exposed (see photograph,

Fig. 11, in Eriksson 1954, p. 20). Other outcrops of interest occur on and close to the hill Jupukka. Here, ferruginous quartzites and dolomitic limestones occur in a few sparse outcrops. Apparently equivalent rocks occur in the Erkheikki iron-ore field, 4 km to the SSW, on the south side of the Torneälv. (See analyses A 2, A 3, A 8, A 9 and A 12 in Table 1.)

Further greenstones probably occur further east, close to the Finnish border. Though only 3 outcrops are known, the magnetic maps seem to indicate the existence of a westerly dipping sequence of greenstones. At Airivaara, close to the Muonio älv, good outcrops of banded basaltic tuffites, partly in amphibolite facies, occur and are probably typical for the area southwards towards Kolari. It is proposed to refer to them as the Kolari greenstones (Kg on map) until more certain information is available about their stratigraphic position from investigations in Finland and the Huuki sheet to the north. South and SSW of Airivaara they probably become progressively metamorphosed to higher grades and even migmatized.

Käymäjärvi group (1b—1d)

This includes a relatively varied series of rocks, largely of greenstone character (tuffs, agglomerates) but also graphitic and non-graphitic phyllites, limestones and iron-rich metasediments, totalling about 1 000 m. The name is derived from the village of Käymäjärvi (Pajala NV) where the relationships are relatively well known from geological mapping and detailed geophysical surveying. Geijer (1931, pp. 72—75) first recognized that the greenstones occur in an antiform structure and are overlain by graphitic phyllites, limestones and iron-rich metasediments. This is confirmed by the present investigations. Eriksson (1954, p. 16, fig. 8), in his description of the Käymäjärvi area, noted the agglomeratic character of the greenstones and occurrence of tuffitic sediments of basic composition. He also included many pertinent remarks on the iron-rich quartzites and limestones (op.cit. Figs. 9—10). The stratigraphic succession of the Käymäjärvi group at Käymäjärvi is as follows:

5. Tuffs, andesitic—basaltic composition	650 m
4. Limestone	1—20 m
3. Iron-rich metasediments	5—10 m
2. Graphitic phyllites	10—15 m
1. Agglomerates, tuffs of basic composition	400 m+

Petrological studies of these rocks are still very sparse.

These deposits are magnetic iron-ores of strata-bound type, first studied by Geijer (1925, pp. 5—10). Special publications are in preparation concerning drilling carried out by SGU on the Marjarova and Pellivuoma deposits and will include further data about the stratigraphy of the hanging and foot-wall rocks, (Table 1, analysis A 7). Meanwhile it is worth noting that the rock types in the Pellivuoma deposit strongly resemble those of the Erkheikki deposit (F. Ros, pers. comm.) though it is difficult to see how these can belong to the same stratigraphic horizon without invoking a complicated tectonic relationship.

Elsewhere within the Pajala sheet rocks of this type are found at Kaunisvaara and have a similar stratigraphic position relative to the greenstones. Here a long narrow zone of magnetic iron-ore is associated with limestones and dolomites and overlies greenstones and phyllitic rocks. These have been described in some detail by Lundberg (1967, pp. 5—13). A typical succession revealed by drilling is as follows:

	Quartzites	
Youngest	Graphiteschist	200 m
	Dolomite	30—40 m
	Phyllite	220 m
Oldest	Volcanic greenstone (agglomerate)	40 m +

The quartzite rocks are an important part of the hanging wall but belong to an even younger sedimentary formation and are not therefore included here with the Käymäjärvi group.

The agglomeratic rocks (Table 1, analysis A 13) have equivalents in the Käymäjärvi field. They are obviously of considerable thickness, probably 500 m or more and together with the iron-ore, are mainly responsible for a distinct gravimetric high continuing north-eastwards on to the Huuki sheet. They apparently rest on a non-magnetic rock, possibly phyllite, which in turn rests on members of the Suorsa greenstone group (1a).

The sequences described above from both Käymäjärvi and Kaunisvaara resemble in many details those from the Masugnsbyn region (Tärendö and Lainio sheets) described by Padget (1970, pp. 14—19) and Witschard (1970, pp. 18—19).

Pahakurkkio group (2a—2d)

The group consists largely of quartzites, pelitic and semi-pelitic metasediments, commonly schistose, and a few conglomerates. The most satisfactory outcrops on the Pajala sheet are in the Käymäjärvi area where not only can the order of succession be established within the group owing to the presence of way-up structures such as cross-bedding and the like but also the relationship to underlying rocks (Profile II). The best exposures occur about 4 km south-east of Käymäjärvi village and from these the following succession can be established:

Youngest	4.	Quartz-mica-schist	400 m+
	3.	Monomict conglomerate with quartzite pebbles	5 m
	2.	Quartzites with distinct cross-bedding	600 m
Oldest	1.	Basal conglomerate	1 m

The basal conglomerate rests conformably on greenstones of the Käymäjärvi group. The pebbles, a few centimetres in size only, are largely of quartz or quartzite. Above the conglomerate a thick sequence of quartzites is continuously exposed. These show a moderate degree of grading. Cross-bedding often emphasized by numerous dark bands (Fig. 3), is evident throughout. The highly monomict conglomerate, previously figured by Eriksson (1954, Fig. 7), consists of quartzite pebbles almost devoid of matrix. It is probably of local extent but bears a striking resemblance to a conglomerate occurring on Paloleuska on the Lainio sheet and referred to the Pahakurkkio group by Witschard (1970, pp. 24—26).

Above the conglomerate pelitic and semi-pelitic rocks become more important but have not been separately mapped.

The sequence described above and shown in Profile II, can be seen on strike to the north-west, on the hill Sammelvaara. Here penecontemporaneous erosion of certain layers has taken place and subsequent infilling by coarser material is evident. Similar conglomerates and quartzites are known from Lompolovaara and Kursuvaara west and east of Käymäjärvi respectively. For further details, see Eriksson 1954, pp. 11—15.

In the Kaunisvaara area, quartzite rocks seem to overlie the Käymäjärvi group conformably too, at least in the section Sahavaara—Kaunisvaara (drill-hole data) where they represent a direct continuation of quartzite outcrops seen to advantage near the Muonio älv, north of Areavaara (Huuki sheet). More detailed accounts of the stratigraphy here are given by

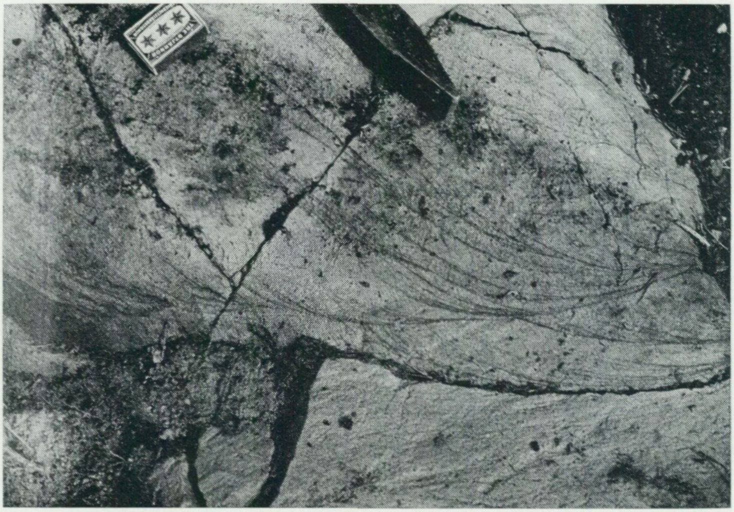

Fig. 3. Cross-bedding in quartzites of the Pahakurkkio group, Sammalvaara *(Pajala NV)*.
Diagonalskiktning i kvartsit (Pahakurkkiogruppen) (Pajala NV).

Lundberg (1967) and Lindroos (1974). In the opposite direction, that is SSW of Kaunisvaara, the Pahakurkkio rocks seem to rest on greenstones referred to the Suorsa greenstone group and hence are older than the sequence at Kaunisvaara. In other words, the Pahakurkkio group bears discordant relationship to older rocks on a regional scale and its stratigraphically younger age is therefore confirmed supporting the way-up evidence in individual outcrops. A major discordance on a regional scale is possibly present west of Liviöjärvi (see Profiles III and IV).

The metasediments seen to make up the Pahakurkkio group at Käymäjärvi and Kaunisvaara occur elsewhere on the Pajala sheet but with significant differences. Firstly, the clastic facies (quartzite) is proportionally reduced with respect to the pelitic one (mica-schist), and is not necessarily basal to the group. A good example of this is the quartzite at Liviöjärvi, 10 km WSW of Pajala (Eriksson 1954, p. 23). Furthermore, evidence has increased during the course of the investigation that Pahakurkkio-type rocks other than those at Käymäjärvi and Kaunisvaara lie unconformably on older rocks. This is evident on a regional scale. When interpreting the aeromagnetic data south-west of Pajala (Pajala SV) a broad, trough-like zone of rocks of low specific weight and weak magnetic susceptibility seems to rest unconformably on rocks with greater magnetic susceptibility interpreted as the Suorsa greenstone group. This is evident despite extensive gneissification and is hereafter referred to as the Liviöjärvi trough (Liviöjärvitråget). This trough has a width of 5—6 km and continues to the north-east (Pajala NO) where it is called the Muotkavaara trough. West of Liviöjärvi the Pahakurkkio-type rocks seem to rest unconformably on the greenstones (Profiles II and III).

These conclusions are not contradicted by the geological information, sparse as it is.

A possible easterly extension of the Pahakurkkio group may be represented by quartzites and mica-schists WNW and WSW of Kengis bruk (Pajala NO), and by mica-schists at Mukkavaara and immediately to the north near the Torneälv (Tärendö NV).

Porphyry group (3a—3d)

Some highly characteristic rocks (3b) occur at Peräjävaara, close to the Torneälv. They were described by Eriksson (1954, pp. 3—31) as quartz and microcline porphyries. Those seen by the present author are reddish in colour and essentially feldspar porphyries with microcline microperthite individuals up to 7 mm in size in a fine-grained matrix of quartz, feldspar and accessory biotite. They are interpreted as rhyolites or acidic tuffs and though unlike any other rocks of the map-sheet closely resemble certain rhyolitic rocks of the Vittangi and Kiruna areas (cf. Offerberg 1967, p. 81) assigned to the Kiruna porphyry group. Of further interest is a small quantity of apatitic iron-ore (2.16 % P_2O_5) which superficially resembles certain well-known iron-ores of the Kiruna porphyry province and further supports correlation with the Kiruna porphyry group (Eriksson 1954, p. 31). The present investigations show the porphyry to occupy a NE trending zone and to be interlayered with magnetite-bearing formations interpreted as greenstones (Profile III). Its relationship to the Pahakurkkio group can only be surmized but appears to be essentially concordant.

The porphyritic rocks at Peräjävaara are, therefore, considered to be high in the stratigraphic sequence and not in its lowermost part as believed by Eriksson (1954, p. 30) and Ödman (1957).

At a locality 3.5 km south-east of Peräjävaara (5c) several small but interesting exposures occur on and close to a cut-line in the forest. Here quartzitic rock of Pahakurkkio-type is intruded by 2 types of acid porphyry, one with large feldspar individuals (3b) closely similar to the porphyry at Peräjävaara described above and the other a quartz-porphyry of medium grain-size. The contact-relationships cannot be followed very far owing to lack of exposures but the quartzite is evidently much recrystallized and contains thin zones of skarn material. Fragments of quartzite have been observed within the porphyry. Intrusion of the porphyry at fairly high temperature seems to have taken place and was possibly synchronous with the formation of the porphyries at Peräjävaara.

The Palovaara conglomerate (3d)

This conglomerate was studied in some detail by Eriksson (1954, pp. 28—30, Fig. 15) at a locality west of Kursunpalo (Fig. 4). He noted the presence of porphyry pebbles and certain deep-seated rocks and drew the conclusion that the conglomerate marked a great hiatus or unconformity between two major geological rock sequences.

Further conglomeratic rocks about 8 km to the south-west, on the hill Palovaara, seem to belong to the same formation and form a suitable type locality. They contain a large number of pebbles of locally derived, ill-sorted material including fragments of an andesite-porphyry. This porphyry (3c) is well exposed in the Liviöjoki. It is massive and has an andesitic composition (Table 1, analysis A 15). Erosion of this porphyry clearly provided much material for the overlying Palovaara conglomerate which as regards its pebbly material and general field relations resembles closely the Haukkalaki conglomerate on the Tärendö sheet (Padget 1970, pp. 29—31).

In both cases the age of the conglomerates relative to the other sedimentary units is difficult to ascertain due to lack of exposures. Some indication may be obtained by comparison with intrusions of andesine porphyry on the Vittangi sheet (Eriksson and Hallgren 1975). These are shown to be younger than all sedimentary formations including the Maattavaara quartzite group in the legend, though this seems to be based on very slender evidence. If the andesitic porphyries of the Vittangi and Pajala sheets are time equivalents then the Palovaara conglomerate represents a relatively young phase of erosion and local deposition. A similar conclusion was reached for the analogous Haukkalaki conglomerate on the Tärendö sheet by Padget

Fig. 4. The Palovaara conglomerate, west of Kursunpalo (Pajala NV).
Palovaarakonglomeratet, väster om Kursunpalo (Pajala NV).

(1970). Obviously some isotopic age determinations would clarify the situation. In any event the Palovaara conglomerate has a rather different significance for the geological evolution than proposed by Eriksson (1954, pp. 29—30).

Kuusivaara (Mäntyvaara) quartzite (4)

This is located on elevated ground named Kuusivaara on newer topographic maps, (Tärendö SV), Mäntyvaara on older ones. The rocks are distinctly quartz-rich sediments, much metamorphosed and recrystallized. A few ”way-up” sedimentary structures in the form of cross-bedding have been found after careful search indicating a synclinal structure for the formation as a whole which in turn seems to be unconformable on the Suorsa greenstone group (1a). It is here equated with the well-known Vakko quartzite of

Norrbotten, e.g. the Övre Hauki complex of the Kiruna area (Offerberg 1967, pp. 94—95), and with the quartzite at Rissavaara on the Tärendö sheet (Padget 1970, p. 29). Other correlations are, however, possible. With the Pahakurkkio group, for example, on lithologic grounds and with stratigraphically older formations such as the Tjärro quartzite on the Vittangi sheet (Eriksson and Hallgren 1975).

General stratigraphic correlations

Correlations with the major lithostratigraphic units of the Tärendö and Vittangi sheets are given in Fig. 5. The main feature of possible dispute is the correlation of rhyolitic porphyries of the Porphyry group (Pajala sheet) with pelitic schists and greenstones of the Kalixälv group (Tärendö sheet). Both lie conformably on members of the Pahakurkkio group but otherwise differ significantly from each other.

On neither sheet has it been possible to identify basement rocks equivalent to the older granite north of Kiruna (Offerberg 1967).

28 L Tärendö	28 M Pajala	29 K Vittangi
Rissavaara quartzite	Kuusivaara quartzite	Maattavaara quartzite group
Haukkalaki conglomerate	Palovaara conglomerate	
Andesite-porphyry	Andesite-porphyry	
Kalixälv group	Porphyry group	Porphyry group
Pahakurkkio group	Pahakurkkio group	Kilavaara quartzite group
Veikkavaara greenstone group	Käymäjärvi group Suorsa greenstone group and Kolari greenstones	Vittangi greenstone group

Fig. 5. Correlation of the main lithostratigraphic units on the map-sheets Tärendö, Pajala and Vittangi.

Korrelation mellan Tärendö-, Pajala- och Vittangibladens större litostratigrafiska enheter.

Basic—intermediate intrusive rocks

The rocks here described form a small but significant element of the geology of the Pajala sheet and include gabbro, gabbro-diabase in small bodies, and a few diabase dykes. Most are poorly exposed but geophysical airborne surveys have greatly improved our knowledge of their form and distribution.

Sattajärvi gabbro

Aeromagnetic surveying in the early 60's revealed the presence of three distinct magnetic anomalies in the area 8 km SSW of Sattajärvi village (Pajala SV, Pajala SO). Geological reconnaissance in 1963 brought to light many hitherto unknown outcrops of gabbro on the hill Kuusi-Kiilesvaara thereby explaining one of the three anomalies. No outcrops could be found over the other two, though local blocks of gabbro, occur over the northerly one (i. e. west of Kiilesrova). The area was mapped geologically by Stacey (1965) and the limits of the main gabbro body defined with a fair degree of certainty. The rock is equigranular, medium-grained and mesocratic with a modal composition as follows: plagioclase (An_{36-48}) 49.2 %, quartz 2.0 %, biotite 7.0 %, hornblende 15.5 %, pyroxene 14.7 %, apatite 1.5 % and accessories 8.6 %. Most of the pyroxene is altered to hornblende and the feldspar saussuritized. Careful search was made in outcrops for compositional banding and cumulate features without success. Only slight differences in colour and degree of weathering could be detected. However, xenoliths, 1—20 cm in size, are by no means infrequent. These are somewhat lighter in colour than the gabbro proper, often have angular shapes and are fairly fine-grained. In composition they resemble gabbro but have a slightly higher proportion of feldspar to dark minerals. They are considered to represent an earlier chilled margin of gabbro broken up by later intrusions and the fragments distributed by magmatic currents.

Of special interest is the fact that the xenoliths are often crudely aligned in layers for which approximate dips and strikes can be obtained. When the values are plotted on a map a synform type of structure is evident (Fig. 6), the layers being discordant to the walls of the gabbro body as a whole. Interpretation of the gravimetric data, indicates the gabbro to be of limited volume and to have a dip of 40° to 50° to the east and south. A thickness up to 450 m has been calculated with a narrow dyke-like exten-

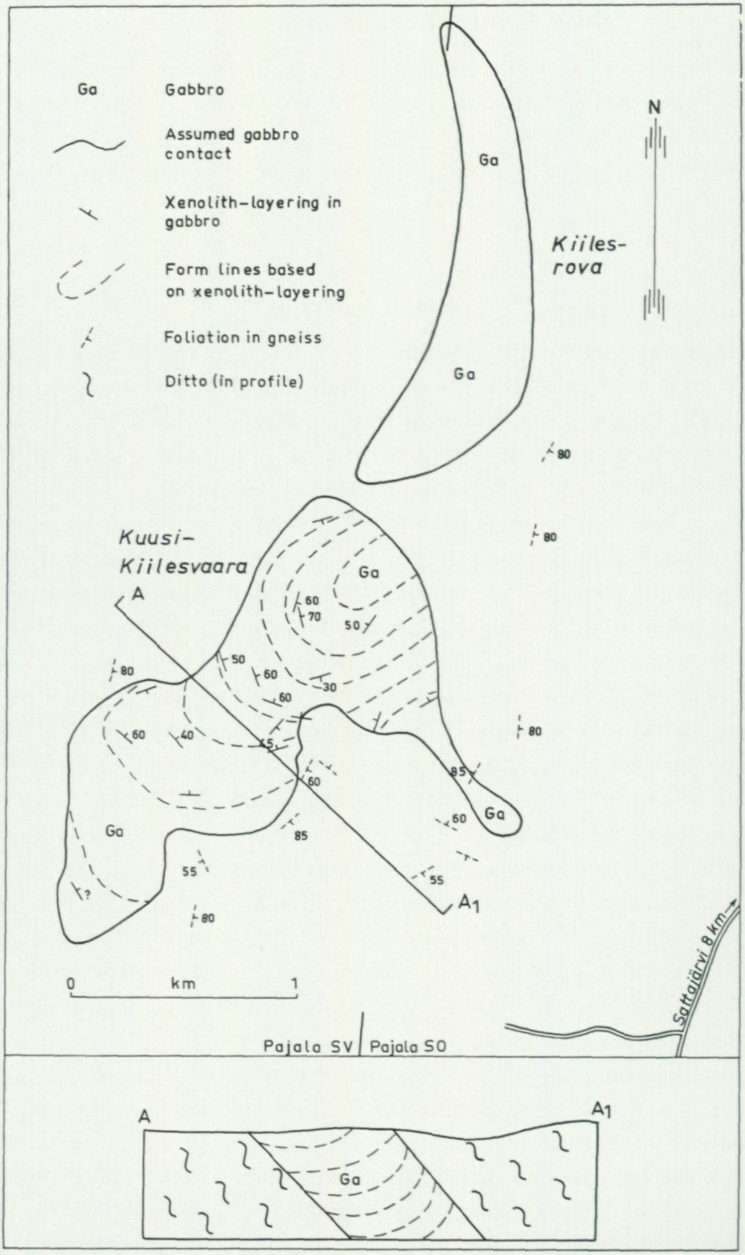

Fig. 6. The Sattajärvi gabbro showing internal structure on Kuusi-Kiilesvaara (Pajala SV-SO). Godkänd ur sekretessynpunkt för spridning. Statens lantmäteriverk 1977-04-14.

Sattajärvigabbron på området Kuusi-Kiilesvaara. Gabbrons inre struktur är markerad med brutna linjer (Pajala SV-SO).

sion to the north. Geological studies indicate it to be an intrusive prior to the main phase of regional thermal metamorphism and gneissification which affected the area.

Pajala gabbro

A small magnetic anomaly occurs close to Pajala. Drilling carried out by SGU in 1967 showed it to be due to zones of magnetite in a gabbro-like rock. The latter is fairly massive and consists of plagioclase (50—60 %), hornblende and biotite.

Other gabbroic rocks

The Saalovuoma body is exposed along the Torneälv east of Peräjävaara and is much veined by granite. Gravimetric data indicate the main mass occurs in this position though magnetic anomalies extend over a much wider area and may represent extensions of the gabbro. This can be confirmed in the case of the Käryjoki body since outcrops occur close to the road to Käymäjärvi. Further bodies of this type, probably small in volume, may be present northwards as far as Kaunisjoki. All are surrounded by granite at the present level of erosion but may once have been parts of a larger, continuous body.

An exception to this is found north-west of Peräjävaara where discordant relations to supracrustal rocks have been deduced. Of further interest is the fact that the present, disconnected bodies lie in a structural trough of regional dimensions which crosses the map-sheet Pajala NV in a north-easterly direction. This trough continues on to the Tärendö sheet where it is occupied by the Tärendö gabbro (Padget 1970, pp. 32—34). This gabbro and its gneissified equivalents are present in the extreme south-western part of the map-sheet Pajala NV.

A smaller, more circumscribed body, the Kiilarova body, was studied by Eriksson (1954, p. 34) who described it as hornblende granite. Ödman subsequently (1957) referred it to his Haparanda Series. The present author considers it to be essentially gabbro partially altered by granitization to diorite and much veined by granitic material. Whether it belongs to the time interval occupied by the Haparanda Series cannot be determined on field evidence alone.

Minor basic intrusives

Diabasic dykes have been observed in a number of outcrops, notably in quartzitic rocks on Kuusivaara (Pajala SV), SE of Käymäjärvi and on Kursuvaara ENE of Käymäjärvi (Pajala NV). They also cut the porphyritic rocks near Peräjävaara and are thus later than the main stratigraphic units. In all cases, however, they show the effects of later regional metamorphism and not infrequently scapolitization.

Of particular interest are the observations of Lundberg (1967, pp. 13—15), in connection with the Stora Sahavaara iron-ore deposit. Drilling carried out in the 60's by SGU revealed the presence of a number of diabasic dykes (metadiabase) 10—15 m wide with plagioclase in the compositional range An_{48-50} and occasionally showing ophitic texture. They cut both ore, associated skarn as well as the metasedimentary formations. They are, however, scapolitized and in some cases affected by granites and related thermal metamorphism. Of further interest is the occurrence of dyke-like bodies of gabbro-diabase. These have a coarser grain-size than the diabase and probably form larger bodies. An example of this is seen on the hill Suksivaara (Pajala NV) where a body is markedly discordant to the layered rocks. Both north and south of Suksivaara there is every indication from ground magnetic surveying that similar bodies exist and these are included on the geological map accordingly. Close to Sahavaara particularly clear discordant relationships are seen and drilling confirmed the presence of two gabbroic bodies each 10—15 m wide separated by a greenstone in which 2—3 m wide diabasic dykes are intruded (Lindroos 1971). Gabbro-diabasic rocks also occur on Koijuvaara and in greenstones west of Suorsapakka (Pajala SV).

These basic dykes are therefore regional phenomena post-dating the layered rocks but pre-dating the regional metamorphism and granite intrusion. They may be synchronous with intrusion of the gabbros. An exception to this is provided by a 1.5 m wide dyke of andesite-porphyry in the Saarenvaara area (Pajala SV, 1a). This cuts migmatitic gneisses at a high angle to the regional lineation and appears to post-date them.

Andesite-porphyry

On the map-sheet Pajala SV a rather distinctive elongate body of andesite-porphyry occurs. Where exposed, in the Liviöjoki stream it is generally a dark and massive rock with light coloured plagioclase crystals. In thin section it shows considerable alteration with the development of hornblende and epidote. On the magnetic maps it coincides with an area of low susceptibility from which the form of the body can be drawn. As such it is markedly discordant to layered greenstones of the Suorsapakka area. It is thought to be intrusive into these rocks and hence younger in age. From the spatial relationships it is also younger than the NE—SW folding and therefore younger than most of the layered rocks.

It closely resembles an andesite-porphyry at Haukkalaki (Padget 1970, p. 39) on the Tärendö sheet both as regards petrology and relationships with other rocks. In both cases it is cut by certain regional faults and overlain by an ill-sorted conglomerate, the Palovaara conglomerate which contains pebbles of the same porphyry (see stratigraphic section above).

On the Vittangi sheet Eriksson and Hallgren (1975, p. 120—122) have described rather similar bodies of andesine-porphyry. The feldspars are somewhat larger and more elongate.

Tectonics

Faulting

Direct observation of faults is very rarely possible on the Pajala sheet. Mechanical brecciation of the rocks has, indeed, only been seen at two places — in rocks cropping out in a stream south of Kursunpalo (Fig. 7) and in local blocks at the roadside, 3.5 km west of Kiilarova (Pajala SV). At the latter locality granitic rocks are fractured and veined by quartz and carbonate.

Drilling of the various iron-ore deposits has revealed the presence of numerous faults, often with significant displacements (Lundberg 1967, pp. 35—36). The magnetic maps, however, show that faulting is of common occurrence on the sheet. Cases are easy to find where magnetic sheets are abruptly terminated and while this effect can be explained in other ways faulting must be, more often than not, the more likely cause. The faults included on the geological map-sheets are usually those necessary to explain the observed distribution of rock types or when relationships seem unambiguous. The amount and direction of movement are, however, usually more difficult to determine.

No attempt has yet been made to analyse fault directions in a statistical

Fig. 7. Brecciated rock fragments in leucodiabase. Streamsection south of Kursunpalo (Pajala NV).

Brecciabildning i leukodiabas. Blottning i bäck söder om Kursunpalo (Pajala NV).

way and, indeed, the overall pattern of faulting is not clear. It probably occurred in different phases, the most recent one being post-granitic. Attention was directed towards this by Witschard (1970, p. 77) from his work on the Lainio sheet. He called it the rigid deformation phase and believed it to be responsible for dividing up the area into blocks, and later in age than the regional metamorphism.

The existence of fault-bounded blocks is a very noticeable feature of the Kiruna and Vittangi sheets and is present on the Pajala sheet also. Thus the Käymäjärvi area, with its interesting stratigraphy, is such a block, bounded on at least 2 sides by major faults, here named the Sammakkovaara and Kaunisjoki faults. For this reason stratigraphic continuity with the rest of the sheet cannot always be demonstrated.

Folding in general

The existence of folds of regional dimensions was deduced by geologists at an early stage and has been confirmed during the present investigation. The recent magnetic surveys have enabled us to get an even better picture of their geometry while estimates made regarding dip of magnetic sheets have greatly helped in drawing the profiles.

The more important structures are as follows:

1. Käymäjärvi folding
2. Saalovuoma trough
3. Jupukka — Suorsa anticline
4. Muotkavaara — Liviöjärvi syncline
5. Pajala — Kengis fault-folding

The above belong to one of two groups based on trend. 1 and 5 are earlier (F_1) structures; 2, 3 and 4 later (F_2) structures.

The *Käymäjärvi folding* is essentially two, NW trending anticlines separated by a syncline (Profile II). The more westerly of these two anticlines is in the form of an elongated dome, largely replaced by granite. The anticlines are in turn flanked by major synclines made up of quartzitic sediments of the Pahakurkkio group (Profiles I—III). These are well seen on the high ground Sammelvaara — Käymävaara and on Lompolovaara. In both cases cross-bedding in the clastic rocks enables the geometry of the folds to be established. There is, for example, a marked tendency for certain limbs to be overturned to the north-east. The foldaxes seem to be largely horizontal except south and south-west of lake Käymäjärvi where they plunge southwards, that is, towards the Saalovuoma trough.

Saalovuoma trough. A major tectonic depression can be deduced for the area between Kaunisjoki, Saalovuoma and Peräjävaara. This is occupied largely by gabbro bodies and granite but along its flanks metasedimentary formations help define it more clearly. Thus the Kaunisvaara—Sahavaara rocks dip west or north-west whilst the migmatized metasediments of Sammakovaara dip south-east or south, which is also the direction of plunge of the Käymäjärvi folding.

The feldspar porphyries of the Porphyry group mark approximately the axial zone of the depression in the vicinity of Peräjävaara.

The Jupukka — Suorsa anticline. This structure is also of regional extent and complementary to the Saalovuoma trough. It brings greenstones to the surface and the anticlinal structure of these is best seen in the Suorsapakka area where the foldaxis plunges to the north-east.

North of the Torneälv, in the Jupukka area and beyond, the fold axis plunges in the opposite direction, i.e. to the south-west. This change in direction of plunge takes place in the vicinity of Erkheikki where relationships are difficult to unravel despite detailed drill-hole data and geophysical surveying. Interference of the two main structural directions probably takes place in this area.

Muotkavaara — Liviöjärvi syncline. East of the main zone of the Suorsa greenstone group and to some extent mantling them, occur sediments of the Pahakurkkio group distributed in two trough-like zones, one north of the Torneälv (Muotkavaara), the other south of it (Liviöjärvi). They are considered to be basins or troughs of sedimentary deposition involved in downfolding on the NE trending axis.

Pajala — Kengis fault-folding. A curious structural direction is evident between Pajala and Kengis, one element of which is a narrow antiform structure striking north-west. This is clearly at a high angle to the prevailing strike and more comparable in direction to the Käymäjärvi folding. Like the latter, overturning to the north-east and overthrusting may be involved. An unexplained feature is the northerly dip of certain magnetic sheets despite evidence in outcrops to the contrary.

The existence of 2 major fold directions intersecting at a high angle is a common feature of the geology of northern Norrbotten and not least for the map-sheets Pajala and Tärendö (Padget 1970, pp. 47—52). The north-westerly trending folds, here termed F_1 are, however, normally more isoclinal and even recumbent, with the sense of movement to the north-east, e.g. Masugnsbyn syncline (28 L) and Käymäjärvi folding (28 M). The north-easterly trending folds here termed F_2, in contrast are more open and seem to transect the north-westerly ones. These include the Kalix syncline (28 L) and Saalovuoma trough (28 M) and are therefore thought to be younger in age. The amount of time separating the two phases is unknown.

Granite and related rocks

These almost certainly form a very large per cent of the total area of the Pajala sheet, probably more than 50 per cent. As far as is known they are all younger than both the layered rocks and basic intrusions and belong to the Lina granite phase. No attempt has been made to carry out systematic petrological studies of these rocks, partly because of shortage of time, partly because they are not known to contain minerals of any economic importance. The observations below are therefore largely based on field studies, particular attention being given to relations with other rocks. Great attention has also been paid to the geophysical data.

Granite

Granite of massive, homogeneous character is not common. A long narrow body of coarse-grained, almost pegmatitic granite occurs in the north-east and is topographically represented by the hills Käryvaara, Jatkovaara and Honkavaara. Medium-grained granite forms most of the hill Käymävaara, north-east of the lake Käymäjärvi (Pajala NV).

These areas are geophysically homogeneous. The granites are potash-rich and resemble those belonging to the Lina granite series, dated at around 1 550 m.y. (Welin 1970, Gulson 1972) by the Rb-Sr method.

Granodiorite

This characteristic rock occupies a small area close to the Siikajoki, north of Anttis (Pajala NV) and is a direct continuation of a granodiorite body on the adjacent Tärendö sheet. It is fairly massive but contains dark, basic ovoids (inclusions) a few centimetres across and some narrow zones of steeply dipping mica-schist. For further description and analyses, see Padget 1970, pp. 45—46. Its contact relations are not seen on the Pajala sheet and it may extend further east, up to the Saalovuoma gabbro. It is also believed to belong to the Lina granite series, but is not a syenite as believed by Eriksson (1954 Pl. 1) and Ödman (1957).

Syenite

A small area of syenite occurs on the hill Kokkovuoma (Kokovuoma), 5 km north-west of Kaunisvaara and on the border with the Huuki sheet. It was found by Tanner (1918) and reported on by Geijer (1931, p. 92). It consists largely of plagioclase with an albitic composition, microcline and a little pyroxene, partly altered to hornblende. Quartz is virtually absent.

Migmatite-granite

This term is used to cover virtually all other granite-type rocks on the sheet in which the granitic component is conspicuous. Typical examples are seen on Saarenvaara (Pajala SV), at Kallio, on Korkeavaara (Pajala NO) and marginal to the Käymävaara granite massif mentioned above. North and south of Pajala extensive tracts of granite gneiss occur, for which interesting aeromagnetic maps are available. These show an abundance of parallel magnetic zones clearly indicating that layered supracrustal formations have been extensively granitized, i.e. soaked in granite material to give granite with schistose relicts. Biotite is a common component in the latter. One darkish gneiss is dioritic in composition. It seems to coincide with areas with more continuous magnetic sheets and can be interpreted to mean that a fairly basic rock formation (greenstone) has been granitized. Occasionally quite basic rock is found without much of the granitic component being present at all, though completely recrystallized. Sometimes the sedimentary relicts are big enough and so little altered that primary bedding features and pre-granitic folding can be discerned without difficulty. Pegmatite is quite common and may be in sufficient volume to dominate in quite large outcrops. It is regarded as the end product of the granitization process.

Fig. 8. Folded migmatite gneiss, east of Rytijärvi (Pajala NO). Boulder of local origin.

Veckning i migmatitgnejs öster om Rytijärvi (Pajala NO). Lokalt block.

There is thus considerable inhomogeneity in the rocks of the migmatite-granite areas, at least within certain broad limits. This may or may not be reflected in the magnetic maps. However, gravimetric data show clearly where lighter rocks such as granite and migmatite are concentrated in the migmatite zones. There is, for example, a broad zone extending from Kassa on the Torneälv in a SSW direction and this coincides in a general way with a zone of low magnetic intensity and low gravity.

North of Pajala a similar gravimetric low occurs in the area of Muotkavuoma though this would hardly be expected from the aeromagnetic data. Finally, it should be pointed out that while the main body of granite is emplaced in the lower part of the stratigraphic sequence there is no field evidence suggesting the existence of an older basement corresponding to the one north of Kiruna described by Offerberg (1967). Regional gravimetric studies may however require a revision of this conclusion.

The migmatitic rocks often display small-scale, plastic folding (Fig. 8). Usually this seems to be related to the main fold pattern but this is not always the case. Further study has not been possible owing to lack of exposures. On Kuusivaara (Mäntyvaara) the migmatitic layering is broken up (Fig. 9) indicating the operation of a post-migmatitic deformation.

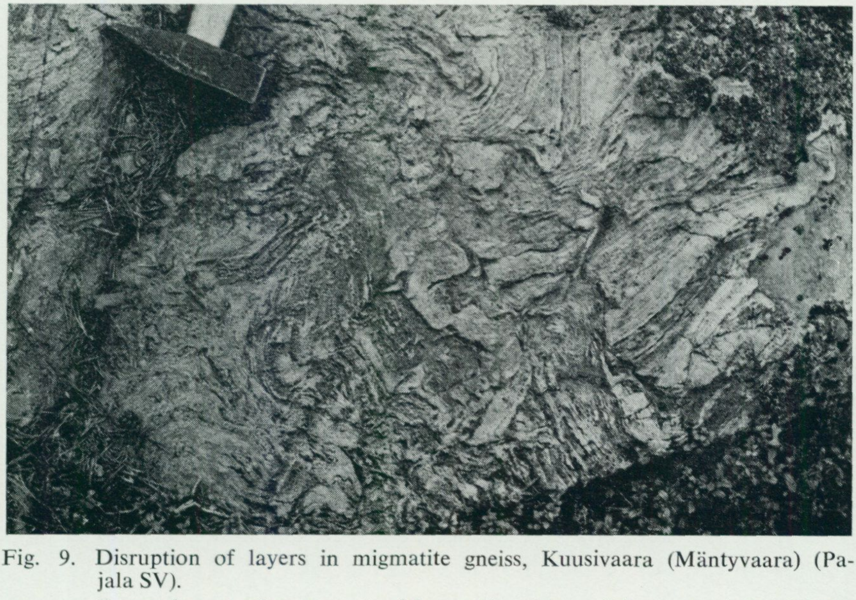

Fig. 9. Disruption of layers in migmatite gneiss, Kuusivaara (Mäntyvaara) (Pajala SV).
Brutna lager i migmatitgnejs på berget Kuusivaara (Mäntyvaara) (Pajala SV).

Fig. 10. Quartz-sillimanite nodules in gneiss north-east of Pajala. Bouiders of local origin (Pajala NO).
Kvarts-sillimanitkörtlar i lokala gnejsblock nordost om Pajala (Pajala NO).

Metamorphism

No systematic study of the metamorphic features of the rocks of the Pajala sheet has been carried out. It is, however, clear that most non-granite rocks show evidence of a regional, thermal metamorphism of conventional Barrovian type. Most of this seems to post-date the main phase(s) of folding and to be related to the emplacement of the potassic Lina granite. Primary sedimentary structures are commonly visible in the layered rocks and some can even be traced up to granite boundaries. The least metamorphosed rocks are those normally occurring in synformal cores, as for example, the agglomeratic tuffs and greenstones north-west of Käymäjärvi.

Of some interest is the occurrence of quartz-sillimanite nodules in migmatites on the hill Nivanlehto, close to the lake Iso Rytijärvi (Fig. 10). These were first reported on by Fredholm (1886) and correctly interpreted by Geijer (1931, p. 71) as products of restricted material transport under conditions of regional metamorphism. The nodules represent a good example of metamorphic differentiation following de-alkalization of a parent rock.

Geological evolution of the area

In the description above care has been taken to record the relationships between rocks and tectonic elements. The evolutionary picture which emerges is certainly a fairly simple one in its main outlines and shows many similarities with adjacent areas. It is, however, almost certainly more complex but this can only be resolved in the future with the application of techniques such as age determination by isotopic means and by a more sophisticated study of the tectono-metamorphic features in thin section.

The first event is a major episode of basic volcanism, probably in a marine environment and belonging to a larger province extending WNW to the Kiruna area and beyond. In the later stages a more differentiated environment existed with the deposition of chemical precipitates such as limestone and certain ferruginous beds. The greatest known thicknesses of volcanic rocks and their resorted sedimentary derivates occur in the Käymäjärvi and Kaunisvaara areas.

The metasediments of the succeeding Pahakurkkio group represent a radical change in conditions with the influx of much clastic material, the source of which is unknown. There are, however, strong indications that most of this material was deposited in the same basin-like area as the volcano-sedimentary rocks (Käymäjärvi group) mentioned above. Higher units, possibly extended outwards from the basin on to the older basaltic rocks of the Suorsa group.

The Porphyry group represents a later phase of acidic volcanism, limited in extent on the Pajala sheet but more extensive in the direction of Kiruna where it has been dated at 1 605 ± 65 m.y. (Kiruna) and 1 635 ± 90 m.y. (Kaska Tjåurek) by Welin, Christiansson and Nilsson (1971).

Possibly some intrusions of andesite-porphyry occurred in this interval and after a relatively short interval these were eroded and the material deposited to give ill-sorted conglomerates of local extent (Palovaara conglomerate). Folding then affected all the layered rocks. This took place in two main phases, the first of which was the more extensive. It should be noted that there is no clear evidence on the Pajala sheet for the intrusive events represented by the Haparanda series. Elsewhere in Norrbotten some of the gabbroic rocks of the Pajala sheet could belong to this phase too but are for the time being placed closer to the potassic granites in time with which they have closer spatial relationships. Most of the dyke intrusion was also completed before the emplacement of the dominantly potassic granites and related migmatization. Recent age determinations indicate ages around 1 535 m.y. for this granite emplacement (Gulson 1972) elsewhere in Norrbotten.

Subsequent to this followed an extremely prolonged period of erosion probably only disturbed by rigid fault- and block-movements. Dyke-like intrusion in the granite and gneiss terrains is very rare.

Economic aspects

As far as is known the iron-ore occurrences are by far the most important deposits in the area. They are readily detected by geophysical methods and their sub- outcrop and 3-dimensional form have been further clarified in recent years. No mining, however, has been carried out to date. The present investigations have demonstrated more clearly the stratiform character of these deposits and their position in the stratigraphic column, i.e. in the upper part of the Käymäjärvi group. The resolution of the fold structure in the Käymäjärvi area is important in this connection.

Concurrent with and subsequent to the regional investigations drilling of the more promising ore zones has been carried out by SGU. Details are included in a number of internal and published reports, for example those of Lundberg (1967) and Lindroos (1974) in which new estimates are made of tonnage and grade. Clearly the main ore concentration is found in the Kaunisvaara area (Lindroos 1974) where the Stora Sahavaara, Ruutijärvi, Tapuli and Palotieva deposits comprise 90 % of the known reserves amounting to about 180 million metric tons of iron-ore with an iron content of 27—41 %. For location of ores and further references, see Lindroos 1974.

A vertical dyke-like body of magnetite about 60 cm thick occurs on the hill Suorsapakka in thermally altered volcanic rocks. It seems to be of very limited size and is probably characteristic for certain magnetite anomalies elsewhere in this area. Sulphides are present in very minor quantities in certain greenstones but no significant mineralization is known. Sulphur is an important constituent of the Kaunisvaara iron-ores and a few ice-transported blocks with weak magnetite, chalcopyrite, pyrite mineralizations have been found at scattered points over the whole map-sheet. Many of these are believed to come from locations outside the sheet. Eriksson (1954, p. 15) reported a weak copper mineralization in conglomerate west of Käymäjärvi. This occurs in local blocks, is very weak and is chiefly represented by azurite and malachite staining. The conglomerate belongs to the Pahakurkkio group as described above. No other ore occurrences of economic interest have been found either in situ or in boulders.

Of non-metallic materials mention should be made of certain carbonate formations, particularly in the upper part of the Käymäjärvi group. Locally, thicknesses of 30 m or more have been reported but the quantity and quality are still far short of that necessary for economic production. Possibly certain pegmatites might warrant closer attention as a source of quartz and feldspar.

TABLE 1. Chemical analyses (weight %)
Kemiska analyser (vikt-%)

	A 1	A 2	A 3	A 4	A 5	A 6	A 7	A 8
SiO_2	80.6	92.2	72.9	61.4	53.5	47.9	48.5	51.0
TiO_2	0.53	0.04	0.06	0.91	0.93	0.69	1.28	1.5
Al_2O_3	8.4	0.8	0.2	16.8	9.0	10.9	12.9	13.3
Fe_2O_3	1.7	0.9	5.5	2.4	0.7	1.8	13.6	3.0
FeO	1.5	3.1	9.5	4.7	8.0	7.9	0.39	7.3
MnO	0.01	0.02	0.07	0.09	0.07	0.08	0.11	0.08
CaO	0.6	0.7	4.0	1.5	8.4	10.8	6.42	4.4
MgO	1.7	0.55	2.1	3.9	7.6	7.9	8.63	7.9
Na_2O	1.8	0.2	0.1	2.1	2.9	3.9	0.97	4.1
K_2O	2.4	<0.1	0.1	4.3	1.7	1.3	5.5	3.7
H_2O+	0.7	0.2	0.5	1.6	1.3	1.3	–	1.6
H_2O-	0.06	0.1	–	0.12	0.1	0.4	–	0.2
P_2O_5	0.10	0.01	0.04	0.16	0.10	0.16	0.10	0.11
CO_2	<0.01	1.1	1.6	<0.01	1.0	1.0	0.50	0.6
S	<0.01	1.9	5.2	<0.01	4.1	3.9	0.03	0.8
F	0.03	0.01	0.01	0.09	0.12	0.06	–	0.04
Cl	0.02	0.06	0.14	0.01	0.9	1.6	–	0.34
C	–	0.6	0.08	–	0.67	0.05	–	0.2
BaO	–	<0.01	0.01				–	0.02
	102.2	102.2	102.1	100.1	101.2	101.7	98.95	99.99
Subtr. O	–	0.9	–	–	1.5	1.8	–	0.49
	100.2	101.2	102.1	100.1	99.7	99.9	98.95	99.5

A 1. Quartzite: St. Sahavaara, 8e (dh 62002), Lundberg 1967.
Kvartsit.

A 2. Quartzite: Erkheikki, 5d (dh 69003), SGU unpubl.
Kvartsit.

A 3. Quartzite: Erkheikki, 5d (dh 70003), SGU new.
Kvartsit.

A 4. Quartzitic phyllite: St. Sahavaara, 8e (dh 62002), Lundberg 1967.
Kvartsitisk fyllit.

A 5. Skarn-scapolite quartzite: St. Sahavaara, 8e (dh 63005), Lundberg 1967.
Skarn-skap. kvartsit.

A 6. Skarn-scapolite quartzite: St. Sahavaara, 8e (dh 62001), Lundberg 1967.
Skarn-skap. kvartsit.

A 7. Phyllite: Marjajärvi, 7b (dh 69601), SGU new.
Fyllit.

A 8. Phyllite: Erkheikki, 5d (dh 69003), SGU new.
Fyllit.

Analysts: B. Johansson (A 1, A 4 – A 6, A 10, A 11, A 13 – A 15), SGU.
T. Nilsson (A 2, A 3, A 8, A 9, A 12), SGU.
S. Israelsson (A 7, A 16), LKAB.

	A 9	A 10	A 11	A 12	A 13	A 14	A 15	A 16	A 17
SiO_2	49.1	46.8	31.0	36.5	50.2	55.4	61.9	52.7	58.7
TiO_2	1.3	0.77	0.48	0.73	1.15	1.12	0.65	0.96	1.25
Al_2O_3	16.8	11.1	7.0	9.8	14.3	17.5	16.1	14.5	12.6
Fe_2O_3	2.7	0.5	2.6	33.4	5.2	3.7	2.7	17.9	0.6
FeO	6.5	11.1	31.2	*	7.8	4.2	2.9	0.13	7.4
MnO	0.08	0.11	0.03	0.03	0.24	0.17	0.05	0.20	0.39
CaO	6.3	5.7	1.9	1.1	8.4	6.0	4.4	1.91	4.5
MgO	5.4	5.4	1.8	1.6	7.4	2.5	2.5	6.13	3.4
Na_2O	4.2	2.4	2.6	3.7	3.5	3.0	4.1	1.95	1.4
K_2O	1.7	3.8	1.3	1.0	0.4	3.8	2.5	2.50	5.6
H_2O+	1.9	1.2	0.4	0.5	1.1	1.0	0.8	–	1.4
H_2O-	–	0.1	0.1	0.2	0.1	0.1	0.1	–	0.2
P_2O_5	0.24	0.21	0.14	0.09	0.11	0.48	0.16	0.03	0.03
CO_2	2.9	0.2	0.1	2.0	0.02	0.07	0.03	0.41	1.20
S	1.5	5.6	17.6	14.6	0.27	<0.01	<0.01	0.08	0.4
F	0.05	0.11	0.08	0.04	0.02	0.08	0.04	–	0.15
Cl	0.64	1.1	1.0	0.42	<0.01	0.02	0.07	–	0.42
C	0.11	6.4	8.0	5.0	–	–	–	–	–
BaO	0.04	–	–	0.03		–	–	–	–
	101.46	102.6	107.3	110.24	100.2	99.14	99.00	99.41	99.7
Subtr.O	0.93	3.0	8.0	7.41	0.1	0.02	0.02	–	0.2
	100.53	99.6	99.3	102.8	100.1	99.12	98.98	99.41	99.5

A 9. Phyllite: Erkheikki, 5d (dh 70003), SGU new.
Fyllit.

A 10. Graphite schist: St. Sahavaara, 8e (dh 62001), Lundberg 1967.
Grafitskiffer.

A 11. Graphite schist: St. Sahavaara, 8e (dh 63005), Lundberg 1967.
Grafitskiffer.

A 12. Graphite phyllite: Erkheikki, 5d (dh 69003), SGU new.
Grafitfyllit.

A 13. Greenstone agglomerate: Cross-road in Sahavaara, 8e, Lundberg 1967.
Grönstensagglomerat.

A 14. Porphyritic greenstone: 4.4 km ESE of Suorsapakka, 3c, SGU new.
Porfyrisk grönsten.

A 15. Andesite-porphyry: Liviöjoki W of Pajala, 4c, SGU new.
Andesit-porfyr.

A 16. Gneiss: Marjajärvi, 7b (dh 69601), SGU new.
Gnejs.

A 17. Phyllite: Sahavaara, 8e (dh 63005), Lundberg 1967.
Fyllit.

* Can not be determined because of high sulphur content.
Kan ej bestämmas på grund av hög svavelhalt.

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SGU = Sveriges geologiska undersökning

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APPENDIX

GEOPHYSICAL INVESTIGATIONS ON THE MAP-SHEET 28 M PAJALA

BY

HERBERT HENKEL

CONTENTS

Sammanfattning

De flygmagnetiska mätningarna inom kartområdet utfördes 1961 och tyngdkraftsmätningarna slutfördes 1974. Bergartsproverna som samlats in under den geologiska karteringen har undersökts med avseende på de fysikaliska egenskaperna täthet, magnetisk susceptibilitet och remanent magnetisering, totalt har 600 prover uppmätts.

Tolkningen av den flygmagnetiska kartan har gjorts med avseende på anomalistruktur och anomalinivå. Bandat anomalimönster avser områden med parallella och kontinuerliga anomalier. Oregelbundet anomalimönster avser områden där bandning är diffus och osammanhängande eller där bandning saknas. Gånglikt anomalimönster avser enstaka uthålliga anomalier med diskordant uppträdande.

I tolkningen har dessutom tagits fram läget för magnetiska kontakter, läget, och i vissa fall rörelsebeloppet, för magnetiska dislokationer, samt

sannolika konnektioner mellan likartade anomalier. I pl. 2 A anges områden med olika anomalimönster. Linjerna för olika grad av bandning återger anomalistrukturen. Rasterytorna anger den relativa magnetiseringsnivån för områden med oregelbundet anomalimönster. I fig. 23 återges några mindre tydliga strukturer i dessa områden. En del av dessa har tolkats som domer. Lokalt förekommer anomalier som kan anses vara orsakade av gångar. Pl. 2 B visar magnetiska dislokationer och möjliga laterala förskjutningsbelopp som påverkar lätt identifierbara anomalier (referensstrukturer). I kartområdet dominerar 3 riktningar, NV, N och ONO resp., vidare förekommer en underordnad riktning NO. En del av dislokationssystemen sträcker sig långt utanför kartområdet, några av N—S-riktningarna kan följas över 100 km söderut.

Tyngdkraftsanomalierna återspeglar fördelningen av tunga och lätta bergarter. De högsta anomalierna orsakas av basiska vulkaniter och gabbror medan sedimentbergarter vanligen ger måttliga anomalier som är negativa inom vulkanitområden och positiva inom granitområden. Regionalt sett befinner sig kartområdet i ett tyngdkraftsminimum med överlagrade kortvågiga anomalier orsakade huvudsakligen av suprakrustalbergarter. Med hjälp av gravimeterkartan, magnetiska kartan och täthetsbestämningarna kan i många fall djupet till underytan bestämmas för suprakrustalkomplexen och för vissa avgränsade intrusiv.

Dessa djup är i genomsnitt 2—4 km. I profilerna på fig. 22 redovisas möjliga volymsfördelningar, varvid hänsyn tagits till uppmätta tätheter och magnetiska kontakter.

Geofysiska markmätningar redovisas i pl. 2 och i fig. 26.

Bergarternas fysikaliska egenskaper är sammanfattade i tabell 2. De olika bergarternas fysikaliska egenskaper återges med densitets — susceptibilitetsdiagram och med susceptibilitets — q-värdesdiagram i fig. 12—19. Generellt kan sägas att ökad täthet medför ökad magnetisering utom för basaltisk grönsten som har en tung omagnetisk undergrupp. Suprakrustalbergarterna är i allmänhet måttligt till starkt magnetiska utom kvartsiter och kalkstenar som är svagt magnetiska eller omagnetiska. Remanensen är vanligen helt underordnad den inducerande magnetiseringen utom för basiska djupbergarter där höga q-värden kan förekomma (t. ex. Saalovuomagabbron). En kombination av magnetisk-, gravimetrisk- och parameterinformation gör det möjligt att tämligen väl avgränsa områden med suprakrustalbergarter från sådana med djupbergarter.

Introduction

The aeromagnetic measurements on the map area 28 M Pajala were carried out in 1961. Technical information concerning these measurements is given in Werner (1963). Several extensive ground geophysical surveys covering a total of 171 km^2 have been made within the map area. In 1974 a regional gravity survey was made with an average station spacing of 0.75 km. Measurements of physical properties of rocks have been made on all rock specimens which were collected during the geological mapping. These so called parameter measurements include density, magnetic susceptibility and remanent magnetization. They have allowed an improved understanding of the vertical and surface distributions of rocks.

The interpretation of aeromagnetic maps consists mainly of an anomaly pattern analysis and the delineation of contacts and dislocations. Dip and depth estimations are made in those cases where anomalies appear undisturbed and regular. Interpretation maps in the scales 1:20 000 and 1:100 000 are deposited in the archives of the Geological Survey.

A simplified version of these maps in the scale 1:250 000 and a gravity map are presented in Pl. 2 (separate folder together with the aeromagnetic and geological maps).

Physical properties of rocks

Six hundred rock samples which have been collected during geological mapping of the region, have been measured with respect to the physical properties density, magnetic susceptibility and remanent magnetization. A large number of in-situ susceptibility measurements have been made on several areas of plutonic rocks and some areas of supracrustal rocks. These results are shown as susceptibility histograms in Fig. 17 and as frequency polygons in Figs. 11 and 16. 23 oriented samples have been collected on three gabbro massifs. Two of these show pronounced NRM (natural remanent magnetization) directions deviating from the present geomagnetic field.

The density is determined as wet bulk density with an accuracy of 0.01 g cm^{-3}. The magnetic properties are determined in three directions with a relative error of 2 % and a resolution of about $3 \cdot 10^{-6}$ cgs. The in-situ susceptibility measurements have the same accuracy and a resolution of about $2 \cdot 10^{-5}$ cgs.

Grouped results of these measurements are given in Figs. 4—11. On the diagrams each sample is represented with one symbol. For rocks groups with a very large number of samples, however, curves for equal areal frequencies (of 1, 2, 5 and 10 samples within the unit area 0.04 cgs and 0.2 dekades respectively) are used to represent the distribution of samples. When rock samples have susceptibilities below 10^{-6} cgs they will be plotted on the density axis in the susceptibility-density diagrams. For rock groups with a considerable number of samples having these very low susceptibilities, their density range and the number of samples with susceptibility below 10^{-6} cgs is denoted below the density axis. For the study of magnetic contrasts, susceptibility frequency distributions are given for certain rock groups (Figs. 11 and 16—17).

Valuable petrological information on rock types may be gained from the covariation of certain physical parameters for example a plot of susceptibility versus density. In such a plot, moreover the effect of magnetite content (which is logarithmically proportional to the magnetic susceptibility) on density can be allowed for. The reduced density is more closely related to the silicate mineral composition (silicate density). Statistically this silicate density directly reflects the chemical composition corresponding to an acid to basic variation. Any geological process which affects either of these parameters will show up as a trend in these covariation diagrams (Henkel 1976).

In the following sections each main group of rocks is discussed with reference to diagrams of the covariation of density and susceptibility and susceptibility — q-value (ratio of remanent to induced magnetization). In a final chapter conclusions are drawn regarding the magnetic contrasts to be expected between rock groups and their expressions on the aeromagnetic map.

Sedimentary rocks, Figs. 11—13

These rocks are grouped together without stratigraphical distinction as they show similar petrophysical properties in any stratigraphical position. The largest group consists of *gneisses,* mainly from the southern part of the map region. Their silicate density is fairly low indicating a dominantly acid composition, Fig. 12. The bulk of these rocks have moderate to high susceptibility, a minor group has low susceptibility. This rather large range of variation is sufficient to cause magnetic banding when different magnetic

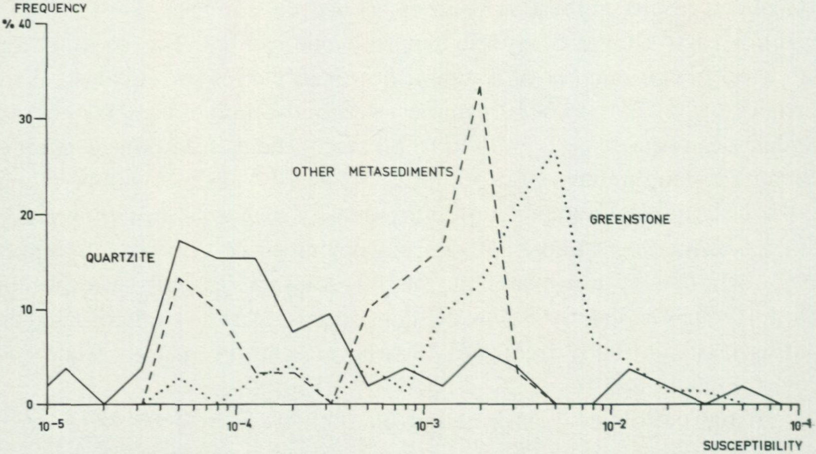


Fig. 11. In-situ susceptibility measurements on supracrustal rocks. Class width 0.2 dekades.
Hällsusceptibilitetsmätningar på ytbergarter.

types are interbedded. The magnetic banding in these regions should not necessarily be interpreted as changes in composition. The q-values are generally low, around 0.4, and there are only few restricted exceptions where q-values as high as 40 are encountered (Fig. 13). Measured in-situ susceptibility, Fig. 11, shows a high frequency around $3 \cdot 10^{-3}$ cgs. Compared to granites from the same area (south-eastern quadrangle), the gneisses have twice as large a susceptibility. Therefore low magnetizations can be interpreted as granites in areas with irregular anomaly pattern within the south-eastern quadrangle.

The second largest group comprises *pelitic schists* from various stratigraphical levels mainly from the western quadrangles. Their silicate density is somewhat higher than that of gneisses, pointing towards an acid to intermediate composition.

Two distinct regions can be observed in the susceptibility distribution, a low magnetic, and a moderate — high magnetic. For this rock group too, a banded magnetic pattern can be expected which does not necessarily indicate compositional changes. The q-values are low with an average around 0.4 and a large range of variation. The lowest values being at 0.05 and the highest at 9. Sillimanite-bearing varieties have no significantly different petrophysical properties.

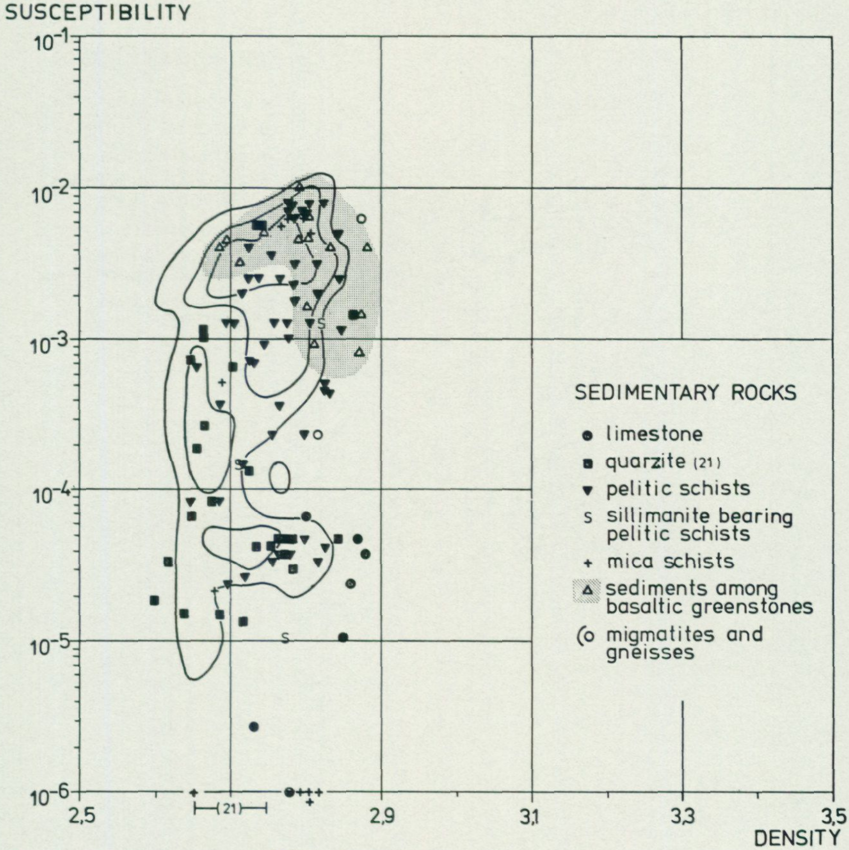


Fig. 12. Density — susceptibility diagram.
Densitet — susceptibilitetsdiagram.

Quartzites, mainly from the western quadrangles, have densities in the expected interval 2.60—2.75 g cm^{-3} with a frequency maximum at 2.65. The larger part of quartzite samples shows very low susceptibilities with a frequency maximum at $8 \cdot 10^{-5}$ cgs.

But in a few instances, where magnetite becomes a considerable constituent of these rocks, very high susceptibilities are encountered. A large fraction is completely unmagnetic. (Their density range and number of samples is indicated below the density axis in Fig. 12.)

Accordingly the magnetic anomalies from these rocks will generally be smooth and low but may in cases give very high anomalies. The lowest

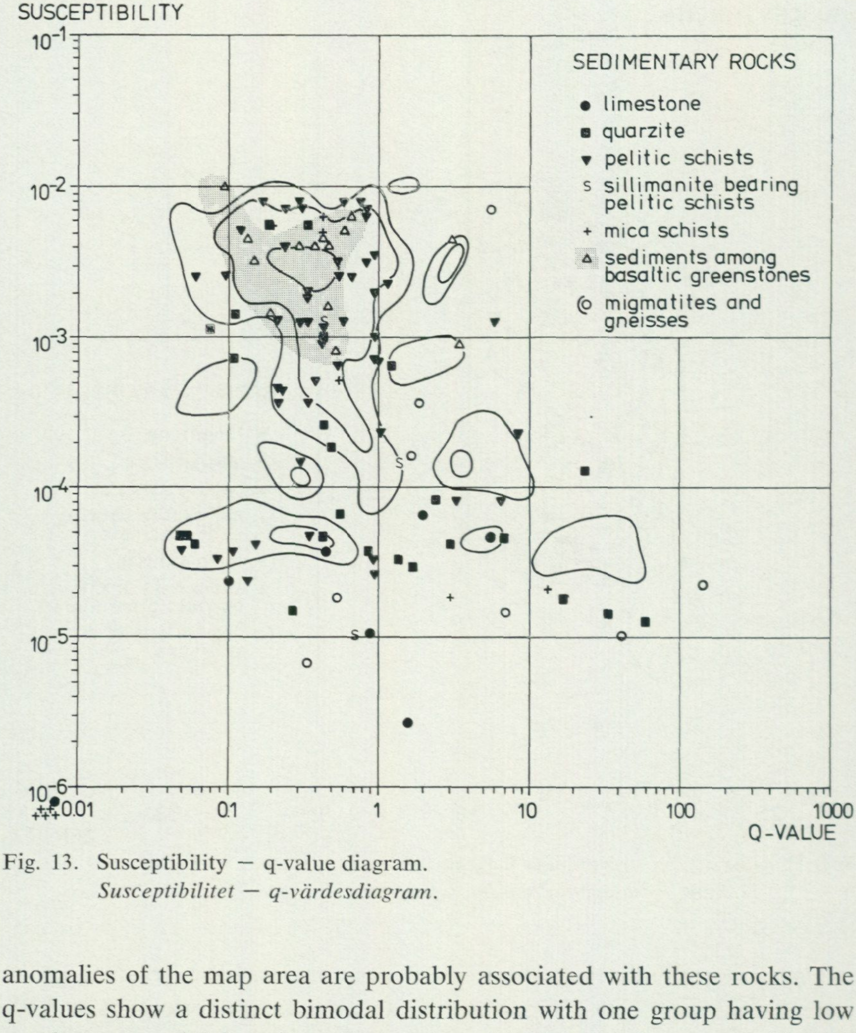


Fig. 13. Susceptibility — q-value diagram.
Susceptibilitet — q-värdesdiagram.

anomalies of the map area are probably associated with these rocks. The q-values show a distinct bimodal distribution with one group having low q-values around 0.2 and another group with high q-values up to 80. The latter group has hematite as an important constituent which gives rise to a comparatively large remanent magnetization.

Limestone is represented with a few samples from the north-western quadrangle. They have rather high densities around 2.85 g cm^{-3} and low susceptibilities around $3 \cdot 10^{-5}$ cgs. The remanent magnetization is relatively high with q-values around 1.

Mica schists with densities around 2.75 g cm^{-3} have very scattered susceptibilities covering the whole range from unmagnetic to highly magnetic. For this rock group too, magnetic banding can be expected not to indicate changes in composition. In the susceptibility-q-value diagram, a distinct negative correlation trend is characteristic for this group.

Among basaltic greenstones a variety of *meta sediments* have been sampled. They have slightly higher densities than other supracrustal rocks and they are rather magnetic with susceptibilities of $3 \cdot 10^{-3}$ cgs. Their q-values are moderate, around 0.5.

Volcanic rocks, Figs. 14 and 15

This group of rocks differs from the sediments by having a large high density subgroup comprising volcanics with basaltic and ultramafic composition. A geographical difference among the petrophysical properties of these rocks is strongly indicated. Thus the rock samples from the Suorsa region are dominantly of intermediate to mafic composition while those from the northern quadrangles (Käymäjärvi and Kolari regions) are dominantly mafic to ultramafic in composition. Acid volcanics are restricted to the Peräjävaara region. The volcanic rocks from the Suorsa and Peräjävaara regions have all rather high q-values at an average of 0.7, which also is observed on the rocks from the porphyry group within the map area 28 J Fjällåsen.

Basaltic volcanics from the northern quadrangles show a characteristic distribution on the susceptibility-density diagram of Fig. 14. The low magnetic fraction has a large density variation indicating compositions ranging from basaltic (density around 2.9) to ultramafic (density around 3.1). The Kolari greenstones fall in the ultramafic end of the trend. Two samples of equivalent greenstones have been added from the neighbouring map area 29 M Huuki. The high magnetic fraction has a lower density indicating basaltic composition with a tendency towards intermediate for two samples from the Käymäjärvi area. The q-values are low for the high magnetic group (about 0.4) and scattered from 0.02 to 8 in the low magnetic group.

Basic volcanics from the south-western quadrangle (Suorsa region) have a single cluster with rather high magnetization and densities indicating a composition less mafic than the corresponding high magnetic group of basaltic volcanics from the northern quadrangles. The samples are scattered all over the Suorsa region. The q-values are scattered around a fairly high mean value of 0.7. Extreme high values of over 10 occur.

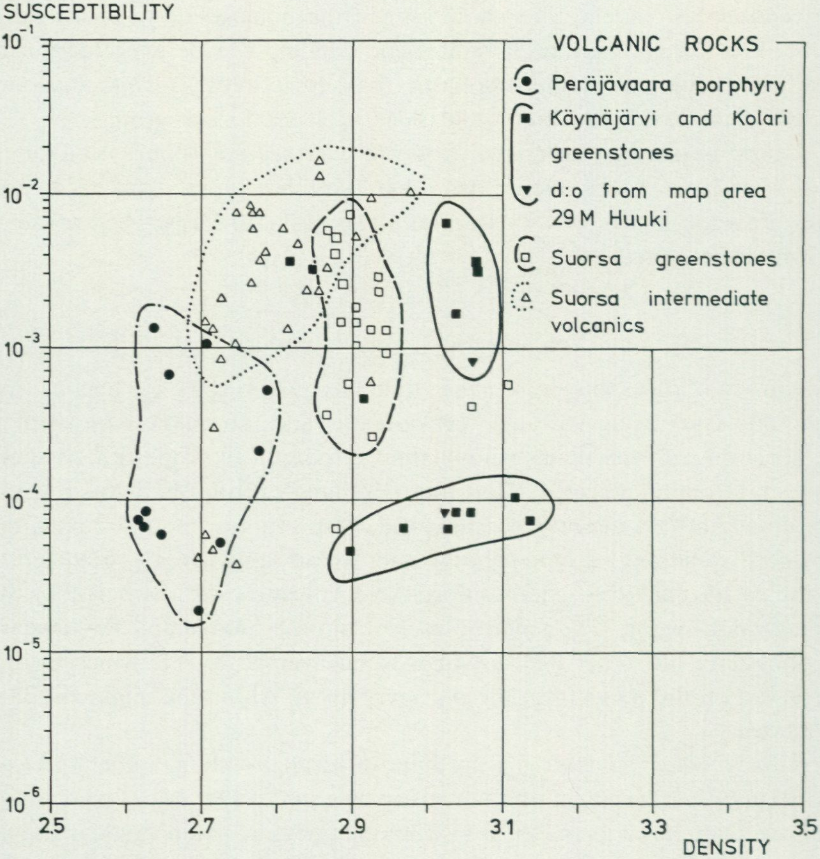


Fig. 14. Density — susceptibility diagram.
Densitet — susceptibilitetsdiagram.

Intermediate volcanics from the south-western quadrangle (Suorsa region) have a large cluster in the high susceptibility area of Fig. 14. Their densities indicate typical intermediate compositions. The samples are spread over the entire Suorsa region. Andesite porphyries occur in the lower density area. The q-values are scattered around a high average q-value of 0.6. The low magnetic samples all have q-values larger than 1.

Porphyries from the Peräjävaara area, have rather low densities, but not as low as would be necessary for rhyolites. The main part of the samples thus have a composition equivalent to granodiorites or syenites (compare

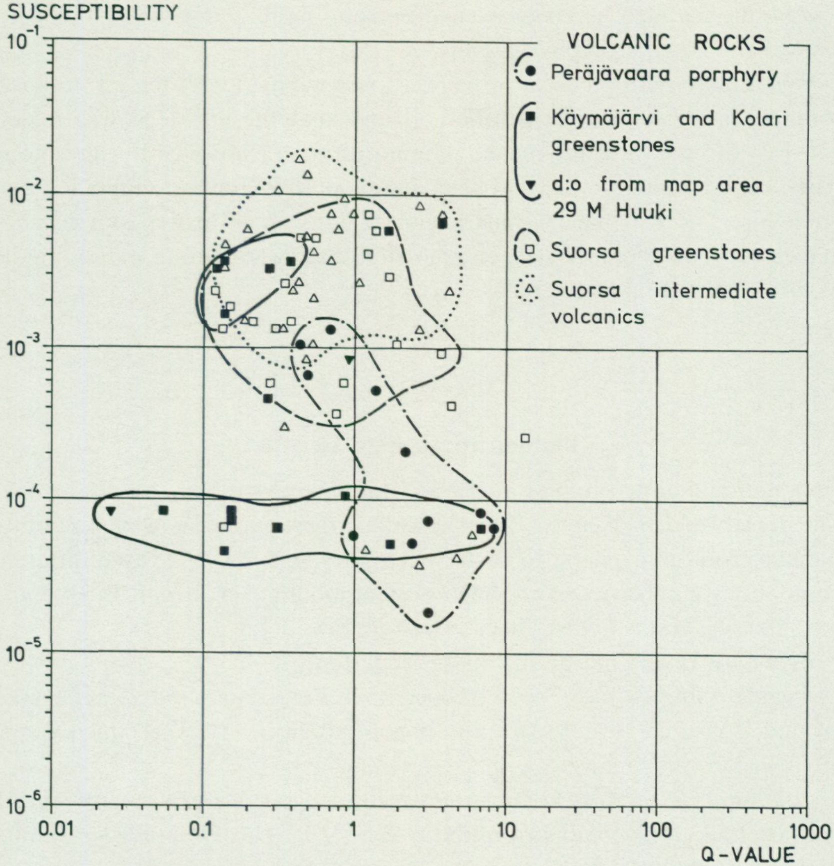


Fig. 15. Susceptibility — q-value diagram.
Susceptibilitet — q-värdesdiagram.

the corresponding properties for these plutonic rocks in Fig. 18), but their susceptibilities are significantly lower than for these rocks. A moderately magnetized group has q-values scattered around 0.4 and a low magnetic group has q-values around 4.

It is obvious that the petrophysical properties of the volcanic rocks are strongly geographically differentiated. The properties of the samples from the northern quadrangles are very similar to basalts of the Kiruna greenstone group in the map areas 29 K Vittangi, 30 K Soppero and 30 L Lannavaara while the volcanic rocks sampled in the Suorsa region have properties resembling the high magnetic volcanics from the map area 28 K Fjällåsen which belong to the porphyry group.

When these petrophysical properties are combined with the information from the gravity map, it becomes obvious that the entire Suorsa region consists of intermediate—mafic composition volcanics with ultramafic types subordinate as the area displays moderate gravity anomalies and gradients. The Käymäjärvi and Kolari regions show higher gravity anomalies and considerably steeper gradients thus representing mainly mafic — ultramafic composition rocks.

Plutonic rocks, Figs. 16—20

Dominating among plutonic rocks are *granites* which have a uniform silicate density of 2.62 g cm^{-3}. They show the largest variation in susceptibility ranging from unmagnetic to such high values as $5 \cdot 10^{-3}$. Three different populations can be observed, having susceptibilities at $<10^{-6}, 4 \cdot 10^{-5}$ and $1.5 \cdot 10^{-3}$ cgs respectively. The q-values are low, 0.3.

Pegmatite is very like granite in its properties.

Syenite samples have been collected at Peräjävaara having densities around 2.67 g cm^{-3} and susceptibilities of about $3 \cdot 10^{-3}$ cgs, the q-values are low.

Granodiorite samples comprise a very homogeneous group with silicate density 2.69 g cm^{-3} and susceptibility $2.5 \cdot 10^{-3}$ cgs. Q-values are similar to those of granites, i.e. 0.3.

Some samples of *diorite* show fairly uniform silicate densities around 2.8 g cm^{-3} and susceptibilities around $4 \cdot 10^{-3}$ cgs. Q-values are again similar to those of granite. Granite, syenite, granodiorite and diorite will all give rise to high magnetic anomalies of irregular pattern. Only granites can in addition give moderate low and very low anomalies. They will also give gravity lows.

Gabbro samples have been collected from 3 larger gabbro massifs and from a few other scattered localities. All samples show a fairly narrow silicate density range around 2.86 g cm^{-3} and high to very high susceptibility. Some tendency for high q-values is present, the highest value being 8. These rocks will obviously produce very high magnetic anomalies with irregular pattern (or in cases circular anomaly patterns). Samples with

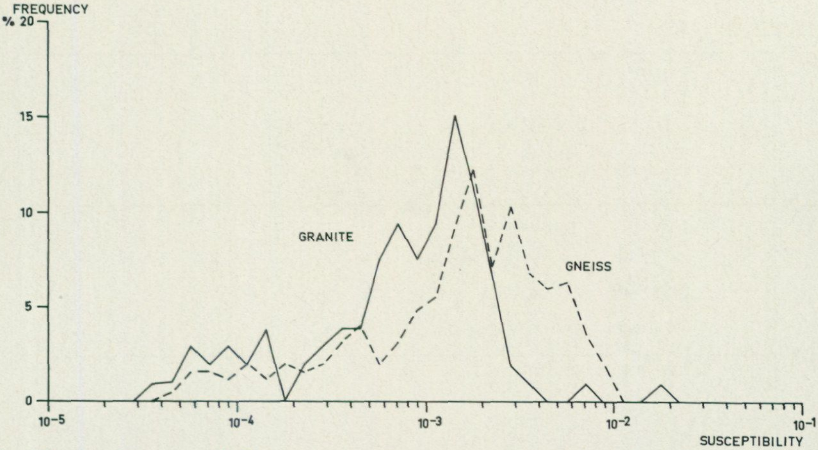


Fig. 16. In-situ susceptibility measurements on granites and gneisses from the south-eastern quadrangle. Class width 0.2 dekades.

Hällsusceptibilitetsmätningar på graniter och gnejser från SO-bladet.

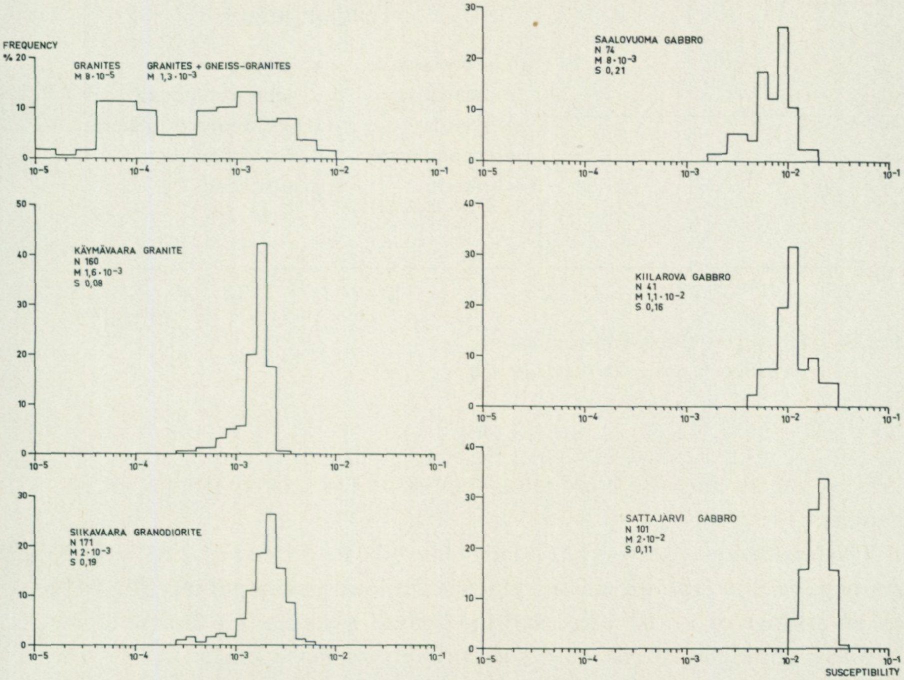


Fig. 17. In-situ susceptibility measurements on plutonic rocks. Class width 0.2 dekades (upperleft diagram) and 0.1 dekades, N, M, S denote number of measurements, mean value, and standard deviation respectively.

Hällsusceptibilitetsmätningar på djupbergarter.

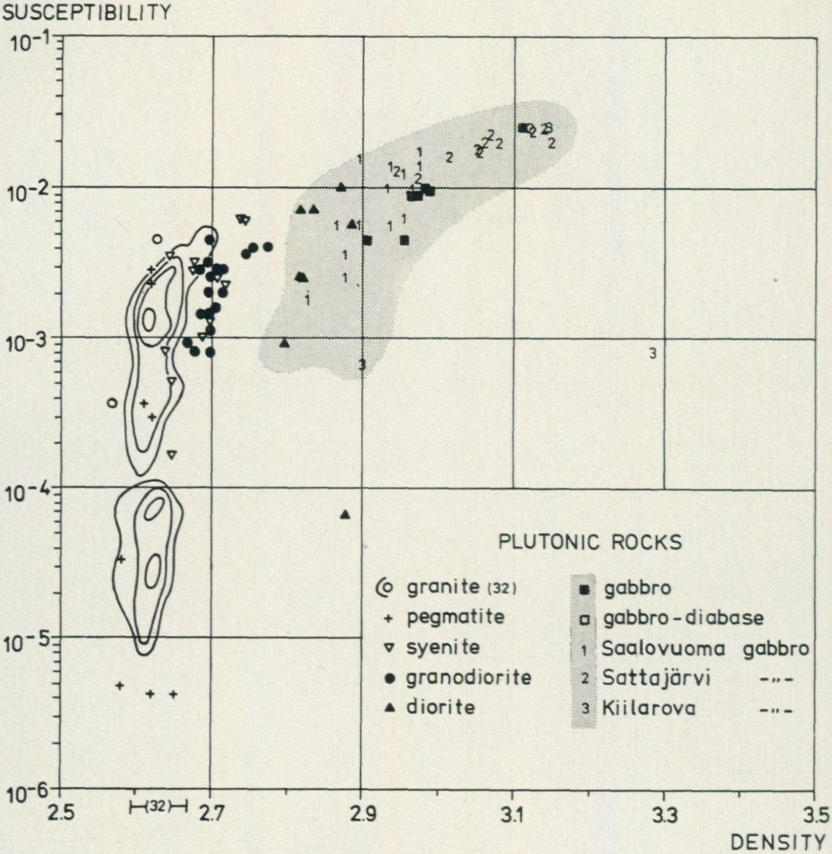


Fig. 18. Density — susceptibility diagram.
Densitet — susceptibilitetsdiagram.

large q-values must be considered important for paleomagnetic investigations.

The Saalovuoma gabbro has a fairly low silicate density of 2.85 g cm^{-3}. Among the three gabbro massifs this has the lowest susceptibility (Fig. 19) on an average of $8 \cdot 10^{-3}$ cgs, and the highest q-values in a characteristic negative correlation trend with susceptibility on an average of 1.5. The NRM (natural remanent magnetization, Fig. 20) exhibits a characteristic direction with inclination 65 and declination 320 degrees respectively. This direction has been observed on several gabbro massifs in Norrbotten,

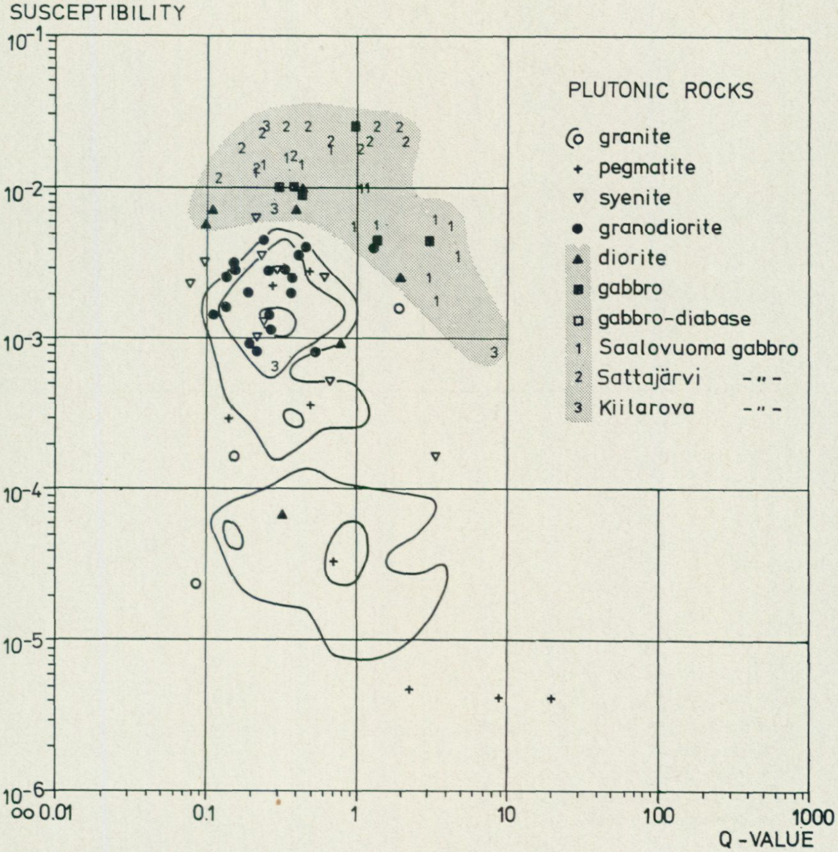


Fig. 19. Susceptibility — q-value diagram.
Susceptibilitet — q-värdesdiagram.

among them the Tärendö gabbro (Cornwell 1968), the Peuravaara gabbro (Henkel 1977) and the Naakajärvi cone sheet system (Henkel 1977).

The Sattajärvi gabbro has a higher silicate density, 2.93 g cm^{-3} and a very high susceptibility of $2 \cdot 10^{-2}$ cgs. It has a characteristic correlation trend in the susceptibility — q-value diagram which has been observed on other extreme magnetite-rich gabbros, such as the Akkavare gabbro (Henkel 1975). Its direction of NRM has a declination of 205 and an inclination of 40 degrees. The declination is slightly larger than that of the Saalovuoma gabbro while the inclination is lower. The average NRM directions of these two gabbro massifs lie on a great circle through the

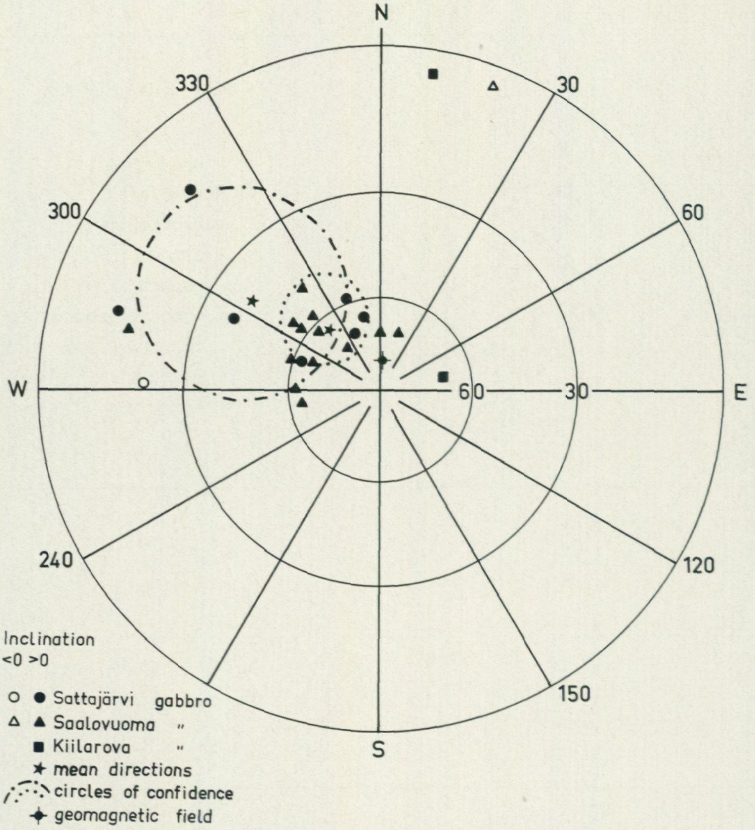


Fig. 20. NRM of some gabbro massifs.
NRM för några gabbromassiv.

present geomagnetic field, indicating that different amounts of viscous remanence only are responsible for differences in NRM between these massifs.

The Kiilarova gabbro. Only three samples are collected from this gabbro. One of these has extremely high silicate density (almost 3.3 g cm^{-3}) and a high q-value of 8, while the others coincide with the Sattajärvi gabbro. In-situ susceptibility measurements, mainly on local boulders, give an average susceptibility of 1.1 · 10^{-2} cgs. The NRM directions are inconclusive.

Conclusions regarding the physical properties of rocks

The density reflects as a rule a basic to acid variation in composition of the rocks. Therefore, when larger rock volumes are considered, the gravity anomaly can be used to depict the average rock composition. *The remanent magnetization* is small as a rule. Exceptions are found only among gabbros and a minor part of the supracrustal rocks. This small remanence seems to be more or less parallel to the present geomagnetic field and for the majority of rocks therefore the *total magnetization* T can be approximated as a linear function of susceptibility k:

$$T = k\,H\,(1 + q)$$

where H is the geomagnetic total field (which is 0.522 Gauss in the map area). The average q-value is 0.71.

$$T = 0.89\ k$$

The highest magnetizations are found among basic plutonic rocks and volcanic rocks. Within these groups a variation by a factor of 10 is to be expected, giving rise to a similar variation of the magnetic anomaly on a high background level. Judging from the large areas of high gravity and magnetic banded anomalies, a certain underrepresentation of the most magnetic members of the volcanic rocks of the greenstone group seems to have occurred. The basic members of this group will give *large positive gravity* anomalies when present in larger volumes. Some of the gabbros will show exceptionally high magnetizations as they have an additional high remanence.

Intermediate magnetizations are displayed by all rocks found within the map area. In this case the density is the only distinguishing factor and for larger volumes the gravity anomaly together with the magnetic pattern must be used to suggest rock types.

Low magnetizations are found among acid plutonic rocks, metasediments and volcanic rocks of the greenstone group. Especially the occurrence of unmagnetic greenstones should be mentioned, as they can be identified by their very distinct combination of low magnetic and high gravity anomalies. The acid plutonic rocks usually will give rise to *large gravity lows.*

In Fig. 21 a comparison is made of the ranges of magnetization of larger rock groups.

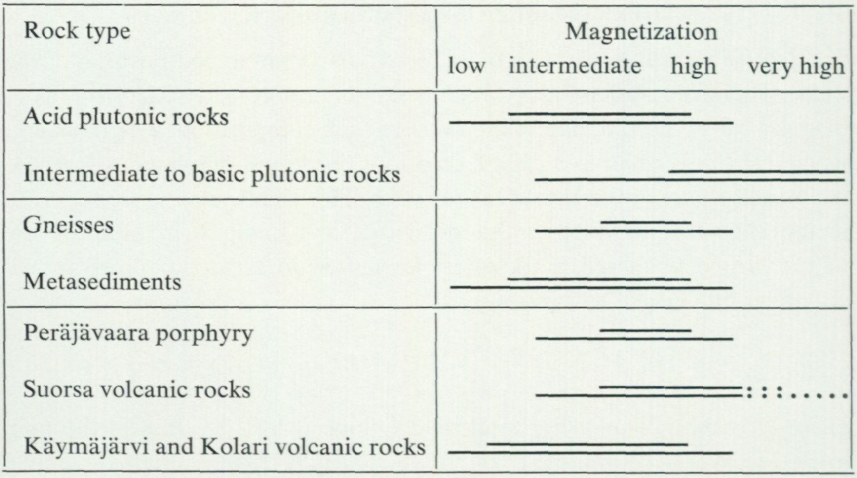


Fig. 21. Variation of bulk magnetization in different rock groups. The single line shows the total range of magnetization, the double line denotes the location of the main part of samples, and the dotted lines indicate the assumed range not represented in the parameter measurements.

Magnetiseringen för olika bergartsgrupper.

Gravity interpretation

In the map area a regional gravity survey has been made with an average station spacing of 0.75 km. The Bouguer anomaly map, Pl. 2 C, is based on a total of 3 215 stations including selected stations from local surveys made for prospecting purposes. The anomalies are terrain corrected and the Bouguer density used is 2.67 g cm^{-3}. The gravity anomalies give a good picture of the volume distribution of rocks with different composition. On three profiles a computation of 3-dimensional rock distributions has been made. In some other cases depth estimates have been computed using anomaly parameters and standard diagrams for simple shaped bodies. As a rule there is a very close correlation between gravity and surface geology.

Regional anomaly patterns

The map area and its surroundings show large variations in regional gravity anomalies. To the north and south-east extensive minima of –30 mgal dominate, while anomalies to the west increase over a large area having maxima up to +5 mgal. This super-regional anomaly pattern appears to have a wave length of about 100 km. Within the map area, local anomalies have wave lengths of about 20 km and below. Roughly three different gradients can be observed, 2—3, 4—6 and 10 mgal km^{-1} which indicate that significantly different density contrast are involved in the cause of the anomalies. The correlation of magnetic and gravity anomalies gives important information for the interpretation of geological structures. When gravity anomalies coincide with magnetically banded patterns, a combination of the amplitude of anomalies and their gradients can suggest which supracrustal rock type is responsible for the observed structure. When gravity anomalies coincide with magnetically irregular patterns plutonic rocks are the most obvious cause of these anomalies, and again amplitude and gradients reveal the composition of the rocks in question.

In the northern quadrangles a system of positive anomalies with steep gradients (about 10 mgal km^{-1}) is associated with magnetically banded anomalies from map squares 9e to 5d and from 9e to the north, and at 9h (and northwards). A smaller positive anomaly with similar gradients stretches from 9a to 7b. Between these maxima several more or less rounded minima occur at 9b, 9d, 9f and 8h which coincide with regions of irregular magnetic anomaly patterns and low magnetizations. The rounded positive anomaly at 6c coincides with a high magnetic irregular anomaly.

In the south-eastern quadrangle a large positive anomaly with gradients of 2—3 mgal km^{-1} goes between map squares 6f and 1f. The southern part of this anomaly coincides with a moderately magnetic region.

In the south-western quadrangle the regional gravity increases from a minimum of –25 mgal via a sharp NNE trending gradient (4—6 mgal km^{-1}) at 4c — 0b into a maximum centered on the Tärendö gabbro on the map area 28 L SO.

Profiles, Fig. 22

A more detailed gravity interpretation has been made along three profiles. In the model computations infinitely long prisms with polygonal cross sections were used. The dimensions at the surface have been determined from aeromagnetic anomalies or from geological observations. The density contrasts used are averages for the proposed geological formation.

The north-western profile, which runs over the Käymäjärvi structure and the Käymävaara dome, shows the limited depth extend of the Käymäjärvi

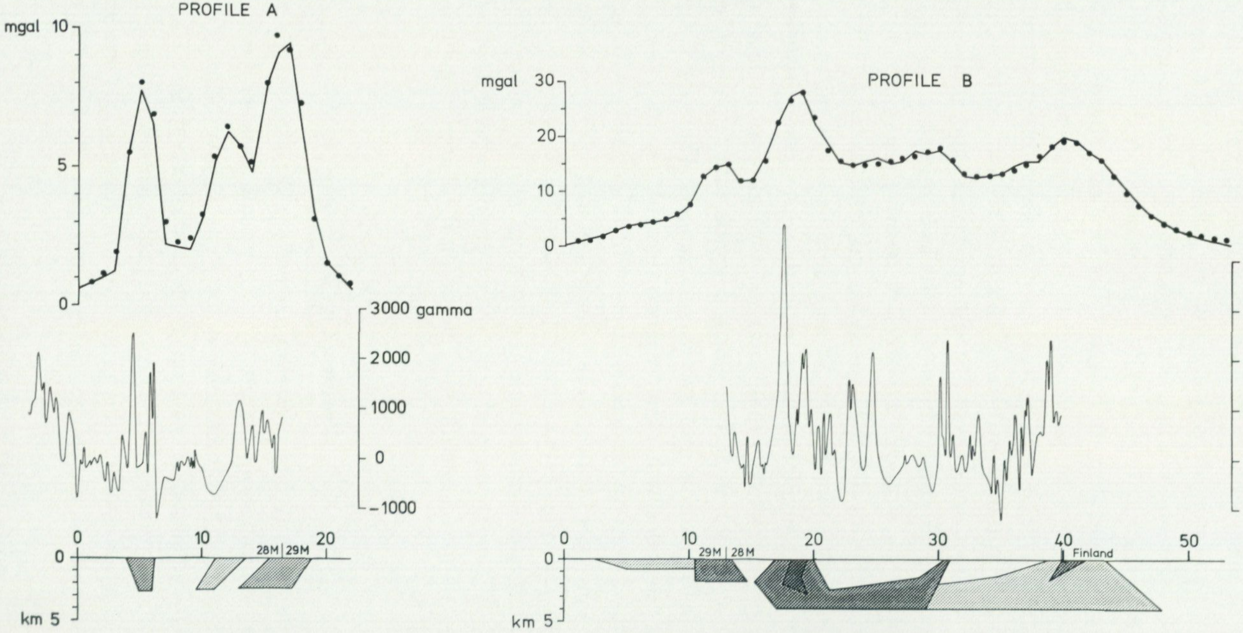
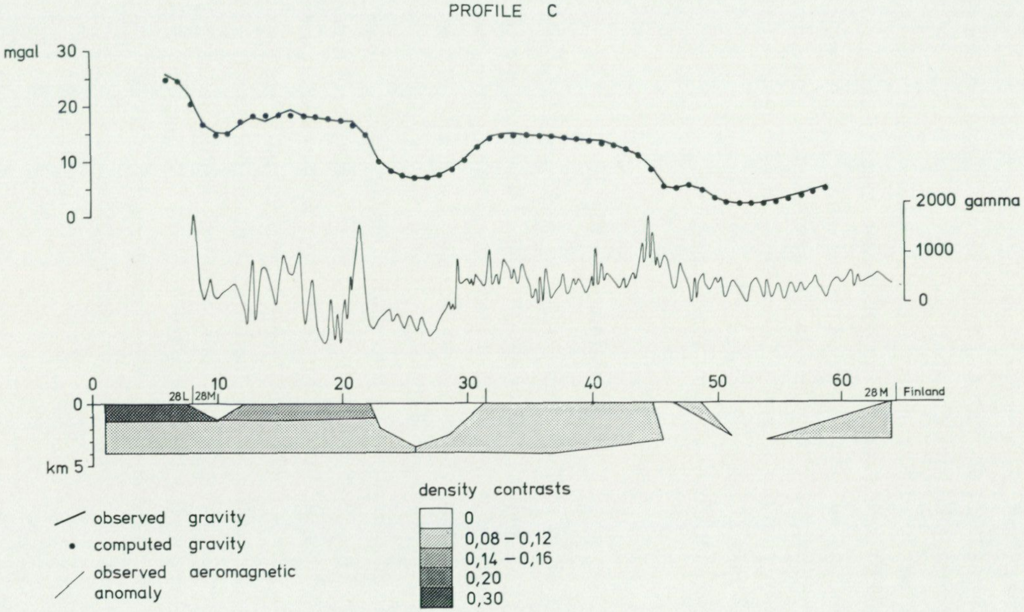


Fig. 22. Gravity and magnetic profiles, together with computed density distributions.
Tyngdkrafts- och magnetiska profiler, tillsammans med beräknade densitetsfördelningar.


PROFILE C
mgal
30
20
10
0
2000 gamma
1000
0
0
10
20
30
40
50
60
28L
28M
28M
Finland
0
km 5
observed gravity
computed gravity
observed aeromagnetic anomaly
density contrasts
0
0,08 – 0,12
0,14 – 0,16
0,20
0,30

greenstones and associated rocks. Combined with the north-eastern profile, running over the Sahavaara structure towards the south-east, it clearly shows that the depth of the greenstones increases to the east, while towards the Finnish border it decreases again. Several large faults are necessary to explain the computed rock distributions.

The southern profile, running over the Suorsa greenstone group to the west and gneiss structures to the south-east, gives important information on the relations of these greenstones to other rock complexes. Again important faulting, also indicated by the aeromagnetic maps, is responsible for the distribution of rocks. The occurrences of syenite are at Honkavaara and Peräjävaara closely associated with very homogeneous and regular gravity lows of clearly discordant appearence.

Depth estimations, Fig. 23

Depth estimations to the lower surface of rock units have been made on a number of anomalies outside the profiles. The amplitude of the gravity anomalies together with surface dimensions (some of them obtained from aeromagnetic interpretation) and density contrasts (from parameter measurements) have been used for depth estimates. As the total composition of supracrustal complexes is uncertain, limiting depth values have been determined. These are shown in Fig. 23. The depths of rock complexes belonging to the greenstone group range from approximately 1 km (Käymäjärvi) to about 4 km (Jupukka). Anomalies caused by gneiss complexes (mainly on the south-eastern quadrangle) reach depths of 5 km. Among plutonic rocks, gabbros have rather limited depths, from 2 km (Saalovuoma gabbro) to 0.4 km (Sattajärvi gabbro). Granitic rock bodies have depths of 3 km (Käymävaara), and in gneiss areas over 5 km. Syenites have depths of about 2 km at Honkavaara and Peräjävaara.

Aeromagnetic interpretation

In the first phase, a regional interpretation is carried out. This permits the identification of different patterns and magnetization levels. Three types of pattern are observed: banded patterns consisting of parallel and continuous anomalies, irregular patterns in which these features are lacking or less

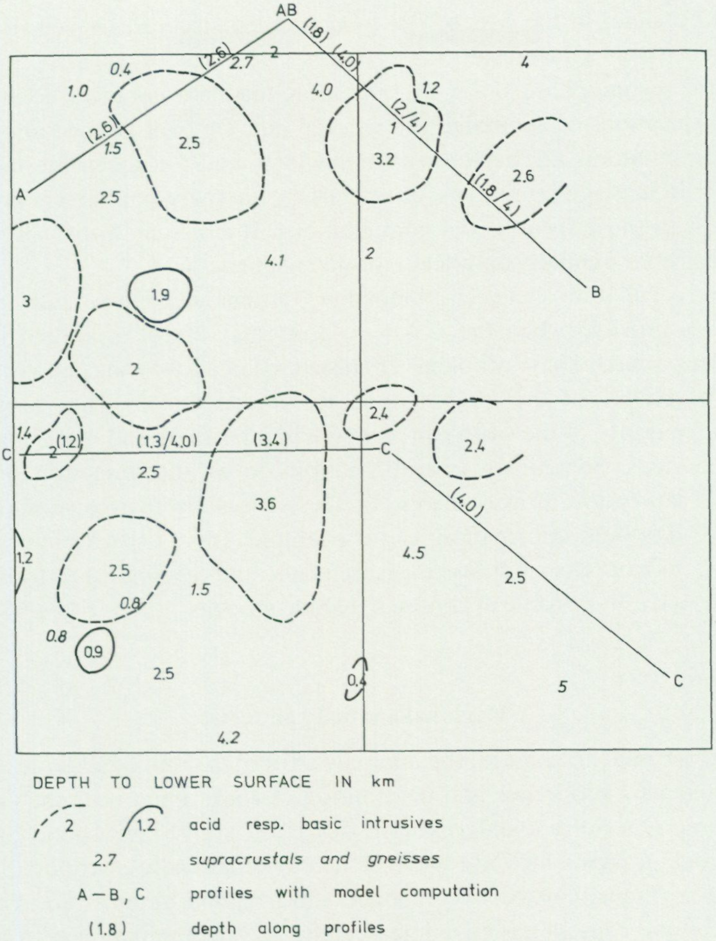


Fig. 23. Depth estimations from certain gravity anomalies.
Djupbestämningar.

pronounced, and dyke type patterns where anomalies are very continuous and generally discordant to banded or irregular patterns. The results obtained depend on the general geometrical configuration of the anomalies. For example it is impossible to identify flat-lying banded structures. Usually a sharp distinction between banded and irregular patterns is possible, in some cases however a continuous transition can be observed. As far as unmagnetic rocks are considered such distinctions are of course not normally possible. In the case of flat-lying banded structures a very irregular magnetic pattern may result.

In the second phase of the interpretation, magnetic contacts, connections and dislocations of anomalies are worked out. On well defined anomalies, dip computations are performed for contacts and for sheet-like magnetic bodies. In these computations, characteristic anomaly-parameters are compared with those from model computations. It is assumed that all magnetizations are essentially parallel to the geomagnetic field.

The correlation between anomalies, anomaly pattern and geology becomes possible when the magnetic properties of rocks are sufficiently well determined. These problems are discussed in a following chapter.

Some phases of the intepretation are evidently somewhat subjective, but the majority of the work can be made in physically and mathematically defined steps. Sometimes several solutions to an interpretation problem will all satisfy the measurements. In these cases alternative solutions are given. Additional information, as for example: gravity, petrophysical properties, in-situ susceptibility measurements and geological information, usually makes it possible to choose a reliable model.

Regional anomaly patterns

On the aeromagnetic maps, the anomaly pattern is dominated by the structure, magnetic properties and distribution of rocks lying near the surface. The three types of anomaly patterns described above correspond to three main rock groups which are more or less systematically distributed in the map area. Transitions between banded and irregular patterns are common in places and cause alternative interpretations. In combination with gravity anomalies it is however possible to reduce the number of alternatives.

Areas with banded pattern

Several large banded complexes occupy considerable areas on the map. Complexes with sharply defined high amplitude maxima are characteristic of the northern quadrangles. On the eastern part of the south-western quadrangle a few banded complexes occur with high anomaly levels and less sharply defined banding. On the south-western and south-eastern quadrangles low amplitude banding is characteristic. The strike of the banded complexes varies but is generally N—S or NE—SW except on the north-western quadrangle where NW—SE strikes are frequent. Folds are observed in several places but are not easily detectable. A good impression of the folding pattern is obtained from the anomaly systems on the map areas 28 M NO and 29 M SO.

A serious problem arises when low magnetic banded anomalies are in contact with low magnetic irregular anomalies because the actual contact can be difficult to delineate. In these situations, the banding is indicated out to the last continuous magnetic band, and in a few cases when characteristic conformal minima (other than contact minima) occur outside such an anomaly, these are included in the banded area. In a few instances extensive minima have been included in the banded complexes. However these may as well be mapped as low magnetic irregular anomalies. The only two rocks with properties corresponding to these situations are granite or quartzites as is obvious from parameter measurements. Both will give gravity lows when present in larger volumes (which as a rule is the case for granites). Many areas of the map are difficult to interpret according to the described system and therefore several alternative interpretations can be presented. Together with the gravity map however it should be possible to limit the number of alternatives. A few cases will be discussed below.

In the north-western quadrangle the banded anomaly complexes are well defined in the Käymäjärvi area. The extremely linear appearance of this banded complex indicates the effect of strong faulting east of the complex, which itself appears to be up-thrown. To the west and east of these anomalies extensive regions occur with low magnetic anomalies almost devoid of structures. These areas could well be interpreted as ”irregular patterns” but their conformity with the banded complex motivates an interpretation as ”banded pattern”. (A suitable low susceptibility and low density rock is quartzite, and a number of scattered outcrops of this rock occur in the area). East of Käymäjärvi the low magnetic structure describes a near circular ring around a low to moderate magnetic anomaly with considerably more structure occupied by a gravity low. South-east of this structure a similar but smaller low magnetic ring is observed, this time occupied by a small positive gravity anomaly. The former structure is almost certainly a granite dome, while the interpretation of the latter remains unclear. Farther to the south and east the whole Käymäjärvi—Käymävaara structure is surrounded by low to moderate magnetic diffusely banded anomalies with low to intermediate gravity anomalies. Pelitic schists or gneisses could according to their physical properties well explain this feature.

In the southern part of the north-western quadrangle an arcuate magnetically banded structure occurs within a considerably gravity low. The shape and amplitude of this low indicates the presence of a massive low density rock. As the magnetic structure has no gravity expression, low density and moderately magnetic banded rocks such as porphyry or quartzite may explain the near surface structure, but at depth granite or syenite becomes the only possible rock type.

In the south-western quadrangle extensive areas are occupied by magnetically banded anomaly systems. The areas around Suorsapakka show high magnetizations while the remaining areas have moderate and even low magnetizations and low amplitudes. Effects of strong faulting are evident and give rise to very linear boundaries of some of the complexes. The interpretation is guided by the gravity measurements. The southern and eastern banded areas lie on moderate gravity anomalies with low gradients indicating that intermediate density rocks are prevailing. Gneisses seem to be the most suitable rock type. The banded areas in the north-western part of the quadrangle show higher gravity anomalies and steeper gradients indicating the occurrence of denser rocks. The gravity anomalies are however low in amplitude and with smaller gradients than those observed over the Kaunisvaara structure. Therefore either rocks with intermediate density (and thus composition) make up the entire anomaly, or high density rocks make up a minor part of it.The latter alternative is shown in the profile of Fig. 22.

The south-eastern quadrangle has in its western parts a dominating banded magnetic pattern which coincides with a moderate low gradient gravity high. This combination of anomalies is easily produced when gneisses constitute a significant part of the rocks. This anomaly pattern can be followed to the north-east. The magnetic amplitudes tend however to increase and the magnetic back ground level becomes lower on the south-eastern part of the north-eastern quadrangle. The reason for this change is unclear and an interpretation including greenstones in smaller volumes seems possible.

Areas with irregular pattern

The areas with irregular anomaly pattern show in many cases a diffuse structure, either conform with the border of the individual anomalies or conform to surrounding banded anomaly systems. A gradual transition between these patterns can sometimes be observed (at map squares 0—1 g—h for example).

Very high magnetizations are restricted to a few local anomalies, the largest being at 6c with an amplitude of 5 000 gamma. A similar anomaly occurs at 5c and 1b (amplitudes 3 000 gamma). At 0—1 f—g an irregular shaped anomaly with an amplitude of 6 000 gamma displays deep contact minima to the north-west, indicating a pronounced effect of remanent magnetization with a north-westerly declination.

Near the western margin, at 2a, high amplitude anomalies appear which continue to the west and show irregular patterns of internal structure. On the map area 28 L SO all of these anomalies have accompanying gravity highs of different amplitude and high gradients and are therefore best explained by the occurrence of basic plutonic rocks.

High magnetizations are displayed by several larger anomaly complexes, at 7—8a, 8—9d, 6b, 5g and 3e—f. They are all associated with moderate gravity anomalies indicating the presence of rocks with intermediate composition.

Large areas with moderate magnetization occur in the south-eastern quadrangle at 4g and 0—2 h—1. Areas with low magnetizations occupy the main part of the map, either as small complexes within banded anomaly patterns, or as large continuous anomalies such as those in 2—4b. They are all associated with gravity lows indicating rocks of acid composition. Some of the interesting irregular pattern anomalies have remarkably well rounded contacts. Such features are separately presented in the map of Fig. 24 together with a listing of their geophysical characteristics. Some of the features may well be domes of granitic or syenitic rocks. The profiles A and B in Fig. 22 are arranged over several of these features.

Dyke systems

In the map area dykes with prominent geophysical expressions are rare. A few anomalies can be interpreted as dykes (compare signature in Pl. 2 A). At map squares 8—9 a—b two dyke swarms trending NNW can be inferred.

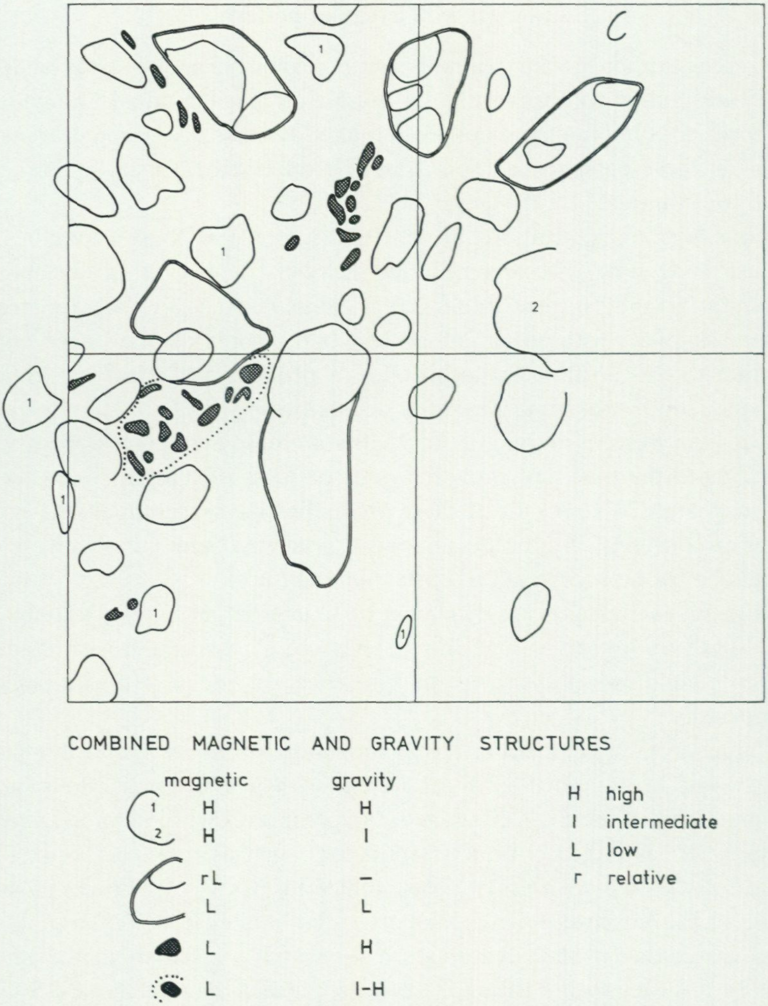


Fig. 24. Diffuse magnetic patterns and associated gravity anomalies.
Mindre tydliga magnetiska strukturer och tillhörande tyngdkraftsanomalier.

Other swarms occur at 4—5 d–e, 4g and 0—1 a—b. Magnetically dykes can only be detected if their magnetization differs significantly from the surrounding rocks and if their width is larger than 20 m. Smaller dykes will only contribute randomly to the anomalies, when dykes strike near E—W their width must increase considerably (up to a factor of 5) in order to be detectable.

Obviously a certain correlation with the directions of dislocation zones can be inferred, which may be caused by intrusions into these zones.

Magnetic dislocations

Magnetic dislocations can be deduced from displacements of reference structures such as banding, characteristic contacts or dykes. The frequent occurrence of reference structures in the map area makes possible a rather detailed investigation. Usually, dislocations parallel to prominent bands and dykes or parallel to the flight lines can not be discerned. As distortions along the flight direction are sometimes attributed to lack of control in the measurements, they are usually not taken into consideration. Therefore, a tendency of underrepresentation in E—W direction is obvious.

The dislocations and inferred lateral displacements are shown on Plate 2 B. The true lateral displacements depend on the occurrence of vertical components of motion and of the interference with the dip of the reference structures. Vertical displacements have not been observed but are very likely to occur. If vertical displacements are significantly smaller than the depth of a vertical structure, then no special expression of the anomaly will result.

Fig. 25 shows four different directions striking —35, 5, 35 and 60 degrees. Two of these directions, —35 and 35 degrees respectively are known from other map areas in Norrbotten while the other two directions seem to be restricted to the eastern part of Norrbotten. Some of the N—S striking dislocations extend for more than 100 km south of the map area. The apparent lateral displacements are all within 3 km and the most frequent amount of apparent displacement is 0.25 km. The spacing of dislocations is approx. 10 km between major zones for all directions. The width of single longer zones may amount to 1 km. Some of the dislocation zones have very pronounced effects on the distribution of rocks as they place together physically quite different rock units. The zones indicated with heavy lines on Pl. 2 C are especially prominent and can, due to the great displacements involved, also be followed on the gravity maps. The extensive NE—SW striking zone and the N—S striking zone may both have vertical throws of about 1 km or more (compare profiles in Fig. 22). A large vertical displacement is also involved in the fault zone east of Käymäjärvi.

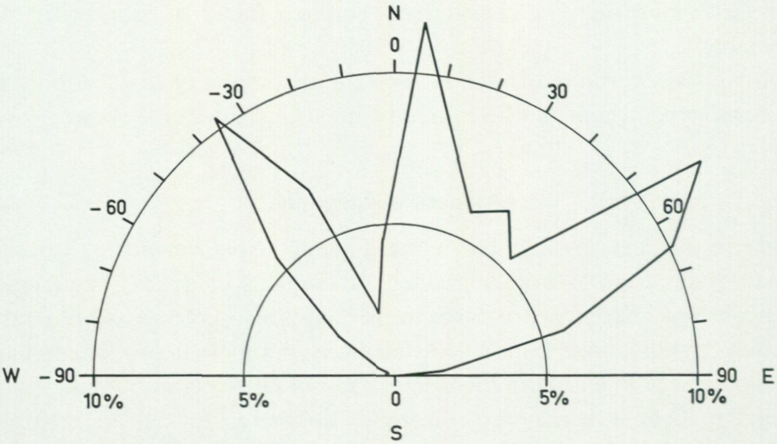


Fig. 25. Frequency distribution of the directions of magnetic dislocations in 10 degree intervals.
Frekvensfördelning för magnetiska dislokationer.

Conclusions regarding the combined interpretation of aeromagnetic and gravity measurements

From the petrophysical properties of rocks from this map area it is obvious that a certain rock has a rather limited density range, while it is found that most rocks have a large variation in their magnetization. In such a situation the combined information from gravity, magnetic and petrophysical measurements is necessary when a prognosis of rock types is to be made. From the aeromagnetic map therefore the structural information is the most important part and to a lesser extent the anomaly itself. The relatively long wave length components of the aeromagnetic anomaly gives, together with the single gravity anomalies, a defined range of density-susceptibility variation. Then using the information from petrophysical properties of rocks and the magnetic structure pattern, usually a very limited set of rocks can be selected which satisfy the observed pattern. From the aeromagnetic map the general dip of sheets or contacts is an important guide to the depth computations where the gravity anomalies are used. A study of the long wave length components of the gravity anomaly gives important information on the local structure on this map area which lies in an extensive gravity low. The corresponding high is in the map areas 30 L and 30 M found to be associated with outcropping high density basement gneisses (Lindroos and Henkel 1977).

In a few areas where the interpretation of the aeromagnetic anomalies alone (and where the geological information is scarce or complicated will not be sufficient, a combined interpretation will be discussed in more detail. A similar discussion can easily be made for the entire map area and makes possible a rather good prognosis of rock types and structures.

The Peräjävaara region is characterized by an extensive gravity low which is roughly circular and on average 8 km in diameter. This gravity anomaly is sharply discordant and has as a rule high gradients indicating an intrusive rock with homogeneous low density. The corresponding magnetic anomaly is much more complex. Within the anomalous area a partly banded pattern is bending around the northern margin of the complex. This pattern is strongly discordant to the surrounding magnetic patterns to the north-east and south-west. It must be concluded that large parts of the anomaly are occupied by stratified rocks with similar and acid composition and large variation in magnetization. Metasediments appear therefore to be a suitable rock type for this pattern. The main volume of the anomalous rock body is however assumed to be an intrusive rock because the depth and the structure of the metasediments, which would be needed to account for the gravity anomaly, appear rather unlikely. Within the anomaly outcrops occur of porphyry, syenite, quartzite and aplitic granite. The occurrence of quartzite makes the occurrence of other metasediments likely. Syenite seems to be the intrusive rock responsible for the gravity low. The occurrence of porphyry is best explained as a local contact facies of syenite as it is restricted to the Peräjävaara region. The similar (with respect to stratigraphy) position of the Honkavaara and Peräjävaara syenites must be emphasized as well as the similar position of the gabbros at Kaalamaakoski, Saalovuoma and Peräjävuoma. The syenites are emplaced in the Pahakurkkio metasediments while the gabbros occur above this stratigraphical level.

The area west of Sahavaara and north of Kursuvaara has very complex gravity and magnetic anomalies. The contacts of the main magnetic and gravity anomalies are strongly displaced in the western part of the area. The rather high gravity anomaly is conformable with the large anomaly around Sahavaara and continues to the north into the map area 29 M Huuki. A magnetic diffuse banded anomaly complex lies conformably but displaced to the west along the gravity anomaly. Farther to the west the entire structure terminates against the Käymävaara granite dome. The described pattern indicates the occurrence of stratified rocks with at least intermediate and up to mafic composition in the eastern parts of the anomaly complex and stratified rocks with acid composition and moderate magnetization in the western parts of the complex. Suitable rocks would be greenstones and associated sediments respectively sedimentary rocks of the Pahakurkkio group. The separate gravity anomaly in the southern part of the complex (at Ahvenvuoma) may well be interpreted as an intrusion of mafic rocks as the magnetic anomaly has a rather irregular appearance.

The area around Suorsapakka and northwards is characterized by very high magnetic anomalies and a rather homogeneous gravity high with moderate gradients. To the south-west the anomaly complex is terminated against a magnetic homogeneous and near circular low (which also corresponds to a gravity low) and to the north-west the previously discussed Peräjävaara structure terminates the anomaly complex. The parameter measurements (p. 46) indicate that the central part of the structure (where most of the samples were taken) is dominated by high to very high magnetic volcanic rocks of intermediate to mafic composition. According to the gravity anomaly it can be concluded that this type of rock well may dominate the structure except at its south-eastern extremity where a much smaller gravity anomaly with low gradients indicates the occurrence of an intermediate to acid rock type (these anomalies will be treated in the next section below). The density contrast of the volcanic rocks to that of pelitic schists is very small and magnetically a tendency for larger variation in magnetization among the pelitic schists is observed. Thus homogeneous high magnetic anomalies within high gravity anomalies indicates the volcanic sequence while changing high and low magnetic anomalies indicate the occurrence of schists. To the east the structure is terminated against a prominent N—S trending fault with large vertical throw which is assumed to be downwards on the western side.

The anomaly complexes north and south of Lylyvuoma constitute prominent magnetic features associated with rather weak gravity anomalies. The magnetic anomalies show a distinctly banded pattern in detail and a parallel arrangement of larger high and low magnetic units. This pattern is not reflected in the gravity anomaly which instead shows a moderate high over the entire area. As the gravity gradients are low this anomaly complex is best explained by the occurrence of acid—intermediate gneisses with properties similar to those occurring on the south-eastern quadrangle.

The entire structure is abruptly terminated to the west by a huge gravity high with moderate and locally even high gradients. Part of this gradient is associated with a prominent almost N—S trending fault with considerable vertical throw (assumed downwards on the western side).

The magnetic high north of the Torneälv Muonioälv junction constitutes part of a near circular feature which can be traced into Finland on the low altitude aeromagnetic measurements made by Rautarruki OY. The corresponding gravity anomaly is indifferent to this feature but shows weak patterns inside it. The magnetic gradients indicate that the structure comes to or near the surface. As the surrounding gravity anomaly is rather high and no significant density contrast occurs, an intermediate composition rock with a rather homogeneous high magnetization must be assumed to explain the structure. The lack of systematic magnetic pattern and the near circular circumference of the structure indicates that a plutonic rock is the most likely alternative.

The prominent gravity low at Muotkavuoma and a similar but weaker gravity low farther to the west are both near circular structures with smaller internal anomalies. To the north-west the Muotkavuoma anomaly is terminated against a large fault trending north-east with considerable vertical throw assumed to be downwards on the north-western side. Magnetically a considerably more complex structure is obvious with a much larger amount of details. As one of the profiles crosses these structures only a short comment on the possible nature of these features will be given here. The almost circular appearance indicates the occurrence of an intrusive rock which must be of an acid composition according to the gravity anomaly and its gradients (which are very high towards bordering mafic volcanic rocks). According to the profile computation, the depth of these intrusions is rather limited giving them a sheet like appearance. The smaller anomaly pattern inside the structures is best explained as near-roof remnants of the surrounding rocks. An important observation throughout Norrbotten is that this type of structure typically occurs where large supracrustal sequences with a considerable amount of mafic rocks are expected. They thus occur in areas where the conditions of an unstable layering necessary for the hypothesis of Ramberg (1972) for the development of diapiric structures are present. It is very likely that most of these observed features are domes in Ramberg's sense. This implies that the surrounding rocks are strongly and systematically deformed into more or less overturned synclines and that the domed rocks represent the mobilized basement to the supracrustal rocks.

Ground geophysical measurements for prospecting

In the map area several large ground geophysical surveys have been made for prospecting purposes. Specifications of the kind and extension of these measurements are given in the table of Fig. 26. On Plate 2 D the position of these measurements is indicated with map scales and -divisions.

Area	Year of measurement	Type of measurement	Area in km²	Map square
Suorsa	1966—67	M	24	2—4b—c
		G	12	
Peräjävuoma	1966—67	M	6	4—5a—b
		G	6	
Erkheikki	1966—67	M	40	5—6c—d
		G	40	
	1970	E	3	
Käryjärvi	1967	M	2.5	6—7e—f
		G	12	
Käymäjärvi	1966—67	M	40	7—9a—b
		G	40	
	1952	E	8	
Kaunisjoki	1968	M	3.5	9d
Kaunisvaara	1963—65	M	45	8—0d—f
		G	45	

M = magnetic vertical intensity
G = gravity
E = electromagnetic slingram

Fig. 26. Specifications of ground geophysical surveys for prospecting purposes. *Markgeofysiska mätningar.*

TABLE 2. Physical properties of rock groups. a, b, c, d, denote total group, high magnetic fraction, low magnetic fraction, and low magnetic fraction below resolution of instrument, respectively.
Units are in cgs. Standard deviation for density is in cgs, for magnetic properties in dekades. Magnetic properties have logarithmic mean values.
Fysikaliska egenskaper för bergartsgrupper.

Rock group	Number of samples	Density		Susceptibility 10^3		q-value	
		mean	st. dev.	mean	st. dev.	mean	st. dev.
1 granite a	118	2.63	0.080				
b	56			1.1	0.39	0.32	0.29
c	30			0.035	0.30	0.73	0.48
d	32			≤ 0.001			
2 pegmatite a	9	2.60	0.017				
b	4			0.96	0.52	0.30	0.35
c	5			0.0046	0.57	3.9	0.58
1+2	127	2.63	0.095	0.066	1.3	0.68	0.49
3 syenite	12	2.68	0.037	1.8	0.47	0.31	0.44
4 granodiorite	19	2.70	0.026	2.2	0.24	0.27	0.28
3+4	33	2.70	0.033	1.3	0.87	0.41	0.86
5 diorite	8	2.84	0.034	2.5	0.72	0.43	0.53
6 gabbro	37	3.00	0.103	10	0.41	0.30	0.49
5+6	45	2.97	0.113	8.0	0.52	0.72	0.50
7 Käymäjärvi and Kolari greenstones a	16	3.00	0.096				
b	8			2.96	0.37	0.39	0.57
c	8			0.070	0.11	0.38	0.72
8 Suorsa greenstones	21	2.92	0.061	1.6	0.42	0.74	0.56
9 Suorsa intermediate volcanics a	31	2.79	0.075				
b	27			3.3	0.43	0.60	0.41
c	4			0.046	0.07	3.4	0.29
8+9	52	2.84	0.093	1.6	0.66	0.70	0.51
10 Peräjävaara porhyry a	12	2.68	0.075				
b	5			0.63	0.30	0.88	0.32
c	7			0.031	0.69	3.3	0.34
11 limestone	7	2.82	0.054	0.013	0.69	1.05	0.58
12 quarzite a	48	2.71	0.070				
b	10			0.86	0.57	0.42	0.74
c	15			0.034	0.24	1.3	1.0
d	23			≤ 0.001			
13 mica schists a	10	2.76	0.060				
b	4			3.2	0.52	0.38	0.17
c	6			0.0023	0.55	2.7	0.37
14 pelitic schist a	51	2.76	0.054				
b	39			1.9	0.48	0.45	0.41
c	12			0.047	0.34	0.50	0.66

Rock group	Number of samples	Density		Susceptibility 10^3		q-value	
		mean	st. dev.	mean	st. dev.	mean	st. dev.
15 metasediments among basaltic greenstones	14	2.80	0.066	3.2	0.32	0.45	0.48
11+12+13+14+15	130	2.73	0.251	0.14	1.4	0.78	0.62
16 amphibolite	2	2.89	0.031	0.054	0.25	0.34	1.32
17 gneisses a	166	2.72	0.056				
b	138			1.4	0.54	0.48	0.51
c	28			0.0036	0.25	1.7	1.1
18 gabbro-diabase	4	2.92	0.034	1.8	0.20	7.3	0.63

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