8. Aspects of the Pre-Cambrian Geology of South-eastern Värmland, Sweden

By

Erik Wiman

Contents

Preface

The investigated region (Pl. A) is situated near the town of Kristinehamn in the south-eastern part of the province of Värmland at the north-eastern corner of Lake Vänern. Field researches extend over a period of more than 24 years, especially within the western part of the geological map-sheet Kristinehamn (no. 122, BLOMBERG, 1903), but also within the sheets of Furuholmarna (no. 136, JOHANSSON, 1917), Björneborg (no. 124, BLOMBERG, 1904), and Väse (no. 151, ALVAR HÖGBOM, see SANDEGREN, 1922).

The region is of special interest, being situated in the boundary zone between the gneisses with hyperites in south-western Sweden and the Småland and Filipstad granites in the south-east.

General Terminology

By *diablasts* the author means drop-like inclusions of one mineral within another. Sometimes the diablasts represent sections of quartz vermicules, but, as will appear in the following, a kind of drop-like quartz in certain plagioclases possibly represents a special kind of synanthetic intergrowth between these minerals. Other diablasts may represent inclusions of older minerals.

By *leptites* are, in accordance with GEIJER (1944, p. 734), meant "a metamorphic (recrystallized) supercrustal rock, with approximately granitic composition, which has secondarily formed grains measuring 0.03–0.05 mm as lower limit and 0.5(–1.0) mm as upper one, excluding eventually occurring remnants of phenocrysts".

The old Swedish mining term *skarn* is used in the meaning of MAGNUSSON, 1957, p. 536, thus representing silicates associated with ores of iron oxides and sulfides often present in the Swedish leptite formation. Skarn rocks occasionally represent a banding of an original sediment.

By *antiperthites* the author means plagioclases, which have been partially replaced by potash feldspars.

Mafic remnants in the rock complex are usually rounded or angular, but they also often appear as black, shorter stripes ("*fishes*"), which may sometimes represent boudinage structures (KROKSTRÖM, 1946). EXNER and POHLE (1951, p. 36) use the term *basic "fish"* in the same meaning as the writer. Along the strike, the remnants (basic "fishes") are interrupted by granitic gneisses or granites (Fig. 4, C, p. 10).

By the term *agmatite* have been distinguished breccias composed of usually mafic rocks, strongly metamorphically altered and partially dissolved, enclosed either in a usually more felsic, magmatic rock or in a migmatitic rock.

By *holoblasts* the author means phenocrysts, porphyroblasts or larger fragments of minerals, the endogenic nature of which is uncertain. Thus the term holoblast does not represent a genetical conception (cf. DRESCHER-KADEN, 1948, p. 10).

Petrographical Methods

The axial angles and birefringences have been measured with the aid of the universal stage and the compensator of BEREK. Refringences have been determined by means of the immersion method in Na-light, the liquids always being checked with refractometer in Na-light. Because of the usually more or less developed zoning of the plagioclases, their composition has generally been determined by measurements $\perp \alpha$ and $\perp \gamma$, using the extinction curves of WINCHELL, 1951. The composition of the olivines has been determined with the aid of the diagrams of TRÖGER (1956, p. 37), hypersthene according to the diagram of WINCHELL (1948), and the composition of the clinopyroxenes according to TRÖGER (1956, p. 62).

The epidotes and clinozoisites have in some instances been determined according to the curves of WINCHELL (1951). Crystals with low birefringence, both $\perp \alpha$ and $\perp \gamma$, have been classed as clinozoisites, crystals with a high birefringence, both $\perp \alpha$ and $\perp \gamma$, as epidotes. The axial angle of the biotites is always very small, and that of the muscovites is always about 40°.

Pleochroic haloes nearly always appear inside the scales of biotite, therefore the haloes have generally not been mentioned in the descriptions of the biotite-bearing rocks below.

Some micrometric analyses (method of WENTWORTH, 1923) of rather homogeneous leptitic and hyperitic rocks have been made. A quartz-monzonite W of Lake Bergsjön has been analyzed chemically by R. BLIX. The specific gravities of the micrometric analyses have been taken from literature (IDDINGS, 1911, and WINCHELL, 1951).

The weight percentages of quartz (QZ) have been determined in some rocks by J. LUKINS according to the method of HIRSCH–DAWIHL (1932).

Introduction

Apart from the local interest of the rocks described in the following, it is hoped that they will serve to elucidate the problem of granitization of various rock complexes, igneous and supercrustal, for the study of which our region seems to be rather favourable. During the last few decades many scientists have treated the processes of granitization, *inter alia*, H. G. BACKLUND (1935–53), T. W. BARTH (1936–52), F. CHAYES (1948), V. M. GOLDSCHMIDT (1921), T. KROKSTRÖM (1946), P. LJUNGGREN (1954, 1957–58), P. MISCH (1949), R. PERRIN (1934), R. PERRIN and M. E. ROUBAULT (1947 and 1949), T. T. QUIRKE (1927 and 1927), R. H. RASTALL (1945), H. H. READ (1943–44 and 1957), D. REYNOLDS (1943–53), and C. E. WEGMANN (1950). Many other scientists have dealt with similar problems. A brilliant survey of the varied views on the problems of granitization is to be found in READ's book "The Granite Controversy" of 1957.

The age relationship between the different formations and the granitizations inside the Kristinehamn region will be easier to understand, if the reader is acquainted with the papers by BACKLUND (especially 1936–41), LANDERGREN (1934), LARSSON (1947 and 1956), LUNDEGÅRDH (1957–60), MAGNUSSON (1933 and 1934), and WAHL (1936).

The oldest recognized group of rocks in the region is a complex of stratified, sedimentary, quartzitic to leptitic formations, which appear only as smaller remnants. The leptitic remnants, with the exception of the quartz-phyllite 23–23 (Pl. A), are usually closely associated with larger amphibolite bodies (III–III and parts of IIb–IIb, Pl. A).

The grey gneisses ("grå gnejs" of HÖGBOM) of the map have not been investigated by the author, because their classification and interpretation must be very uncertain. Some of them possibly represent altered amphibolites.

Wide areas of the map are occupied by a fine-grained, aplite-like reddish gneiss called *Väse gneiss* by the author. This gneiss differs conspicuously from the other types of gneisses present, as already recognized by ALVAR HÖGBOM (see SANDEGREN, 1922), who terms the Väse gneiss red homogeneous fine-grained gneiss. Stratigraphically the Väse gneiss does probably not belong to the leptite series. This gneiss seems to be at least partly older than the hyperites.

Several petrographical, textural, and structural features of the Väse gneiss are suggestive of a primarily sedimentary origin of this rock; the Väse gneiss may, thus, represent an originally arkosic sedimentary formation of great thickness, later intruded by sills of hyperite, to which are due the preservation of the arkoses during the subsequent geological development.

Several smaller areas of fine-grained, aplite-like reddish gneisses appear within the Kristinehamn granite, on the eastern side of the boundary between the granites of the south-eastern part of Sweden and the gneisses in the south-west. They are generally too small and often too diffuse to be entered on the map (Pl. A). Only 6–6 and 20–20 are associated with hyperites. Thus, at least these gneiss areas may represent Väse gneiss too, although they occur inside the region of the Kristinehamn granite.

The reddish, aplitic gneisses represented by 8–8 (parts of it) and 12–12 surrounding the amphibolitic complex of IIb–IIb, and those of 11–11, 18–18, and 21–21 have been described below together with the leptitic series. The rock of the gneiss area 18–18 is, however, rather similar to the Väse gneiss in the western part of the map, but occurs in the continuation of the leptitic rocks of 8–8 and 12–12.

The Väse gneiss often grades into a reddish gneiss with generally smaller black spots and stripes rich in biotite. This rock has been distinguished by ALVAR HÖGBOM (*op. cit.*, p. 7) as red dark spotted gneiss. It is termed *Ölme gneiss* by the author. This gneiss is somewhat more coarse-grained than the Väse gneiss and is richer in mafic components. It occupies rather large areas inside the gneissous region in the western part of the map (Pl. A). The Ölme gneiss is very heterogeneous, but it is often rather massive, and is sometimes difficult to distinguish from gneissous varieties of the Kristinehamn granite (eleven such areas marked on Pl. A) and from certain varieties of the Väse gneiss. The Ölme gneiss has therefore been described together with the Väse gneiss in Chapter I.

Like the leptitic rocks, the Ölme gneiss exhibits folding immediately W of the investigated region and on the isle of Vålön in Lake Vänern. Its occurrence as inclusions in the hyperites is suggestive of pre-hyperitic age (p. 44).

All the hyperites represent younger, Archaean, basaltic rocks, which have been transformed largely into garnet-bearing dolerites and amphibolites; they carry inclusions of both leptite (Text-fig. 27, p. 44), leptitic greywacke, Väse gneiss Text-figs. 28–29, p. 45), and Ölme gneiss. A more or less pronounced foliation (cf. Fig. 1) of the gneisses, granites, and some of the hyperites followed the intrusion of the latter. The strikes and dips of the schistosity especially in the granitic gneisses and gneissous granites have been marked on the map (Pl. A) when discernible.

The amphibolite of the isle of Vålön (kk, Pl. A) has also been included among the amphibolitic hyperites. The Emtefalla amphibolite has been provisionally referred to the older formations, but may possibly represent a hyperite too.

Whereas aplites and pegmatites are of rare occurrence in the gneisses and granites, they are rather common in the hyperitic sills in the south-western part of the map.

This is of a certain interest, because ASKLUND (1950, p. 34) contends that some pegmatites in south-western Sweden are associated with the Bohus granite, which would be of a rather late Archaean (post-Jatulian) age.

I

Leptitic and Amphibolitic Rocks and Gneisses

Most of the leptitic and amphibolitic rocks described in the following sometimes exhibit wrinkled folds with steep dips or steep axes. Except the rather schistose Emtefalla amphibolite (I–I, Pl. A), all the rocks discussed here repre-

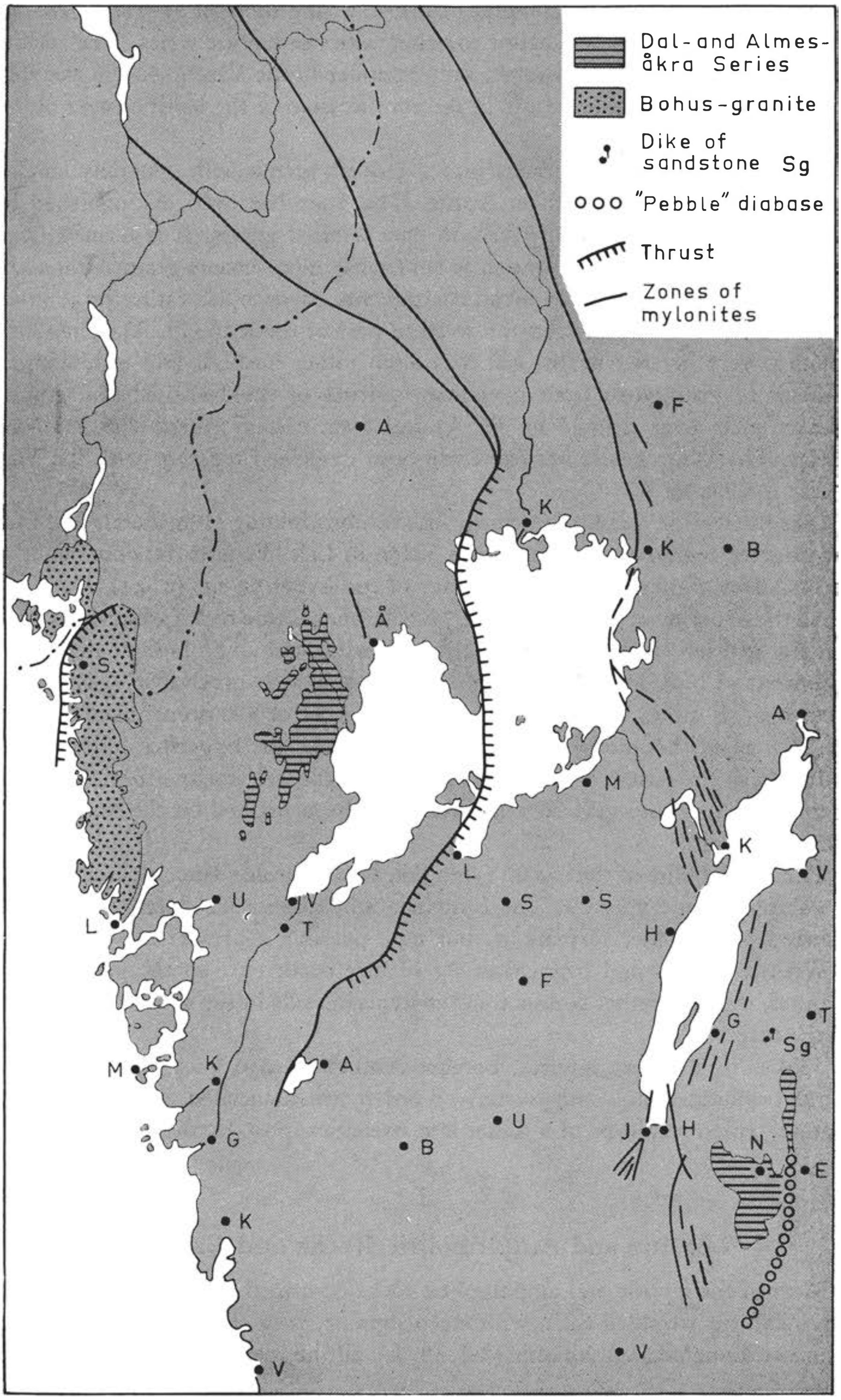


Fig. 1. Tectonic sketch-map of south-western Sweden. According to N. SUNDIUS, 1944, p. 292.

Fig. 2. Stratified leptitic rock on the western shore of Lake Stora Vilången.

sent the pre-hyperitic complex of the region. The Väse and the Ölme gneisses, which are the predominant rocks on the western part of the map, generally exhibit lower dip in varying direction.

A. *Sediments of Greywacke Character W of Lake Stora Vilången*

The northern part of the leptitic area, marked as 16–16, Pl. A, consists of nicely banded (Fig. 2) and fine-grained leptites or quartzites. The proportions between plagioclase, microcline, and quartz (14.1–40.3 % w) vary. The northern part of 16–16 represents the largest leptitic exposure inside the investigated region, with an area of at least 20 × 200 sq.m. The sequence consists of mafic layers rich in epidote (*Type 1*) alternating with less common quartzitic or felsic layers (*Type 2*), and solitary layers rich in biotite (*Type 3*).

Fig. 3. Pebble-bearing layer in a leptitic mafic greywacke (Type 4), N of the hyperite dd, N of Vilångstorp. Two pebbles visible on this side of the hammer and two on the other side.

The main strike of the banded, leptitic rocks of the largest outcrop is W–E, and the dip 65°N. Outliers (*Type 4*) continue 1 km SSE of the main outcrop on the land tongue N of the Vilångstorp farm. The northern part of the hyperite mass dd (Pl. A) is surrounded by *Type 4*, which contains a pebble-bearing layer (Fig. 3) north of the hyperite. The southern part of the land tongue is occupied by a reddish gneiss (9496), the origin of which is doubtful. The leptitic rocks do not continue on the eastern shore of the lake.

The hyperite dd, north of the Vilångstorp farm, is rather coarse and doleritic in its central part, but along its south-western margin it is very schistose. The schistosity is discordant to the stratification of the leptitic bands on the northernmost part of the land tongue (usually below the water level), where the leptitic layers have a strike of N 70° E and a southerly dip of 75°.

On the western shore of Lake Stora Vilången the rock, *Type 1*, is grey and thinly laminated, but also coarsely banded by layers about 3 cm thick. Microscopically the thickness of the layers or foliae varies between 0.5–7.0 mm. The grain-size is about 0.1–0.3 mm. Dark laminae are interfoliated with lighter ones in the chiefly mafic layers.

The dark layers consist mainly of epidote together with some biotite, bluish-green amphibole, and accessory ore; quartz and feldspars are very subordinate. The biotite partly replaces the amphibole. The light layers are composed chiefly of quartz (15.4% w in both layers together) and calcic oligoclase (An_{28}), and more subordinately clinozoisite, amphibole, and ore. The texture is granoblastic. The rock may be classified as a leptitic greywacke. Both Type 1 and the following Type 3 are somewhat similar to the "femic leptites" of SUNDIUS (1947, pp. 19–24).

The leptitic members, *Type 2*, are nicely stratified (Fig. 2). One of the layers investigated consists chiefly of potash feldspar (2V = 68°), much quartz (40.3% w), some pale brown biotite, and clinozoisite associated with some ore. The crystals of quartz are strained and include extremely small remnants of other minerals. The feldspar as well as the quartz is extensively regulated. The texture of the rock is granoblastic. Generally the grains of the rock have a size of only 0.03 mm with porphyroblastic patches and veinlets of potash feldspar.

Another sample taken nearer the contact with the Kristinehamn granite is more coarse-grained, and the content of quartz is lower (26.2% w). A somewhat darker variety, preserved as a fragment in a reddish gneiss, which forms the southern border of the main leptite outcrop, contains almost the same percentage of quartz (26.3% w), as does also a reddish gneiss at this locality (25.8% w).

The layers of *Type 3* (leptitic biotite-epidote gneiss) possibly represent a leptitic mafic greywacke (cf. Type 4 below) and differ from the one mentioned above by a much lower content of quartz. Plagioclase forms numerous, equidimensional porphyroblasts (An_{28}) in a groundmass of potash feldspar (2V = 62°), quartz, plagioclase, biotite, and epidote; accessorily apatite, ore, and titanite. The plagioclase is often more or less distinctly zoned, with a kernel of about

An_{28} grading into An_{20} marginally. The foliation of the rock is distinct, but not very pronounced. The porphyroblasts, which reach 0.2–0.4 mm, sometimes constitutes aggregates of several crystals.

The layers of *Type 4* may be termed leptitic mafic greywacke. This rock has a conspicuous appearance in the field by small ovoid knobs (2–3 cm in size) protruding on the surface of the outcrop N of the hyperite dd. The principal constituent of the ovoids is plagioclase (An_{30}) together with some hornblende and plenty of ore grains. The groundmass surrounding the ovoids is fine-grained (0.05–0.10 mm) and consists of transluscent plagioclase (An_{40}) and potash feldspar, both of about equal importance, further hornblende (about 25% v); subordinately quartz (14.1% w), some biotite patchily replacing the hornblende; accessorily apatite and ore. The hornblende needles, which are partly parallelly arranged exhibit: $c/\gamma = 17°$, γ = bluish-green, β = brownish-green, α = light yellow. No epidote minerals.

A *pebble-bearing layer* (Fig. 3), about 1 m wide, intercalated in the mafic greywacke of *Type 4*, appears on the beach north of dd. The scattered pebbles have the same composition as the matrix enclosing them. The layer dips 80° towards S 20° E like the other rocks of this locality. Characteristic of both the pebbles and their matrix are small ore grains included in often pinkish plagioclase (An_{30}). Further appear aggregates of epidote, light bluish-green amphibole ($c/\gamma = 15°$, twins); accessorily titanite sometimes surrounding ore. The grain-size varies from 0.06–2.1 mm.

B. *Leptitic Rocks near Lake Bergsjön*

These rocks are associated with layers of amphibolite of varying thickness.

(*a*) Inside the north-western end of the streak of gneisses (27–27, Pl. A) 170 m W of the woodland pool of Kvarntjärn, an exposure of *quartzite* (128 sq.m., sketch-map. Fig. 4, A) is found in a hillock, which otherwise chiefly consists of the grey gneiss described below.

The *quartzite* is flamy in white and reddish tones and is partly nicely stratified. Contrary to the wrinkled *grey gneiss* in the same outcrop, the quartzite exhibits persistent W-E strikes in the entire exposure, but the dip varies between 80° S and 90° to 80° N.

The principal constituents of the typical *quartzite* are chiefly quartz (in the white variety almost exclusively), potash feldspar, garnet, pyrite, cyanite, and muscovite. The cyanite appears in fusiform aggregates 1 mm in length composed of thin needles < 0.2 mm ($2V_\alpha = 84°$, $r < v$, $c/\gamma = 10°–11°$, $\gamma–\alpha = 0.016$, and $\beta–\alpha = 0.009$). The grains of the rock generally have a size of 0.10–1.50 mm.

The quartzite is more or less distinctly foliated. In the microscope the quartz grains sometimes look like star-shaped ginger cakes, the angular protuberances of which fit into the angular cavities of its neighbours (sutured texture, Jo-

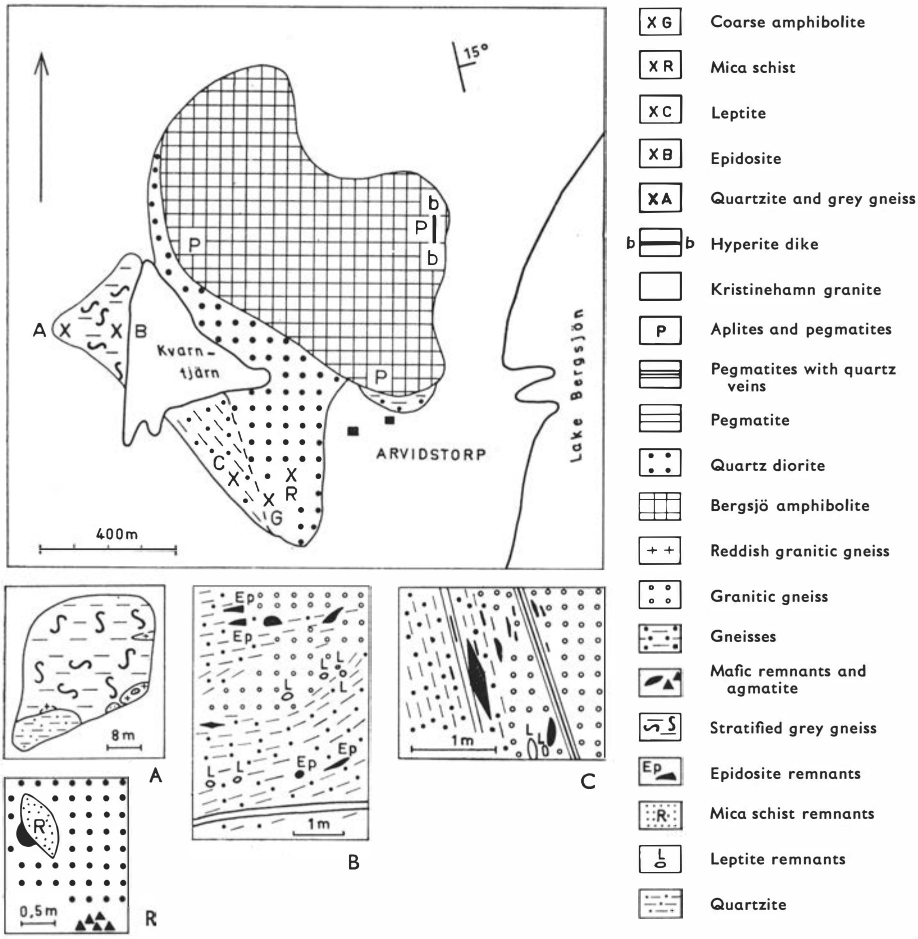


Fig. 4. The Bergsjö area with sketch-maps of the localities A, B, C, and R.

HANNSEN, 1931, p. 230). Muscovite appears to replace the cyanite, but also some of the potash feldspar.

(*b*) The *grey gneiss*, which constitutes the main part of the outcrop, is nicely stratified with strongly plicated layers (Fig. 5). It contains rather much potash feldspar, plagioclase, quartz, and muscovite, some few crystals of garnet associated with ore and apatite. Pleochroic haloes are common in the biotite, whereas haloes are scarce in biotite scales in the other felsic rocks near Kvarntjärn. The plagioclase is an andesine, An_{35}. The grain-size varies from 1.4 mm (larger crystals of microcline) to 0.1 mm, commonly 0.1–1.0 mm.

Granitic varieties of the grey gneiss look like segregations, but sometimes they replace the grey gneiss almost completely (Fig. 6). Granitic veins do not cut across the quartzite of Fig. 4.

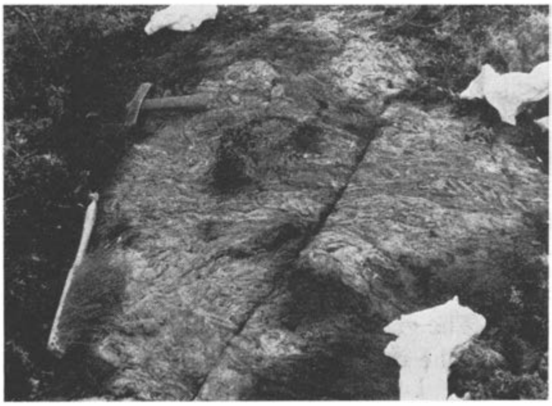


Fig. 5. Folded grey gneiss 170 m W of Kvarntjärn.

An exposure of such granitic gneiss in the south-eastern corner of Fig. 4, and exhibited on Fig. 6, is homogeneous to the naked eye, but porphyroblastic under the microscope. It carries an abundance of porphyroblasts of microcline (2–4 mm), whereas larger crystals of plagioclase are rare. The granoblastic 0.1 mm grained groundmass of the rock consists of quartz, remnants of plagioclase, brownish mica, chlorite (or serpentine?), much muscovite, and some garnet.

In a plate of microcline one inclusion of ore and another of sericitic plagioclase were observed. The microcline and the plagioclase are here homoaxial, and the albite lamellae of the latter run parallelly and perpendicularly to the two systems of twinned stripes of the microcline. The crystals of garnet occasionally contain inclusions of biotite.

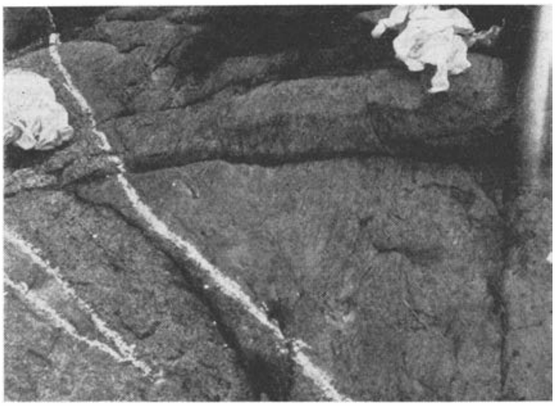


Fig. 6. A fish-shaped remnant of grey gneiss in a porphyroblastic reddish granitic gneis. (Fig. 4, A). Towards the right appears the folded, grey gneiss. White lines have been chalked on the rock.

(*c*) About 40 m W of Kvarntjärn, inside 27–27 (Area B on Fig. 4) streaks of dark *epidosite* are found in the gneissic rock. The principal mineral constituents are quartz (44.63% w) and locally more than 50% epidote, subordinately plagioclase, actinolitic amphibole, and some titanite associated with iron ore. Some grains resembling clinopyroxene have been noticed. The plagioclase, a calcic andesine, is perfectly clear, and often untwinned. The weight percentages of K_2O (0.35% w) and Na_2O (0.33% w) are low. The epidote shows: $2V_\alpha$ = about 90°, $\gamma' = 1.728$, $\gamma - \alpha = 0.017$, $c/\gamma = -2°$, corresponding to about 7 mol% Fe-epidote (WINCHELL, 1951). The rock is nicely stratified with very thin layers. The grains generally have a size of 0.04 mm, but sometimes reach 0.08 mm. The composition of the rock is suggestive of a former calcic sediment.

In the same small outcrop as the epidosite, medium-grained granitic gneiss, granite, and pegmatite also occur. The dark remnants appear with sharp contacts. The medium- to fine-grained granitic gneiss nearest to the epidosite, is somewhat foliated, with more or less schistose stripes rich in biotite and muscovite. It consists of microcline, scattered crystals of sericitic plagioclase, very small and few grains of myrmekite, some quartz, biotite, muscovite, chlorite, clinozoisite, titanite, ore, and apatite. The plagioclase, An_{25}, is partly quite clear and translucent but many of the crystals include sericite and also biotite, and are very often surrounded by very thin rims of potash feldspar. The nicely quadrille-structured crystals of microcline reach 0.3–0.7 mm in size.

(*d*) The whole complex of leptitic rocks (inside 27–27, Pl. A) W of Kvarntjärn continues on the bottom of the pool and south of it (Fig. 4). In the latter area scattered exposures of somewhat schistose strata can be followed in the field about 400 m, with uniform dip of about 40° ENE, coincident with almost all dips inside the region of the Kristinehamn granite on Pl. A (cf. Fig. 4, C). The leptitic remnants in the granitic to quartz-dioritic gneiss 27–27 are only a few metres in length.

The *leptitic rock* consists of potash feldspar, quartz, biotite, and sometimes rather much plagioclase; accessorily clinozoisite, titanite, garnet, apatite, and ore. Solitary porphyroblasts of potash feldspar, partly with microcline grating, appear. In the biotite no pleochroic haloes were observed.

The content of quartz varies in one and the same outcrop, and exhibits in one instance 24.00% w. In thin-section 4104, the plagioclase (An_{25}) is densely impregnated with a grey dust. The very scattered porphyroblasts of potash feldspar of the usually grey leptitic rocks S of Kvarntjärn, attain a maximal size of 2 cm. The porphyroblasts have sometimes pushed the biotite scales aside (cf. REYNOLDS, 1947, p. 215).

The size of the grains in the leptitic rocks generally vary between 0.03–0.30 mm; 0.03 being most common. Certain granitic varities are so similar to the quartz-diorite associated with the Bergsjö amphibolite that it is difficult to distinguish the one from the other.

Table 1. Micrometric analyses of leptitic rocks S of Kvarntjärn.

<table>
<tr><th></th><th>4103
Weight, %</th><th>4104
Weight, %</th></tr>
<tr><td>Quartz</td><td rowspan="2">33.0</td><td>13.5</td></tr>
<tr><td>Plagioclase</td><td>52.8</td></tr>
<tr><td>Microcline</td><td>48.2</td><td>22.5</td></tr>
<tr><td>Mafics (chiefly biotite)</td><td>18.8</td><td>11.2</td></tr>
<tr><td></td><td>100.0</td><td>100.0</td></tr>
</table>

(*e*) Rather diffuse *leptitic remnants with scapolite* as essential constituent occur in the gneissous rocks at the south-eastern border of the Bergsjö amphibolite, north of Arvidstorp (Fig. 4), dipping gently to the SSE. The rock is composed of microcline, quartz, plagioclase (An_{15}), partly greenish biotite, scapolite, titanite, and apatite. The plagioclase is occasionally myrmekitic and is sometimes partly replaced by epidote and sericite.

The rock contains porphyroblasts of microcline or aggregates of microcline grains 2–5 mm in size. Some of the porphyroblasts are surrounded by biotite scales conformably. In hand specimens each porphyroblast reflects the light as one single mirror, but in two thin-sections the large "mirrors" are composed of several small grains. Thus these probably do not represent crushed porphyroblasts, but rather a stage in a recrystallization process. The quartz grains of the rock sometimes measure 0.30–1.00 mm. The potash feldspar of the "groundmass" does not show any visible microcline grating. The most common grain-size here is 0.30 mm. The scapolite is partly symplectitically intergrown with

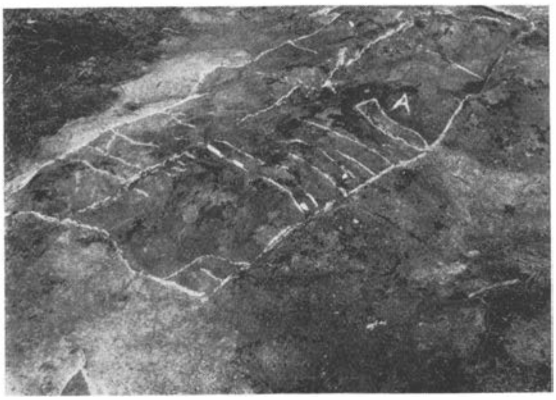


Fig. 7. Rectangular amphibolitic remnant (outlined with chalked lines) with an inclusion of granitic gneiss, marked *A*. The amphibolitic remnant (part of an amphibolitic "fish") is surrounded by the same type of granitic gneiss as the inclusion *A*. The fissures in the amphibolite have been chalked on the outcrop.

plagioclase (?) (Pl. I, Fig. 1). Garnet and muscovite, associated with the biotite, occur in the granitic varieties of the gneiss.

Another conspicuous variety in the gneissous outcrop is composed of plagioclase (An_{16}), microcline-perthite, antiperthite, quartz, brown biotite, and ore. The plagioclase is partly antiperthitically replaced by microcline.

An *amphibolitic "fish"* at the same locality, which possibly represents a boudinaged extension of the Bergsjö amphibolite, contains an inclusion of granitic gneiss (marked *A* in Fig. 7) evidently derived from the surrounding gneissous wall rock. The inclusion is of interest because its feldspars exhibit all kinds of transitions from plagioclase to microcline-perthite sometimes associated with myrmekite. In the plagioclase solitary crystals of epidote occur. The porphyroblasts of both plagioclase and microcline reach 3.5–5.0 mm, the other grains generally have a size of 0.07–0.30 mm.

As remnant of the leptitic formation is also considered a *fine-grained mica schist* (Fig. 4, R) in the quartz-diorite a few hundred metres SW of Arvidstorp. The schist is composed almost exclusively of small scales of muscovite, but also carries solitary small crystals of oligoclase.

C. *The Quartz-phyllitic Rocks at Blomsterhult*

About 15 km SSE of Kristinehamn smaller outcrops of Kristinehamn granite and nicely stratified quartz-phyllitic rocks occur (23–23, Pl. A). Four types have been investigated.

A *thinly laminated quartz-phyllite, Type 1*, is made up of layers consisting mainly of parallel scales of biotite intimately associated with muscovite, and these layers alternate with coarser layers composed mainly of plagioclase (about An_{30}), quartz, muscovite, rather few biotite scales, grains of potash feldspar partly as mesostasis between the other grains, a few crystals of amphibole, garnet, and very little ore. Thus, dark layers interfoliate lighter ones, both about 2 mm thick (1.5–3.5 mm). Both the crystals of quartz and plagioclase carry inclusions of biotite scales. The average content of quartz amounts to about 30% w.

The *quartz-phyllite, Type 2*, differs from Type 1 only by the proportions of the minerals, and greater thickness of the dark laminae. Of late origin are thin veinlets of potash feldspar, which locally penetrate the rock and its minerals in a dendritic pattern. The rock has typical granoblastic texture with a grain-size between 0.1–0.5 mm.

A *stratified epidositic gneiss, Type 3*, is microscopically somewhat similar to an epidote-garnet fels. In one single thin-section (7578) five different laminae occur, viz. the following.

1. Layer composed of quartz, plagioclase (An_{29-32}), and biotite; subordinately enters also clinozoisite. Anastomosing, very thin veinlets of potash feldspar penetrate this layer locally.

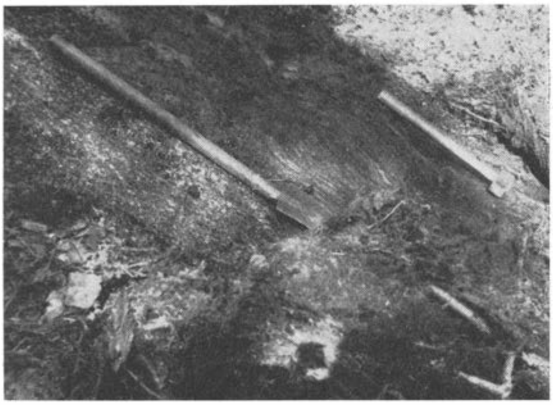


Fig. 8.

Fig. 9.

Fig. 8. Stratified quartz-phyllite (between the spade and the hammer). Left of the spade, a porphyroblastic variety of the quartz-phyllite nearest to the Kristinehamn granite.

Fig. 9. Thinly laminated to veined grey leptitic rock ("190", 19–19, Pl. A) enclosed in the Björneborg amphibolite (IIb–IIb, Pl. A).

2. Layer No. 1 grades into layer No. 2 (10 mm thick), which consists of an almost coherent mass of clinozoisite-epidote poikilitically studded with quartz grains or synanthetically intergrown with quartz. A rather diffuse stripe inside this layer carries tremolite ($2V_{\alpha}$ = large, γ and β very light greyish-green, and α = colourless). The clinozoisite has a low birefringence in sections both $\perp \alpha$ and $\perp \gamma$.

3. This layer (6 mm thick) has similar texture as the preceding one, but instead of clinozoisite, garnet appears, replacing the former entirely. Quartz constitutes more than half of the volume.

4. This layer grades in turn into another of similar composition as layer 2, but richer in quartz.

Layers Nos. 2–4 are remarkable by their very simple mineral composition, being composed almost exclusively of clinozoisite, respectively garnet, intergrown with quartz. The grains generally measure 0.1 mm across.

Porphyroblastic quartz-phyllite, Type 4, constitutes a zone, 1 m wide, at the contact with the Kristinehamn granite, but it has been observed at one single locality only (Fig. 8). The rock contains numerous porphyroblasts of plagioclase (An_{28}) about 4 mm in size sometimes containing small patches of potash feldspar, in a groundmass of biotite, solitary grains of common hornblende, some clinozoisite and epidote, few grains of quartz and potash feldspar, titanite, ore, garnet, apatite, and zircon. The rock is more or less schistose.

D. *Leptites and Amphibolites of the Björneborg Area and Associated Agmatitic Rocks*

About 6 km ESE of Kristinehamn another area of leptitic rocks (12–12, 8–8, Pl. A) extends along the border of the amphibolitic area marked IIb–IIb on the general map (Pl. A).

Whereas the leptitic zone 12–12 along the eastern border of the amphibolitic rocks has a rather homogeneous, aplitic composition, the zone 8–8 is much more heterogeneous. The intervening amphibolitic rocks II b–II b are, inside the southern part of the area, extremely heterogeneous, varying between amphibolitic, dioritic, and granitic rocks, partly fine-grained and striped, partly developed as agmatitic breccias. The schistose parts of the complex (for instance, in 19–19) are sometimes intensely deformed into small folds with almost vertical axes. Such folds are especially typical in the schistose or veined grey leptite layers interfoliating the more amphibolitic types, also occurring inside the veined leptitic rocks of 19–19.

(*a*) *Reddish leptites* (12–12 and 8–8, Pl. A). The leptite 12–12 on Pl. A is possibly a recrystallized arkose, the clastic texture still being discernible (mean grain-size 0.1 mm). The rock consists mainly of microcline and quartz, the latter to an amount of 41.2% w, subordinately plagioclase ($An_{10\text{-}15}$), more or less paled biotite, muscovite, chlorite, titanite, and ore. Potash feldspar also soaks the rock as a thin intergranular film.

The leptitic rocks of 8–8 are, petrographically, rather similar to those just described. One species consists mainly of microcline and quartz (23.6% w), a few crystals of plagioclase (An_{15}), biotite, aggregates of titanite and ore, and solitary crystals of garnet. Granitic varieties (An_{18}) along the border appear with crystals reaching a size of 0.1–0.5 mm.

Fine-grained, reddish gneisses, as for instance 18–18, appear in the continuation of the leptitic streaks 12–12 and 8–8. The gneiss of 18–18 is rich in potash feldspar, carries an ordinary content of quartz, but is poor in albite and biotite.

(*b*) *Veined grey leptit.* In the westernmost exposure on the hill "190" in the area 19–19 on Pl. A, thinly laminated to veined grey leptitites, intercalated with amphibolitic layers, appear (Fig. 9). The main type (*Type 1*) is composed of alternating dark and light layers. The *dark layers* consist chiefly of plagioclase varying from An_{42} to An_{32}, biotite, and quartz in about equal amounts. Potash feldspar is rather subordinate. Accessorily zircon, a few scattered small grains of clinozoisite, apatite, and ore. The *light layers* consist almost entirely of potash feldspar and quartz, together with solitary grains of brown biotite and ore. Only near the margins towards the dark layers does plagioclase occur. It is the same one as in the dark layers. In one of the thin-sections the potash feldspar exhibits a diffuse microcline grating ($2V_\alpha = 53°$, $\perp\gamma : \alpha/P = +10°$). Perthitic texture has not been observed even in rather large crystals.

The medium thickness of the layers is 0.7 mm. The *dark layers* are more fine-grained (0.1–0.3 mm) than the *light ones*, in which the crystals of potash feldspar reach 0.3–2.4 mm and the quartz grains 0.1–0.3 mm in size. The biotite scales form straight planes. In the *light layers* slightly sericitic plagioclase crystals, quartz, and ore are occasionally enclosed in the potash feldspar. Sometimes small ore grains are enclosed in the plagioclase. In some cases the quartz encloses plagioclase. The lamellae of the plagioclase are occasionally somewhat bent.

The rather *felsic layers* (10–40 mm across) of *Type 2* consist of a groundmass generally composed of grains, 0.1 mm in size, of quartz (31.2% w), some microcline, biotite, chlorite partly replacing the biotite, muscovite, titanite, ore, and garnet. In this groundmass porphyroblasts of both microcline ($2V_\alpha$ = about 50°) and plagioclase (An_{23}), up to 6 × 6 mm, occur.

Some of the porphyroblasts consist of about equal amounts of potash feldspar and plagioclase. The plagioclase is partly stained with sericite and yellowish-brown biotite. The plagioclase of the groundmass is partly myrmekitic. Neither zircon nor pleochroic haloes have been observed in the biotite.

(*c*) *The amphibolitic rocks of the Björneborg area.* Among the intimate mixture of rocks covered by the designation "amphibolite" (IIb–IIb, Pl. A), some more prominent types (1–4) have been selected for closer study.

(1) Some of the amphibolites still exhibit features suggestive of derivation from doleritic eruptives. Such a rock was collected in the middle of the zone, where it is crossed by the road from Björneborg to Vassgårda. In hand specimens the rock has the appearance of a schistose dolerite. It is cut discordantly by a winding vein of aplite, 1 dm wide, from which thin, rather straight veinlets penetrate along the planes of schistosity. The amphibolite is strongly deformed. It is rather coarse-grained with crystals of plagioclase 0.3–5.0 mm in size. The more or less equidimensional grains of the groundmass generally have a size of 0.1–0.4 mm. The mineral constituents are plagioclase (An_{42}), hornblende, only some biotite, sericite and epidote needles (in the plagioclase), and some quartz, accessorily ore and apatite. The laths of plagioclase often enclose grains of both amphibole and ore.

(2) An amphibolite, more strongly deformed, with both laths and rounded holoblasts of plagioclase is found in the hill "190", where it is intercalated in the schistose or veined leptitic gneiss of 19–19. It is a fine-grained granoblastic amphibolitic rock with scattered larger lath-shaped or ovoid aggregates of labradorite, suggestive of original phenocrysts, which often are arranged in parallel stripes. The laths are sometimes 10 mm long; the individual, anhedral plagioclase grains (An_{50-60}), which measure 0.05–0.25 mm, are usually untwinned or exhibit very thin albite and pericline lamellae. The plagioclase is often slightly zoned, the kernel being somewhat more basic. The other mineral constituents are green hornblende (reaches 0.6 mm), biotite sparingly, ore, apatite, and a few grains of quartz.

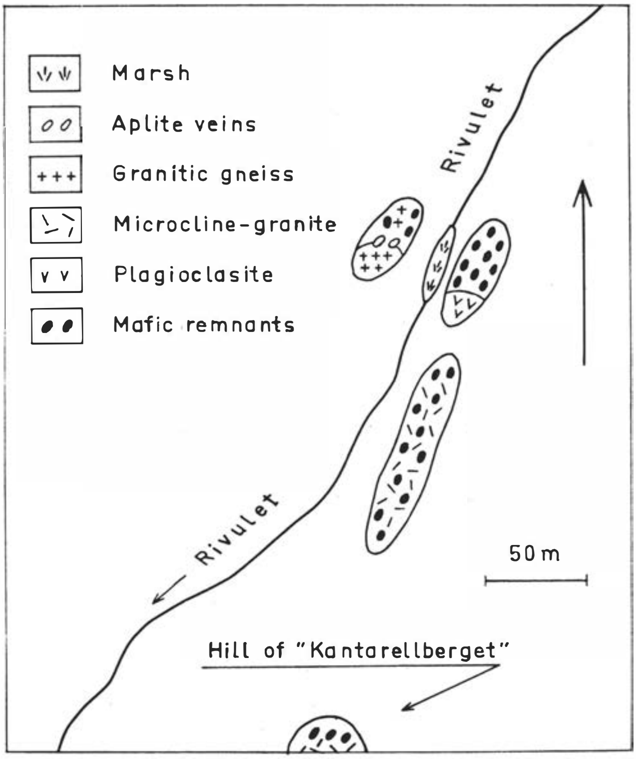


Fig. 10. Part of the agmatitic breccias 2 km ENE of the farm Bäcketorp, 5 km SE of Kristinehamn. In the Björneborg rocks II b–II b, Pl. A.

(3) The southernmost part of the amphibolitic area II b–II b northwest of Björneborg is largely developed as an *agmatitic breccia* crowded with *fragments of mafic rocks* of very variable size, which are embedded in a granitic-dioritic matrix with usually diffuse contact zones. Part of the breccia is shown on the sketch-map (Fig. 10). A fairly homogeneous specimen (north-western part of Fig. 10) of the mafic fragments was selected for closer petrographical study (Fig. 11).

Apart from the absence of lath-shaped plagioclase this rock is very similar to the main type of amphibolite of this zone. It is a fine-grained granoblastic rock composed mainly of common hornblende, labradorite (An_{50}), and pale biotite. Occasionally a few larger crystals of plagioclase occur. These are extensively altered into *patch-antiperthite* or the main individual may be a potash feldspar with remains of plagioclase (Pl. I, Fig. 2). Diablasts of quartz are sometimes found in the plagioclase.

The rock contains several rounded zonary built *nodules* some few centimetres in diameter (Fig. 11), which consist mainly of epidote and clinozoisite. The central part is composed of these two minerals and muscovite in about

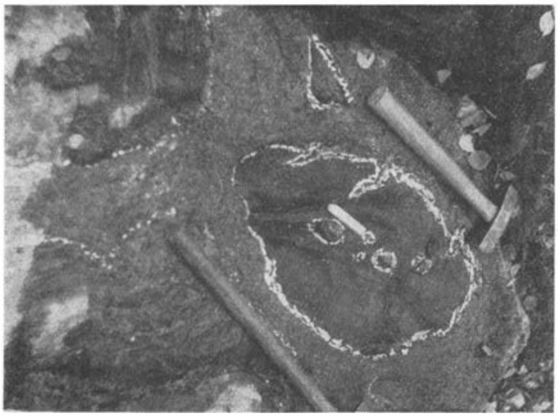


Fig. 11.

Fig. 12.

Fig. 11. Fragment of black fine-grained amphibolitic rock (delimited by a chalked line), a piece of chalk being placed at one of five nodules. The mafic fragment is surrounded by a reddish granite.

Fig. 12. Plagioclasite surrounds more or less angular mafic fragments in agmatitic breccia. North-eastern part of sketch-map, Fig. 10.

equal quantities, and a paled biotite sparingly; accessorily ore, titanite (one of the crystals has a length of 1 mm), and garnet partly *synanthetically* intergrown with epidote. The outer shell of the nodule contains more epidote than clinozoisite, but somewhat less muscovite than the centre of it. It also contains solitary grains of transluscent plagioclase, quartz, and ore. The outermost shell, transitional into the surrounding fine-grained amphibolite, is composed of plagioclase (An_{40}), much hornblende, epidote, and solitary grains of quartz and ore.

As shown by the optical data below, both epidote and clinozoisite occur, developed partly as needles, partly as equi-dimensional grains. The epidote crystals exhibit $2V_\alpha = 80°$, $c/\alpha = +3°$, $\gamma-\alpha = 0.036$, $\gamma-\beta = 0.014$, and $\beta-\alpha = 0.022$, corresponding to 20–24 mol% Fe-epidote (WINCHELL, 1951). The clinozoisite from the more central part of the nodule shows, $c/\alpha = -2°$, $\gamma-\beta = 0.008$, and $\beta-\alpha = 0.007$, corresponding to 3–8 mol % Fe-epidote. Similar nodules have been observed also in other amphibolitic fragments.

(4) Some other fragments in the agmatitic breccia carry about equal quantities of plagioclase (An_{45-50}) and bluish-green hornblende. However, the amphi-

bole crystals have often been replaced by a brown or greenish-brown biotite and varying quantities of epidote; the latter sometimes appearing as larger individuals of honey-combed pattern. In one thin-section square to rectangular crystals of plagioclase are enclosed in larger porphyroblasts of amphibole.

Besides amphibolitic rocks also other members of the Björneborg rock sequence are represented in the breccia, more or less altered by metasomatic processes.

(*d*) *The matrix of the agmatitic breccia* consists of various felsic, granitic to granitoid rocks, which have replaced, more or less extensively, the amphibolitic and leptitic rocks described above.

In the north-eastern outcrop on the sketch-map (Fig. 10) the agmatite exhibits rather sharp-edged black remnants surrounded by light-coloured or nearly white *plagioclasite derivatives* (Fig. 12). Smaller areas or patches of the same white plagioclasite, grading into porphyroblastic grey rocks, also occur on "Kantarellberget" (Fig. 10) S of the locality mentioned above. The rocks may be classified as various types of porphyroblastic diorites. The principal mineral constituent is plagioclase (An_{32}), partly square-shaped, reaching 7 mm, occasionally somewhat sericitized with myrmekitic borders. Further, varying amounts of biotite with a few remnants of amphibole and some quartz (one sample with 4.83% w), epidote, clinozoisite chiefly as thin needles in the plagioclase, zircon, rare scales of muscovite, some garnet, apatite, and ore. Potash feldspar ($2V = 61°$ and $\perp \gamma : \alpha / P = +7°$) appears only in some thin-sections and then as solitary grains. Biotite and epidote are often associated in small aggregates. Small grains of plagioclase, epidote, ore, and quartz are sometimes included in the garnet. In the biotite pleochroic haloes are exceptionally abundant (sometimes 7/1 sq.mm).

Granitic material with remains of older schistose structures penetrates the fine-grained dark Björneborg rocks as an anastomosing network in one locality inside the agmatitic breccia. The *gneissous rock* is composed of porphyroblasts of partly saussuritized plagioclase (An_{32}, crystals 1–5 mm) and microcline (7 mm), sometimes including older fragments of plagioclase. Further, quartz, biotite, epidote, clinozoisite, muscovite or sericite, an almost isotropic yellowish serpentine, rather large crystals of titanite, and ore have been noted. The subordinate "groundmass" of the rock appears with grains measuring only 0.01–0.03 mm.

In a small outcrop in the north-western part of the sketch-map (Fig. 10) the mafic fragments of the agmatitic breccia have been soaked with two types of felsic material, viz. one *aplitic*, which forms an anastomosing network, the other a rather coarse *reddish granite.*

The former (grains 0.15 mm) is composed of partly sericitic oligoclase (An_{20}), a few grains of myrmekite and potash feldspar, quartz, epidote, brown biotite, and an optically negative chlorite associated with some titanite and ore, and a few remnants of light bluish-green amphibole. Diablasts of quartz and small crystals of plagioclase are enclosed poikilitically in crystals of epidote.

The *reddish granite* (Fig. 11) differs notably in hand specimens by its more youthful appearance from the other granites of the area. It is composed of partly sericitic plagioclase (An_{28}), some antiperthite, porphyroblasts of potash feldspar without visible microcline grating, including small grains of plagioclase, smaller grains of quartz, brown and green biotites, epidote associated with the former, and accessorily ore. On the surface of the outcrop diffuse remains of an old schistose structure can be seen, which is conformable to a similar but more pronounced structure in the mafic remnants of the agmatite.

In the north-western and north-eastern outcrops on Fig. 10 and on "Kantarell berget" fine- to medium-grained granitic gneisses occur. They seem to be afiliated to the reddish granite and the porphyroblastic diorites described above. Besides plagioclases, they contain potash feldspar and only small amounts of quartz. The rocks seem to grade into *quartz-monzonites.*

In the same exposure as the quartz-monzonite in the north-western outcrop on Fig. 10, an associated *aplite* appears only as subordinate small patches; it is composed of plagioclase (An_{11}), much quartz (about 40% w), some perthite; subordinately brown and green biotites, and chlorite; accessorily titanite and ore.

On the eastern part of "Kantarellberget" larger stripes and smaller areas are occupied by a rock, which is partly rather similar to the Kristinehamn granite in hand specimen, but certain differences are revealed under the microscope. The rock is composed of much microcline-perthite ($2V = 69°$ and $\perp\gamma:\alpha/P = +11°$) represented by crystals reaching 3.5 mm, varying amounts of plagioclase ($An_{8\text{-}11}$) with crystals measuring 7 mm, rather much biotite and titanite, chlorite, some quartz (19.34% w), orthite, epidote associated with sericite in the plagioclase, but also with ore and apatite. Locally the *microcline-rich granite* grades into more *quartz-rich granitic rocks* (27.1% w) immediately W of the road between Vassgårda and Björneborg.

The most conspicuous feature of the *microcline-rich granite*, in relation to the latter granite and other granites in the field, is the presence of large porphyroblasts of microcline and a rather sparse mesostasis of smaller crystals (0.05) composed of plagioclase and quartz. However, sometimes porphyroblasts of plagioclase also occur. Potash feldspar partly encloses smaller crystals of plagioclase. Only solitary grains of myrmekite occur.

E. *The Östanmåsa Amphibolite*

The amphibolite body (VII–VII, Pl. A), situated only 1 km SSW of the southern end of the Björneborg rocks (IIb–IIb), is at least 500 m long and 50–100 m wide. Very typical dikes of hyperite appear close to it. The Östanmåsa (also Östanåsa) amphibolite has the appearance of a medium-grained diorite and is composed of plagioclase ($An_{35\text{-}38}$), amphibole partly replaced by biotite, rather light epidote, some quartz, zircon, and rarely calcite. The grain-size of the rock in general is about 0.6 mm.

At the northern and southern ends of the small, lense-shaped area occupied by the amphibolite, pinkish holoblasts of microcline usually appear in the rock, where it grades into the Kristinehamn granite. The holoblasts measure 5 mm and enclose smaller crystals of plagioclase (partly with laths of epidote), hornblende, epidote, and ore (inclusions of plagioclase and hornblende visible, Pl. 1, Fig. 3). Also holoblasts of quartz occur. They enclose crystals of plagioclase and amphibole.

F. *The Amphibolitic Rocks at Lindås*

A narrow zone of scattered small outcrops of fragmental amphibolitic rocks soaked with granitic material extends from Lindås southwards between the lakes of Ullvättern and Stora Vilången (IIa–IIa in Pl. A). The northernmost part of the zone, at Lindås, is clearly of the nature of an agmatitic breccia.

The main type of the Lindås rocks has a somewhat doleritic texture with partly lath-shaped crystals of plagioclase, 1 mm in length. The rock is composed of plagioclase (An_{50}), often with epidote and needles of clinozoisite, common hornblende, biotite, titanite, ore, and apatite. Garnet and patches of epidote occur in the southern part of the zone. The rock is often (E of a road) rather dense, black to dark-green. The enclosing material, carrying the amphibolitic fragments, is almost always the ordinary Kristinehamn granite.

G. *The Bergsjö Amphibolite*[1]

1. *The central body of the Bergsjö amphibolite.* It is rather difficult to estimate the original extension of the Bergsjö amphibolite, because of its eventual consanguinity with the quartz-diorite and quartz-monzonitic varieties of the latter. If the latter are included the complex covers an area of at least 1.3 sq.km.

Two types of amphibolite will be described below; one more *gabbroic* (*Type 1*) and another more medium- to fine-grained and *dioritic* (*Type 2*); the dioritic variety seems to be the more common. Often the gabbroic rock grades into dioritic varieties, and these, in turn, into more acid microcline-bearing rocks.

The *gabbroic variety* (*Type 1*) often carries square plates of plagioclase (about 35 sq.mm) and clinopyroxene (about 70 sq.mm). Laths of plagioclase are often enclosed in plates of clinopyroxene and in the amphiboles. Patches, 10–20 mm wide, of rather equidimensional crystals of plagioclase often occur.

A section of a plagioclase crystal, cut nearly $\perp \gamma$, exhibited from the kernel towards the margin the following compositions: An_{45}, An_{51}, An_{45}, An_{42}, and An_{30}. Another crystal had the composition An_{50}, and still another An_{56}.

The clinopyroxene, is rather diopsidic with the following optics: $2V_\gamma = 57°$ (calc. $55°$), $c/\gamma = 42°$, $\beta = 1.677$, $\gamma - \alpha = 0.028$, and $\beta - \alpha = 0.006$.

[1] III–III, Pl. A, sketch-map Text-fig. 4.

The *dioritic variety, Type 2*, is characterized especially by smaller laths of plagioclase, sometimes enclosed in the clinopyroxene ($2V\gamma = 57°$), in the amphiboles, and the biotites. The latter mineral is somewhat more common in the gabbroic variety. A solitary crystal of *potash feldspar* was found in this rock. Plagioclase is sometimes intimately intergrown with amphibole in a symplectitic manner.

Larger patches (4 × 4 mm) composed entirely of small plagioclase laths occur. These laths (0.1–0.5 × 0.03–0.1 mm) are of similar size as those enclosed in the crystals of the mafic minerals. The mafic crystals are often rather square, and often of similar dimensions as in the gabbroic variety. The plagioclase laths have the composition An_{52}–An_{40} decreasing to about An_{30} at the margin.

The clinopyroxene of the gabbroic as well as of the dioritic variety is usually more or less extensively altered, mainly into actinolitic hornblende. It is sometimes nearly colourless, more often pleochroic with α = colourless, β and γ light green ($c/\gamma = 17°$). A marginal zone of intensely bluish-green hornblende is very common along the borders of the pseudomorphs ($c/\gamma = 15°$, γ = bluish-green, β = brownish-green, and α = yellowish). It also occurs as isolated individuals.

The central parts of the bluish-green amphibole are either occupied by light-green amphibole or by clinopyroxene. Sometimes all these three minerals are replaced by biotite. The clinopyroxene (and sometimes also the actinolitic hornblende) is often stained with ore.

Clinozoisite generally replaces parts of larger plagioclase crystals in both the gabbroic and the dioritic variety, but sometimes aggregates of higher birefringent epidote are found instead. More rarely both epidote and clinozoisite appear inside crystals of plagioclase as, e. g. near the eastern contact of the Bergsjö amphibolite at bb (Fig. 4).

The textures of both the gabbroic and the dioritic varieties are doleritic to subophitic (sensu KROKSTRÖM, 1932).

2. *Marginal varieties of the Bergsjö amphibolite along its eastern (1) and south-eastern (2) contacts.* Along the eastern contact zone the marginal variety (1) of the Bergsjö amphibolite carries more amphibole and less clinopyroxene than the main mass, and small laths of plagioclase do not occur in the amphibole crystals. Solitary crystals of potash feldspar replace a calcic plagioclase in an antiperthitic manner. The plagioclase shows recurrent zoning. The amphibole ($c/\gamma = 14°$) is bluish-green and is partly replaced by brown biotite. Smaller quantities of quartz occur and accessorily clinozoisite, garnet, apatite, and ore. The plagioclase crystals are generally 1.0–4.0 mm, the quartz grains often about 0.1 mm. The marginal rock grades into quartz-dioritic varieties described below (p. 27).

Mafic remnants (Fig. 13) *inside the marginal variety* are of some interest, because they may indicate that mafic rocks still older than the Bergsjö amphibolite have occurred in the region W of Lake Bergsjön. These more or less

Fig. 13. The eastern marginal variety of the Bergsjö amphibolite enclosing elongated black amphibolite remnants cut by an apophysis of hyperite bb. A white band of cloth has been stretched out on the apophysis and the remnants have been delimited by chalked lines.

fish-shaped remnants are rather fine-grained (0.05–0.90 mm). The plagioclases are less calcic (An_{31}) than in the Bergsjö amphibolite between them, but mineralogically the remnants are still similar to the marginal variety, and traces of clinopyroxene ($2V_\gamma = 58°$ and $c/\gamma = 43°$) occur also in the remnants.

At the south-eastern contact (2) of the Bergsjö massif, near Arvidstorp (Fig. 4), the *amphibolite margin* (Fig. 14) is mineralogically rather similar to the eastern one, but is more fine- to medium-grained (0.6–2.0 mm) and does not carry any potash feldspar.

Boudinaged *amphibolitic fish-shaped layers* (part of one shown in Fig. 7) *in the granitic gneiss*, about 50 m south of the contact, are petrographically rather similar to the marginal rock here; in the outcrops they resemble boundinaged apophyses of the latter. The "fishes" carry hornblende needles ($c/\gamma = 24°$) 4.0×0.5 mm and often smaller plagioclase crystals (An_{28}).

3. About a hundred metres east of the northernmost corner of Kvarntjärn (Fig. 4), a *rock rich in biotite* is exposed over an area of only 2×3 m. The rock is of lighter colour and more coarse-grained than the surrounding black, medium-grained, ordinary Bergsjö amphibolite. This light variety exhibits sharp contacts towards the amphibolite. It has a rather pegmatitic appearance with very large (10–20 mm) plates of plagioclase (An_{52} grading into An_{32}–An_{20} marginally), large packets of biotite partly replacing bluish-green hornblende, much quartz with strongly undulatory extinction, titanite, apatite, and ore. The plagioclase often contains numerous thin needles of clinozoisite.

In the same outcrop as this rock, concordant *layers or veins of aplitic oligoclasite* (Fig. 15), 0.5–5.0 cm wide, occur *in the Bergsjö amphibolite*, with variable steep to moderate south-easterly dip. These veins are composed chiefly of oligoclase (An_{15}), quartz, solitary scales of biotite, some ore, and titan-

Fig. 14.

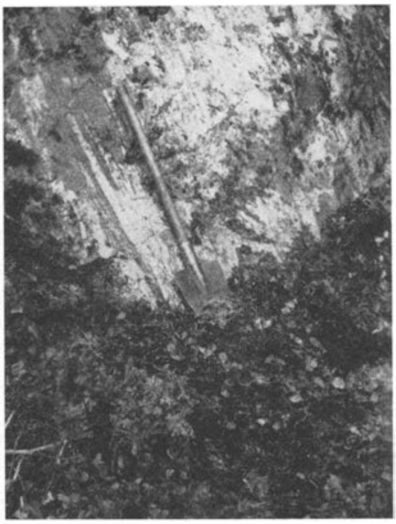


Fig. 15.

Fig. 14. Pegmatite, delimited by chalked lines, cutting the Bergsjö amphibolite north of the eastern farm of Arvidstorp, W of Lake Bergsjön.

Fig. 15. Aplitic layers or veins interfoliate a medium-grained Bergsjö amphibolite inside the massif near the north-western contact.

ite. The texture is rather peculiar (Pl. I, Fig. 4). Rounded holoblasts, which may attain a size of 10 mm, have forced the biotite scales and hornblende crystals of the amphibolite aside, and are separated from this mafic aureole by a zone of very fine-grained mortar-textured plagioclase. The main part of the holoblast is a uniform individual of plagioclase with an almost cryptoperthitic appearance, being densely stained with minute oval droplets of a slightly stronger birefringent mineral, probably quartz. Enclosed in this host crystal occur irregular patches of normal oligoclase-albite densely dotted in a similar way with rounded minute droplets which can be identified with certainty as quartz.

The mafic gneissous "bands", interfoliating the aplitic layers, carry zoned plagioclase (An_{31}), brown biotite, and zoned epidote ($c/\alpha = 2.5°$) abundantly, but also rather much quartz, and a few needles of clinozoisite in the plagioclase. The grain-size is about 0.1 mm.

In the same outcrop also several thicker (0.5–1.0 m) *aplitic and pegmatic inclusions* occur in the amphibolite. Because of their partly horizontal position it is, however, difficult to determine if they are true veins or enclaves of older feldspathic rocks. The texture of the inclusions is not saccharoidal, but rather tends to pegmatitic development. Plagioclase and microcline enter with about equal amounts.

Fig. 16.

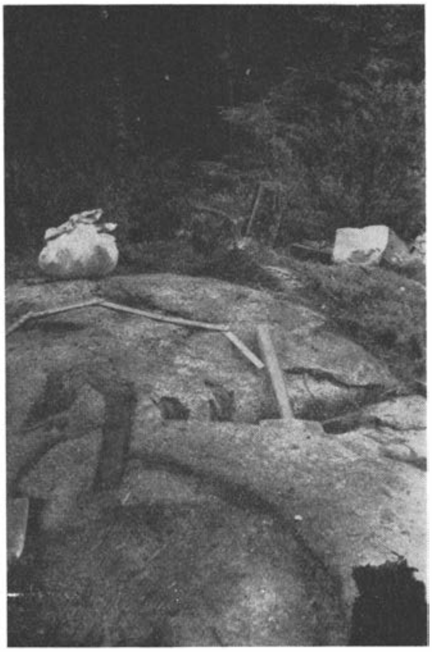


Fig. 17.

Fig. 16. Agmatitic breccia. Mafic fragments (delimited by chalked lines) in the quartz-diorite, WSW of Arvidstorp. The locality is also marked on the sketch-map Fig. 4, R, which shows also the mica schist remnant R occurring in the quartz-diorite.

Fig. 17. Four sharp-edged mafic fragments in an intermediary variety of the quartz-diorite, exposed some few metres W of the main Bergsjö amphibolite body, E of the northernmost corner of Kvarntjärn.

4. At the southern corner of the granitic gneiss area SSE of Kvarntjärn a pile, 10 m wide, of large erratic boulders of a *coarse amphibolite* (Area G in Fig. 4) occurs, and probably rock *in situ* too. In the east it borders on quartz-diorite. The contact is not visible either towards the quartz-diorite or the gneiss.

The rock carries a partly zoned plagioclase, clinopyroxene ($c/\gamma = 42°–43°$, $\beta = 1.680$, $\gamma–\alpha = 0.029$, $\beta–\alpha = 0.007$) with included plagioclase, amphibole, biotite partly replacing the amphiboles, and epidote. The crystals of plagioclase, which contain needles of clinozoisite, are twinned and exhibit a basic kernel of An_{57}. Some of the plagioclase margins exhibit beautiful implication textures by an intergrowth of ore and plagioclase, the ore forming worm-like masses, rods, and packets in the latter. Along the margins of these "worms" or rods of ore small crystals of epidote (Pl. I, Fig. 5) occur. Some crystals of plagioclase, clinopyroxene, and amphibole measure 25 mm, but some only a fraction of a mm. Larger scales of biotite have a size of 1–2 mm.

5. *Quartz-dioritic and quartz-monzonitic rocks* associated with the Bergsjö amphibolite. About 400 m south of the Bergsjö amphibolite (near Area R in

Fig. 4) a quartz-diorite, locally crowded with mafic fragments (Fig. 16) is closely associated with the former. The quartz-diorite grades diffusely into Kristinehamn granite and quartz-monzonite towards the south and into other granitic varieties towards the north-west, nearer the Bergsjö amphibolite. East of Kvarntjärn the granitic rock exhibits sharp contacts towards the Bergsjö amphibolite and carries only scattered sharp-edged mafic fragments (Fig. 17). The area of the quartz-diorite with its more or less granitic varieties has a length of about 1 km and a width of 200–300 m. Sharp to slightly wavy folds appear occasionally in the rock.

The quartz-diorite is composed of plagioclase, solitary holoblasts of potash feldspar, aggregates of small quartz grains, some few remnants of clinopyroxene, bluish-green (γ) to brownish-green (β) amphibole ($c/\gamma = 15°$), brown biotite associated with the latter, epidote, clinozoisite, calcite, titanite, ore, and zircon.

The plagioclases have a composition varying from An_{34} to An_{42}, occasionally more albitic (An_{22}) along the margin. They partly appear as laths, 4.2–5.0 mm long, but often the crystals are more equidimensional, about 4.0 mm across, giving the rock a medium-grained appearance. Smaller grains vary between 0.1–0.7 mm. Thin needles of clinozoisite are often enclosed.

The rather solitary holoblasts of microcline enclose smaller crystals of plagioclase, hornblende with small patches of clinopyroxene, and epidote.

Locally (for instance, in Fig. 16) the quartz-diorite grades into an *agmatitic breccia*, the mafic fragments of which resemble the dioritic variety (p. 23) of the Bergsjö amphibolite. The fragments are black; the grain-size varies between 0.1–0.5 mm; the rock is thus more fine-grained than the ordinary dioritic variety of the Bergsjö amphibolite. The fragments carry an abundance of partly lath-shaped plagioclase (An_{52}), clinopyroxene, bluish-green to brownish-green amphibole, brown biotite and accessorily zircon, ore, and apatite.

The optical data of the clinopyroxene very closely agree with those of the pyroxene in the Bergsjö amphibolite, viz. $2V_\gamma = 57°–59°$, $\beta' = 1.677$, $c/\gamma = 42°–45°$, $\gamma–\alpha = 0.027$ and $\beta–\alpha = 0.006$.

NW of the Bergsjö amphibolite the quartz-diorite grades into the Kristinehamn granite (Fig. 4) and S of the amphibolite into the quartz-monzonite. W of it, the quartz-diorite passes into an intermediary diorite rock, which differs from the quartz-diorite by much higher content of potash feldspars, here developed as antiperthite, anorthoclase ($2V_\alpha = 52°$ and $\perp\gamma : \alpha/P = +10°$), and perthite. The rather square crystals of plagioclase ($An_{30\text{-}36}$) are somewhat more sodic than in the quartz-diorite (here $An_{34\text{-}42}$) and are partly replaced by potash feldspar. Amphibole is less common than in the ordinary quartz-diorite, but still rather abundant.

A reddish medium-grained *quartz-monzonite*, rather similar to the above-mentioned potassic variety in hand specimens, crops out over an area of a few sq.m just NW of "R" on the sketch-map (Fig. 4). It is composed of plagioclase with some sericite and needles of clinozoisite, antiperthite, quadrille-

Table 2. Quartz-monzonite 200 m WSW of the western farm of Arvidstorp, 12 km NNE of Kristinehamn. Analyst R. BLIX. C.I.P.W. system Adamellose.

	Weight, %	Kat., %	Norm		
SiO_2	62.22	58.56	Qz	14.30	
TiO_2	0.82	0.58	Or	25.65	
Al_2O_3	16.64	18.45	Ab	31.25	F
Fe_2O_3	2.65	1.88	Cn	0.25	
FeO	2.74	2.15	An	16.70	
MnO	0.14	0.11	C	0.29	
MgO	1.88	2.63	Σ Sal	88.44	
BaO	0.15	0.05	Hy	6.68	
CaO	3.88	3.91	Il	1.16	
Na_2O	3.43	6.25	Mt	2.82	
K_2O	4.28	5.13	Pr	0.08	
H_2O+	0.63		Ap	0.40	
H_2O-	0.14		Cc	0.26	
P_2O_5	0.18	0.15	Fr	0.57	
CO_2	0.10	0.13	Σ Fem	11.97	
S	0.03	(0.05)	Σ	100.41	
F	0.13	(0.38)			
	100.04	99.98			
−O	−0.12				
	99.92				

structured microcline-perthite ($2V_\alpha = 84°–85°$), some quartz, brown biotite, bluish-green (γ) to brownish-green (β) amphibole ($c/\gamma = 14°–22°$), rather much titanite, apatite, zircon (in the biotite), and ore.

The plagioclase often appears as larger zoned, square or rectangular crystals An_{38}-An_{24} (reaching 6 mm) in a finer granoblastic groundmass. A tendency to recurrent zones is sometimes noticed. The plates of plagioclase are surrounded by small (0.1 mm) crystals of quartz in the groundmass. The feldspar plates are sometimes intersected by thin zones of crushed plagioclase, the interstices between the fragments sometimes being soaked with newly formed potash feldspar. The margins of the plagioclase crystals are sometimes patchily more albitic or potassic. In the plagioclase of the antiperthite very small needles of clinozoisite occur. Sometimes plagioclase crystals as well as biotite and ore are included in larger crystals of microcline-perthite. The potash feldspar of the antiperthite is not typically homoaxial with the plagioclase.

Apatite has been observed as inclusions in ore as well as in titanite (0.5 mm), the latter mineral being, as mentioned, rather abundant.

The chemical constitution of the quartz-monzonite is shown above. The norm of the rock has been calculated according to BARTH (1952).

The quartz-monzonite exhibits chemically certain similarities to the Kuopio syenites described by WILKMAN (1933) and to the granites of Åmål (cf. LARSSON, 1932, No. 203. p. 72) and Varberg (cf. LARSSON, 1932, No. 622, p. 120 and QUENSEL, 1952).

H. *The Emtefalla Amphibolite*

The main body of the Emtefalla amphibolite is situated 10 km E of Kristinehamn. The mineral composition of the rock is rather variable, especially as regards the proportions of biotite and amphibole. It consists mainly of andesine, common hornblende (0.1–1.5 mm; occasionally about 50% of the mafics), brown and green biotites (0.5–1.1 mm), epidote, orthite, clinozoisite, and chlorite; subordinately quartz (0.1–1.0 mm), red garnet, titanite, muscovites, apatite, haematite, and pyrite. The latter mineral associated with quartz sometimes forms thin veinlets. Several smaller trenches in the amphibolite indicate prospecting for ore in the amphibolite. Also between the old Karlskoga road and the Emten lake pyrite-bearing quartz veins occur.

The plagioclase (0.1–3.8 mm) of the main type is partly clear and translucent, but often more or less saussuritized. The crystals are often zonally built with the composition An_{50}-An_{31}. Some scattered, larger crystals of clinozoisite exhibit, $2V\gamma = 89^\circ$ and $\beta - \alpha = 0.005$.

The orientation of the biotite scales reveals two S-planes; one, which coincides with the foliation, is characterized by the biotite being associated with epidote, the other, in which epidote is lacking, cuts the former under about 25°.

The biotite is replaced by chlorite more extensively than anywhere else in the field. The garnet includes minute crystals of both quartz and epidote. In some varieties biotite occurs instead of amphibole.

About 200 m NW of 13–13 the Emtefalla amphibolite becomes more *gabbroic* over an area of about 200 × 200 m. The contacts towards the main amphibolite have not been observed. The gabbroid appearance is caused by square-shaped plates of common hornblende (0.3–7.5 mm) and plagioclase (4 mm). More or less rounded grains of both quartz and sericitized plagioclase are included in the amphibole.

A layer of a rather *coarse granitic gneiss* (14–14 on Pl. A), similar to the Kristinehamn granite, occurs in the new road cutting of the Karlskoga road. The granitic layer is surrounded by the ordinary Emtefalla amphibolite. It carries angular *inclusions* (Fig. 18, 11191) of a *biotite-rich rock*. The margins of the granitic layer are partly sharp, partly more diffuse, with holoblasts of feldspar also in the amphibolite. The granitic gneiss carries holoblasts of microcline, 4 mm in size, and oligoclase.

On the southern slope of a hill crest, 0.75 km ESE of the Emtefalla farm, extends an area of very heterogeneous rock (13–13, Pl. A). A schematic vertical section, shows the relations here (Fig. 19).

Fig. 18. Fragments (one of those 11191) of a biotite-rich rock in a granitic gneiss similar to the Kristinehamn granite. The gneiss is enclosed by the Emtefalla amphibolite. New Karlskoga road, 14–14 on Pl. A.

(*a*) An *eyed granitic reddish rock*, similar to the Kristinehamn granite in hand specimens, with holoblasts of potash feldspar, measuring 3 mm across, sometimes enclosing small crystals of plagioclase. It is composed of plagioclase (An_{22}) often stained with sericite, partly sericitic potash feldspar, quartz, brown biotite, chlorite, muscovite, zoned epidote, titanite, zircon, and apatite.

In a more aplitic variety a typical microcline occurs both as porphyroblasts and as smaller grains in the groundmass, together with plagioclase (An_{12}), some myrmekite, biotite, and quartz.

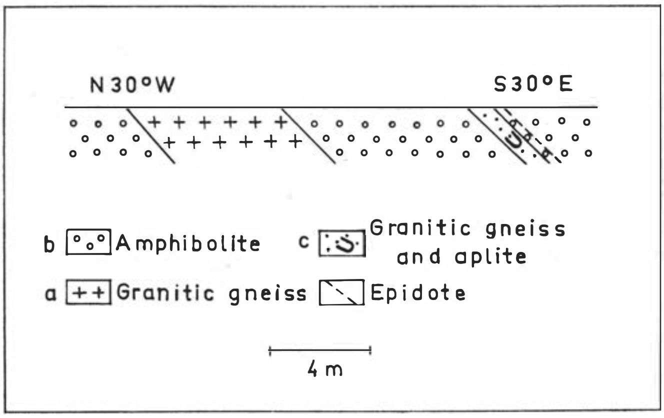


Fig. 19. Vertical section of 13–13 of Pl. A. Dip of schistosity in all the types of rocks is 45° E. The vertical section runs N 30° W.

Fig. 20.

Fig. 21.

Fig. 20. Light patches of feldspar (partly microcline) in dark Emtefalla amphibolite. Light granite towards the left. Detail of 13–13, Pl. A.

Fig. 21. Folded leptitic layer (left of the hammer) in granitic gneiss intercalating the Emtefalla amphibolite, southernmost part of 13–13, Pl. A.

(*b*) *Emtefalla amphibolite with scattered crystals of microcline* bordering on granite (Fig. 20). The crystals of microcline reach 1 sq.mm and sometimes include remnants of plagioclase, which is generally twinned and partly myrmekitic. The "groundmass" is composed of plagioclase, biotite, muscovite, epidote with single kernels of orthite, some chlorite replacing the biotite, quartz sparingly, titanite, apatite, and ore. The An-content of the plagioclase usually amounts to $An_{23\text{-}30}$, but decreases to An_{17} in some stripes. The muscovite often occurs as rather large scales in the plagioclase crystals, which are also pigmented by minute scales of sericite.

(*c*) The photograph (Fig. 21) shows a solitary *folded layer* consisting of a *leptitic rock* in stratum c in the section. It consists of plagioclase (An_{10}), potash feldspar subordinately, much quartz (40.6% w), partly as vermicules in the plagioclase, muscovite, biotite, the latter partly chloritized, solitary grains of epidote, some orthite, and ore. Both epidote and muscovite occur as inclusions in the plagioclase.

Some 20 m NNW of 13–13 a *folded fine-grained gneiss* occurs, nicely banded by nearly black layers alternating with light pinkish ones (Fig. 22). The former are composed of slightly zoned plagioclase (An_{22}), epidote, and biotite; solitary grains of quartz; accessorily apatite, titanite, and ore. The principal minerals in the light layers are plagioclase (An_{22}) and quartz (33–50% v, esti-

Fig. 22. Folded banded gneiss in the Emtefalla amphibolite, about 200 m NNW of the vertical section of Fig. 19.

mated), some potash feldspar, biotite, zoned epidote, and orthite. The layer is schistose and not saccharoidal, and the grains generally have a size of 0.1–0.2 mm, but some crystals reach 1 mm.

A narrow strip of *thinly laminated gneiss*, dipping about 45° E, is intercalated between the amphibolite and the Kristinehamn granite, along the eastern margin of the Emtefalla amphibolite. The laminated rock occurs inside the coarse eyed gneiss of 22–22. Here it exhibits a banding in felsic and more mafic layers of much variable thickness, but these bands are often thinly laminated with laminae only 1–2 mm thick. The darker layers are rich in plagioclase ($An_{20\text{-}27}$) and biotite, but they also carry epidote, muscovite, potash feldspar, and quartz.

Remarks on some other amphibolites. About 4 km NNW of Kristinehamn the rather fine-grained amphibolite (XVI–XVI, Pl. A) N of the Strand school house shows wavy stripes in parts of its body. This Strand amphibolite is partly fine-grained; locally the foliation is very pronounced by alternating mafic and felsic laminae. It differs from most other amphibolites in the same area by more acid plagioclase (about An_{17}) in its marginal zone.

The amphibolite XVII–XVII, Pl. A, is an ordinary schistose amphibolite with parallel laths of plagioclase (An_{32}), needles of bluish-green hornblende (about 40%), and some scales of biotite. Further appear patches of epidote (1 mm across), needles of clinozoisite in the plagioclase, and smaller quantities of quartz (8.3% w). Calcite occurs in thin cracks.

I. *Petrography of the Väse and the Ölme Gneisses*

The lenticular bodies of hyperite on the western part of the map (Pl. A) are, as mentioned, associated with gneisses of mainly two types, viz. one fine-grained with an aplitic appearance, which has been classified as Väse gneiss, the other,

Fig. 23. Deformation structure in the Ölme gneiss. Aplitic veins in an amphibolitic variety of the gneiss. Road cutting between the towns of Kristinehamn and Karlstad, E of the road to the railway station of Väse, immediately W of the area of Pl. A.

which is partly eyed, rather massive and often exhibits smaller black spots and stripes, has been termed Ölme gneiss. Both gneisses are reddish and usually carry larger quantities of potash feldspar.

The mineral composition of the *Väse gneiss* is very simple; the different varieties usually carry much microcline and quartz, generally smaller amounts of plagioclase (about An_{10}) and, more or less accessorily, brown biotite, titanite, ore, garnet, muscovite, and zircon.

Texturally and structurally the Väse gneiss is simple too; its slight schistosity is not always visible. It is almost always rather fine-grained (0.03–1.5 mm).

The following description of the partly eyed *Ölme gneiss*, which still appears with scattered traces of small folds (Fig. 23, cf. introduction, p. 5), is based on specimens from four localities, viz. W of the church at Ölme, at the mansion house of Benneberg, N of the school house at Strand, and from the deep railway section near the mansion house of Gustavsvik. The specimens are rather similar texturally, but the amount of dark constituents varies. The rocks are composed of rather small amounts of plagioclase (An_{6-12}), larger quantities of microcline partly as eyes reaching 4 mm across, and quartz, partly as vermicules in twinned plagioclase. Vermicules and diablasts of quartz also appear in smaller plagioclase crystals, included in or bordering porphyroblasts of microcline. Ordinary individuals of plagioclase, not fringed by myrmekite, generally also occur as inclusions in such porphyroblasts. Sometimes common hornblende occurs together with green and brown biotites. The chlorite exhibits partly a sphaerulitic development. Sometimes hornblende is absent. Pleochroic haloes have been observed in the chlorite and in the biotite. Often grains of ore are altogether replaced by titanite. This mineral is rather scarce, but in the gneiss at Gustavsvik it is abundant, forming rather large crystals.

Orthite was found in two thin-sections. Epidote has been observed only once, as small grains. Apatite appears accessorily.

The Ölme gneiss is rather heterogeneous; at Gustavsvik the gneiss is fine- to medium-grained. Occasionally the prophyroblasts of microcline reach 4.0 mm and those of plagioclase 1 mm across in the other gneiss specimens.

II

The Hyperites and the Hyperite-amphibolites

Hyperites form lenticular bodies probably largely of the nature of sills which in the western and central parts of the region (Pl. A), are usually associated with the reddish Väse and Ölme gneisses. With these sills have been classed also numerous dikes, marked with letters (AA–ÖÖ, aa–ll). These occur in the granitic region in the eastern part of the map, but the hyperite dd, in the same region, is surrounded by a relatively large field of leptitic greywacke N of Vilångstorp on the western side of Lake Stora Vilången. The dikes of hyperite in the granitic region are not always to be distinguished from certain amphibolitic rocks, which occur in the same region in the shape of larger lenticular bodies and confined massifs, which are supposed to represent more or less extensively altered older rocks. These bodies are marked with Roman figures. However, the Emtefalla amphibolite (I–I, Pl. A), which is not associated with leptitic rocks, might represent a former hyperite, but because no definite proofs are at hand, this amphibolite has been treated together with the amphibolites of the leptitic complex.

No definite proofs of an extrusive character of the hyperites have been obtained. Sometimes, e.g. along the eastern shore of the bay of Ölmeviken, the Väse gneiss faithfully follows the winding contour of the margin of the lenticular bodies of hyperite with low easterly dip and evidently constitutes its fundament here. Also the Ölme gneiss often seems to dip underneath the hyperites, e.g. N of Rudsberg railway station. Similar observations have earlier been made by Magnusson (1929) and Högbom (see Sandegren, 1922). The latter (1922, Fig. 9, p. 28) has observed a dôme-like fold of Ölme gneiss with a layer of hyperite-diorite on the island of Mårön near the land tongue of Skäggenäs. According to Högbom, this layer is intruded in both the gneiss and the granite.

Within the granitic eastern area of the map (Pl. A) the schistosity has an easterly dip throughout, but inside the Väse and Ölme gneisses both the strikes and dips of the schistosity and the stratification are more varying.

A rock similar to the Väse gneiss (6–6, 20–20, and small parts, not marked, of 16–16, Pl. A) is also associated with the three hyperite dikes CC, ff, and dd respectively, in the eastern granitic region of the map. The exact relationship between the hyperite dd on the western shore of Lake Stora Vilången and the greywacke, on which the hyperite borders to the north, is not known, but a

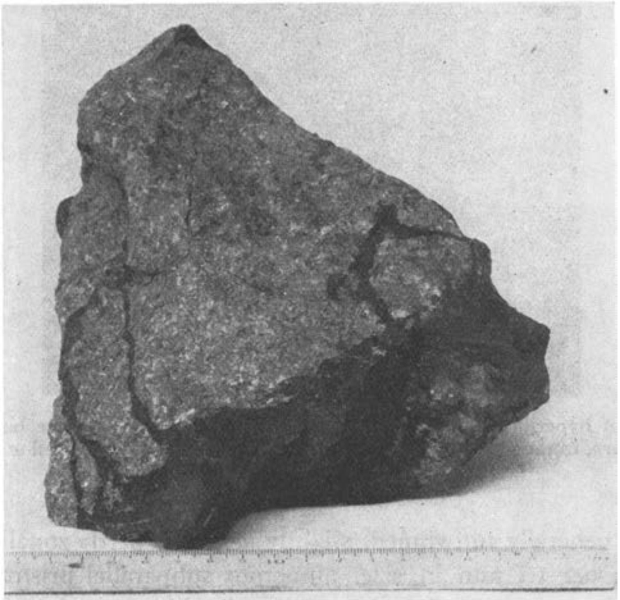


Fig. 24. Hand specimen of coarse granite with apophyses of olivine-bearing hyperite JJ. The locality is represented by a trench at the north-western margin of the hyperite JJ.

fragment (p. 44) of a leptitic greywacke has been found in the latter, near the contact. Also the leptitic rocks of 8–8 and 12–12 (Pl. A), which are associated with the Björneborg amphibolites (II b–II b), locally grade into gneisses similar to the Väse gneiss, but these gneisses have obtained another signature on the map.

At some localities, usually in the close neighbourhood of larger hyperite bodies, the Ölme and Väse gneisses are nicely banded by layers of black, fine-grained, rather massive amphibolite, often only a few cm thick, which eventually represent apophyses of the main sill, intruded conformably to the latter and subsequently amphibolitized.

Sometimes dense inconsistent veinlets, only a few mm thick, extend from olivine-bearing dikes (JJ on Pl. A) into the enclosing Kristinehamn granite in the east (Fig. 24), thus proving the intrusive nature of the former.

A zone of Ölme gneiss banded with amphibolite layers (25–25, Pl. A) occurs 0.7 km NW of Rudsberg railway station and extends conformably to the hyperite frontier, dipping 40° to 70° towards NE and NNE, possibly flooring the hyperite north of it. Similar banded Ölme gneiss is to be seen on the island of Torrholmen 7 km SW of Kristinehamn. Another zone of banded gneiss (24–24, Pl. A), associated with the Väse gneiss, 5 km NE of the gneiss 25–25, strikes W–E and has a steep dip varying between 80° N and 70° S.

At Rudsberg (25–25, Pl. A) the dark amphibolitic bands (Fig. 25) are

Fig. 25. Layer of hyperite-amphibolite (between the camera case and the hammer) in Ölme gneiss at Rudsberg, immediately W of the parsonage house of Ölme. Marked as 25–25 on Pl. A.

composed of generally untwinned, slightly sericitic, partly zonally built oligoclase (An_{17-20}) 0.2–1.1 mm in size, numerous subparallel prisms of common hornblende often 1.5 mm in length, and zoned epidote together with accessory garnet, brown biotite, calcite, apatite, titanite, zircon, and ore. Pleochroic haloes occur in the hornblende.

The adjoining and intercalated gneiss of Ölme type is composed of microcline with a nice grating, rather much plagioclase (An_{11}), partly zonally built, and only smaller quantities of quartz. Some brown biotite, epidote (sometimes with orthite kernels), titanite, and ore occur. About half the amount of plagioclase enters as a constituent of myrmekite, sometimes enclosed in crystals of microcline. The grains generally reach 0.1–1.4 mm.

A thin-section across the contact between an amphibolitic and a gneissous layer (Fig. 26) at Hållerud 14 km NW of Kristinehamn (24–24, Pl. A),

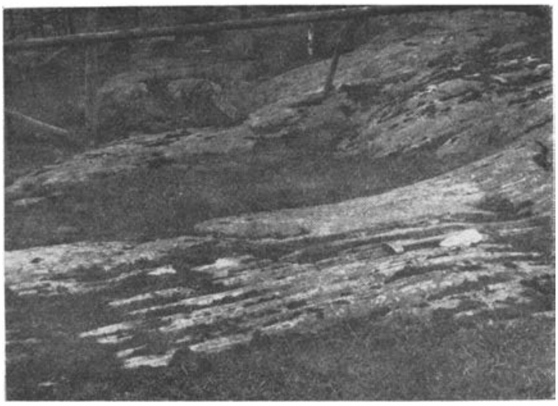


Fig. 26. Layer rich in biotite alternating with layers of Ölme gneiss at Hållerud. Marked as 24–24 on Pl. A.

exhibited the following structure. Under the microscope, the contact between the layers is very diffuse with gradual transition between the rocks. Both are composed of usually myrmekitic plagioclase (An_{6-10}) and microcline in almost equal quantities in both layers, further brown biotite, and quartz. The marginal zone of the dark bands carry larger amounts of brown biotite, some bluish-green common hornblende, and epidote. Titanite is rather abundant here, but apatite and ore are scarce. Myrmekitic plagioclase is more common in the dark layers than in the light ones, in which latter also individual crystals of plagioclase occur. The grain-size generally averages about 0.6 mm. The microcline sometimes carries diablasts of plagioclase.

Provided the dark bands do not represent older pre-hyperitic amphibolitic layers accidentally occurring near a hyperite, they must be interpreted either as apophyses intruded in the Väse gneiss parallel to its contact with the hyperite or they may represent tuff or lava layers of extrusive hyperite, which have been subjected to post-hyperitic regional metamorphism. Nowhere within the wide hyperitic area has, however, any phenomena suggestive of an effusive mode of hyperite eruptions been observed. It thus seems more likely that the amphibolitic bands represent thin apophyses of the main hyperite body, subsequently amphibolitized by regional metamorphism.

A. *Emplacement of the Hyperites*

Because no definite proofs of an extrusive character of the hyperites have been obtained in the field, the hyperites have, as mentioned, been regarded as intrusive. In the preceding pages the contact relations of the hyperites have been touched upon; more detailed descriptions of some of the contacts, and of the different varieties will be given in the following.

The hyperite character of some dikes or sills on the island of Koster in the province of Bohuslän, described by Asklund (1950, p. 34), is not definitely ascertained. The age of the intrusion of the hyperites in general has been discussed by Hjelmqvist (1950) in the surroundings of the mountain of Taberg in the province of Småland; according to him, the granitic texture of the granite is older (p. 12 and 52) than the hyperite intrusions. N. H. Magnusson, who has studied the hyperites extensively in south-western Sweden, found that these hyperites are younger than the surrounding gneisses, in which they have been incorporated by a regional metamorphism (1928, p. 812).

The *distinctive petrographical features of the hyperites relatively to other doleritic rocks* are well embodied in the definition of the term given by S. Hjelmqvist (1950, p. 34): "the typical hyperite is petrographically a diabasic (doleritic) rock with an ophitic or a subophitic texture, the main constituents of which are labradorite, clinopyroxene and most frequently olivine, while hypersthene is sometimes present but is just as often wanting. Besides these minerals there occur ilmenite, magnetite, and apatite. A most characteristic feature is the brown pigmenting of the plagioclase, which gives the rock, in hand specimen, a dark brownish black colour".

Already TÖRNEBOHM (1877) has described the hyperites of Ölme. Unfortunately the specimens described were more or less metamorphically altered varieties, whereas the typical massive hyperite in a quarry at Lid, N of Ölme railway station, escaped his attention. Quarrying for tombstones here probably started after 1877, but before 1936.

Within the western gneissous region of Pl. A the hyperite bodies dip gently towards both west and east, but in the granite region in the eastern part of the map, the more or less sill-like hyperite dikes (HH, OO, and YY), which eventually exhibit a "protogin" schistosity too (cf. Fig. 1), show gentle persistent dips.

The dikes AA, BB, CC, FF, HH, OO, YY, ZZ, and dd are either partly or altogether schistose. ENE of the farm Kummelön, the direction of the schistosity locally varies rather abruptly in a lenticular body.

At least the following hyperite dikes carry *olivine*: AA, BB, FF, II, JJ, PP, and dd. The dikes of RR, VV, WW, XX, hh, ff, ii, and ll are megascopically very similar to those mentioned above. The dike bb, which intersects the Bergsjö amphibolite (Fig. 4), has still typical coronas and also clinopyroxene. Excepting the olivine-bearing hyperites, typical doleritic textures occur in QQ, GG, and in an apophysis of CC. Aphanitic textures appear in the apophyses of JJ and bb.

Among the numerous minor dike-like bodies of hyperite, it is often very difficult to decide whether the intrusion is of the nature of a sill or a dike.

In many cases the nature of dikes is obvious, e. g. the intrusions AA, CC, FF, GG, KK, and bb. However, longer, straight, rather narrow zones of hyperites (20–50 m wide), which perhaps may turn out to be narrow sills with gentle dips (as possibly, for instance, BB, HH, OO, YY, ZZ, cc, and dd), have also been termed dikes, because these and other similar hyperites represent the continuations of the more than 60 km long swarm of dikes ("gångar") occurring on the geological map-sheets Furuholmarna (no. 136), Töreboda (no. 139), and Otterbäcken (no. 145) marked as "gångar" (dikes) by JOHANSSON, 1915 (see no. 139, WESTERGÅRD, 1915), and 1916 (see no. 145, SANDEGREN, 1916). In a later paper JOHANSSON (1927) was still uncertain whether these intrusive bodies belong to the hyperites or not.

The hyperite dikes CC, PP, VV, WW, and RR all appear quite near the sill-like ones of HH and BB, where a schistosity has partly obscured the primary contact relations. The fact that the hyperites CC and ff are associated with reddish gneisses similar to the Väse gneiss, exactly like the sills of the western part of the map (Pl. A), is suggestive of similar nature of the former. It is quite possible that within the area of the Väse and Ölme gneisses many isolated patches of hyperite constitute parts of extensive sheets, the continuity of which is now either hidden by recent deposits or dissolved by denudation. Generally very broad lenticular bodies of hyperite (often 200–500 m wide; see western part of Pl. A), some of them 5 km in length, occur in the granitic gneisses of the Ölme plain. The dikes vary in length from about 1.5 km to about 100 m, and in width from 10 to 50 m. Apophyses of JJ (Fig. 24, p. 35) are partly only 3 mm thick, and are aphanitic, or nearly so, to the naked eye.

The hyperite dikes almost all occur inside the region of the typical coarse granite with some gneissous varieties, but kk, jj, and ZZ occur in the boundary zone between the coarse granite and the Ölme gneiss.

The main strike of the dikes is N–S, but the olivine-bearing hyperite AA strikes NNW, and the amphibolitic hyperite HH probably NNE. Adjacent granites, if at all gneissous, are dipping gently towards the east everywhere, striking NW–N–NE. The strike of the gneisses is much more varying.

To the naked eye, the black olivine-bearing hyperites are very similar to unmetamorphosed ordinary dolerites with laths of plagioclase, about 2.0 × 0.5 mm. Such hyperites occur at Lid (1.7 km N of Ölme railway station), immediately W of Trefors (15 km NW of Kristinehamn), SSE of Svarteberg (at the entrance of the Ölme Bay), on the island of Killingen (S of Svarteberg), at Elofstorp (2 km SE of Trefors). All the olivine-bearing hyperite dikes mentioned earlier also belong to the above type.

The hyperites and their metamorphic varieties have been described by *inter alios* TÖRNEBOHM (1877), ALVAR HÖGBOM (see SANDEGREN, 1922), MAGNUSSON (1933 *a*, *b*, and 1934), BRÖGGER (1934–35), LARSSON (1940, pp. 368–70), and HJELMQVIST (1950).

In the typical hyperites of the Kristinehamn area, olivine is a much more characteristic mineral constituent than is orthopyroxene; the texture is ophitic, with laths of plagioclase enclosed in clinopyroxene; reddish-brown mica (iddingsite?) and ore often replace the olivine.

Along the borders of some of the lenticular bodies (N of Öna) and in the dikes AA and cc larger crystals of orthopyroxene appear, but also the inner corona, occurring around olivine, is composed of orthopyroxene (cf. BRÖGGER, 1934–35, p. 24). More or less metamorphosed marginal zones of the hyperites carry brown biotite and garnet, but also small patches of granophyre (N of Öna, p. 50). In some instances the margins of the hyperites are holoblastic (pp. 45–51).

The majority of the lenticular bodies and the dikes seem to have been altered into amphibolites, for instance GG, HH, QQ, YY, ZZ, and kk; the latter represents the Vålö amphibolite and is composed chiefly of bluish-green amphibole and plagioclase (An_{30}).

(*a*) *The olivine-bearing hyperites.* As type locality of this rock has been selected the black hyperite exposed in the quarry of Lid, 10 km NW of Kristinehamn. The modal composition of the rock is given in Table 3. Besides the minerals mentioned accessorily enter also *zircon* and *apatite*; further secondary *orthopyroxene* surrounding olivine as a corona, *actinolite* present as an outer corona (Pl. I, Fig. 6), some *reddish-brown mica*, and *ore*. Because the scattered mi-

Table 3. Micrometric analyses of hyperites: Lid (1), Lid (2), and BB (3) in % w.

	4004 = 6652 1	4002 2	3033 3
Plagioclase	56.7	59.1	50.3
Olivine	14.5	10.6	20.9
Hypersthene	4.1	5.7	4.4
Actinolite	7.8	10.7	8.3
Clinopyroxene	10.2	7.8	9.2
Ore	6.7	6.1	6.9
	100.0	100.0	100.0

nute grains of reddish-brown mica, zircon, and apatite, are very difficult to estimate quantitatively, they have not been distinguished in the micrometric analyses of the rock (Anal 1 and 2). The modal composition of the hyperite dike BB (3) has been added for comparison.

The zoned *plagioclases* of the olivine-bearing hyperites at Lid have a composition of $An_{59\text{-}66}$ in their kernels; exact measurements are, however, often difficult, because of the inhomogeneity of the crystals due, possibly, to the formation of coronas around the olivine crystals when bordering on plagioclase. The lamellae of one set of the twins are very narrow; crystals twinned both according to the albite law and the pericline law are rather common. The plagioclase is more or less densely stained by a brownish-black dust (also the plagioclases of the olivine-bearing dikes contain such dust).

All the olivine-bearing hyperites mentioned above (p. 38) are very similar to the hyperite at Lid texturally and mineralogically (plagioclases $An_{50\text{-}65}$). The central part of the dike JJ, with double coronas around the olivines, is partly more coarse-grained.

The optical data *mafic minerals* of the hyperite at Lid (1) compared with those of a hyperite dike I–I at Posseberg are tabulated below:

Olivine

	1	I–I
$2V_\alpha$	78°–82°	78°–82°
$2V_\alpha$ (calc.)	81°	
β	1.725	1.725
$\gamma-\alpha$	0.038	0.038
$\beta-\alpha$	0.022	0.021

All the above data of the olivine correspond to Fa_{35} according to TRÖGER (1956, p. 37).

Clinopyroxene

	1	I–I
$2V_\gamma$	56°–58°	54°–58°
$2V_\gamma$ (calc.)	62°	62°
c/γ	45°–46°	45°–46°
α'	1.706	
γ'	1.724	1.724
$\gamma-\alpha$	0.030–31	0.029–30
$\gamma-\beta$	0.021	0.022

Thus, the principal mafic minerals are identical in both rocks, one of which appears as a lenticular body (1), the other as a typical dike (I–I); therefore these two types of hyperites may represent products of a common magma. The data of the clinopyroxene in the hyperite at Lid correspond, according to TRÖGER (1956, p. 62), to $CaSiO_3$ 46%, $MgSiO_3$ 21%, and $FeSiO_3$ 33%. Consequently the clinopyroxene may be classified as a *ferroaugite* in the sense of TRÖGER (1956, pp. 53–54).

The *orthopyroxenes* in both the olivine-bearing, relatively unmetamorphosed lenticular bodies and in the dikes generally occur only as radiating needles in the corona (Pl. I, Fig. 6) nearest to the olivine crystals, which are often replaced by *ore* and *reddish-brown mica.* Sometimes also the hypersthene corona is replaced by ore. The outer corona is usually composed of *actinolite*, occasionally altered into brownish-green hornblende. *Garnet* has been observed in the innermost corona (dike AA) only once. Chlorite and serpentine are absent or very scarce in all the hyperites above mentioned.

In the hyperite of Lid several equidimensional crystals of olivine are often grouped in a ring-like manner (rings 10–20 mm across). The *rings of several olivine crystals* surround separate crystals of clinopyroxene, which include laths of plagioclase in an ophitic manner. From outside the rings, the ordinary rock constituents intrude between the olivine crystals. The above ring structure is not always easy to discover, because it becomes rather complicated, when the olivine crystals are fringed by coronas of radiating minerals only in contact with the plagioclase crystals.

The above-mentioned double coronas appear around each separate crystal of olivine in both the hyperite at Lid and in the hyperite dikes. Similar coronas have also been described by, *inter alios*, BRÖGGER (1934–35), BARTH (1939), GUIMARAES (1948), HJELMQVIST (1950), LUNDEGÅRDH (1943), and SHAND (1945).

In one thin-section both olivine, smaller laths of plagioclase, and apatite are included in a crystal of clinopyroxene.

The hyperitic lenticular bodies in the western part of the Kristinehamn area are, no doubt, closely related petrographically to the hyperite dikes or dike-like hyperites, all mineralogical and textural qualities, as well as the dark pigmenting of the plagioclases, being identical. Not only the lenticular bodies in the west, but also the olivine-bearing dikes are often partly amphibolitized along their margins (AA, FF, dd). Some of the doleritic dikes (GG, CC, QQ) are altogether amphibolitized. The amphibolitic hyperite dike GG still exhibits textures suggestive of pre-existing olivines with their coronas. *Garnet* occurs not only in the hyperites in the west, but also in the olivine-bearing dikes, e.g. in AA and dd. Garnet has also been observed in the doleritic dikes of hyperite-amphibolite (in, for instance, GG, OO, CC, QQ). The doleritic hyperite-amphibolite HH, also with textures suggestive of pre-existing olivine, contains megascopic crystals of garnet in the amphibolitic marginal zone.

In the quarry at Lid very coarse-grained, black rather thick (10–20 cm across) linear streaks of a *pegmatitic rock* occur, which border on the normal hyperite with diffuse contact. These streaks are composed of perthite-antiperthite, zoned plagioclase (An_{35}), some quartz, and rather large crystals of *apatite.*

The occasional occurrence of aphanitic to pilotaxitic apophyses has already been mentioned (Fig. 24). They represent apophyses from the olivine-bearing hyperite JJ (10 km SSE of Kristinehamn, Pl. A) with double coronas around olivine; branching apophyses intersect the crystals (Pl. II, Fig. 7) of the adjoining granite. The apophyses are generally more than 3 mm wide and exhibit a multitude of translucent laths of plagioclase (An_{47-55}, An_{47} with $\beta = 1.556$), olivine, reddish-brown mica, and ore. The two latter minerals partly replace the olivine, which here is fringed by a *single corona.*

At the north-western contact, 5 km ESE of Kristinehamn a more than 20 m long and 0.1–1 m wide doleritic apophysis of the amphibolitic hyperite CC intersects the coarse Kristinehamn granite.

The *hyperite dike* bb, which intersects the Bergsjö amphibolite (Fig. 4), does not contain olivine. The rock carries, however, aggregates of ore and reddish-brown mica surrounded by coronas of radiating crystals of hornblende, brownish-green in the inner part, bluish-green in the outer, all suggestive of *former olivine.* Clinopyroxene ($\alpha' = 1.706$ and $\gamma' = 1.724$) is still present, enclosing laths of plagioclase in an ophitic manner. An aphanitic to dense apophysis of bb intersects the marginal variety of the amphibolite (700 m SSW of the Gåsviken farmstead, Pl. A), the photo (Fig. 13) of which also demonstrates mafic remnants present in the eastern marginal variety of the Bergsjö amphibolite.

(*b*) *Amphibolitic and schistose hyperites.* There is a gradual transition from massive, olivine-bearing hyperites into the amphibolitic marginal zones, which usually surround the hyperite bodies. Along the western margin of the hyperite dike dd (centre with olivine surrounded by double coronas), where the typical ophitic texture is gradually destroyed, this transition can be studied in great detail. The large laths of plagioclase disintegrate into granules (Pl. II, Fig. 8), the pyroxene is replaced by poikilitic or symplektitic aggregates of amphibole and plagioclase, olivines by aggregates of ore, biotite, and amphibole.

Similar relations were observed along the north-western margin of BB. Garnet appears probably in all amphibolitic hyperites. It is often very difficult to settle from petrographical data only, if an amphibolite represents a former hyperite or not.

The plagioclase of the amphibolitic hyperites varies from An_{27} to An_{45}. For instance, the kernels of QQ show An_{33}, the margins An_{27}, and the whole crystals of hyperite HH An_{45}.

Whether the lenticular bodies of hyperite in the west are mainly hyperite-amphibolites or olivine-bearing hyperites, has not been investigated, but probably amphibolitic derivatives are the more common.

(*c*) *The amphibolitic hyperite* kk is probably rather representative of most of the hyperite-amphibolites on the islands 10 km SW of Kristinehamn. The rock is schsistose and has been classified as a hyperite by H. E. JOHANSSON (1917, map-sheet no. 136, Furuholmarna), but its hyperitic character is, however, doubtful. The rock consists of slightly rounded crystals of plagioclase (An_{31}), often stained with sericite, bluish-green common hornblende ($c/\gamma = 18°$), varying amounts of brown biotite, partly zoned epidote, some quartz, ore, and very few crystals of titanite. The rock is relatively coarse-grained, and the crystals reach 4.2 mm.

The amphibolite is cut by several straight veins (1–2 cm wide) of quartz with scattered often rather large grains of pyrite.

Several gneissous layers (some of them resembling massive varieties of the Ölme gneiss), 0.1–2 m thick and often more than 20 m in length, appear inside the amphibolite.

B. *Felsic Remnants in the Hyperites*

Below will be described inclusions of a leptite rich in clinozoisite (a), greywacke (b), Väse gneiss (c), and Ölme gneiss (d).

(*a*) On the main road Kristinehamn–Karlstad, 1 km NNE of the railway station at Ölme, a *leptitic inclusion* (at least 1×0.2 m) appears in the margin of a hyperite body. Towards the north the inclusion is covered by till, and towards the south by the road metal (Fig. 27). An aplitic to pegmatitic narrow dike intersects the hyperite a few metres E of the inclusion.

The rock is very fine-grained with generally pinkish colour and with stripes and patches of fine-grained grey material. The pinkish parts consist mainly of oligoclase-albite (An_{15}) and much quartz, whereas potash feldspar seems to be absent. The greyish stripes and patches mainly consist of clinozoisite, partly sericitic plagioclase, epidote, pale brown biotite, very few scales of light-green chlorite, some yellowish chlorite, muscovite and solitary grains of quartz, titanite, ore, and a zoned orthite.

The clinozoisite exhibits $2V_\gamma = 85°$, $\beta = 1.725$, $\gamma-\beta = 0.005$, and $\beta-\alpha = 0.004$. According to WINCHELL (1951) these data correspond to 5 mol% Fe-epidote. The rather rare epidote shows $\gamma-\beta = 0.020$. The grain-size varies between 0.1 and 0.3 mm; one crystal, 1.3 mm in length, was observed.

Fig. 27. An inclusion of a leptitic rock rich in clinozoisite in the hyperite. Observe the undulating contact between the inclusion and the hyperite along the right contact of the inclusion. The hammer appears along the left contact. Locality 1 km NNE of the railway station of Ölme.

(*b*) An inclusion of *leptitic greywacke* appears in the marginal, amphibolitized part of the olivine-bearing hyperite dd on the land tongue N of the farm Vilångstorp. The inclusion, which is about 15 cm broad, is very fine-grained and slightly schistose and is similar to the adjoining leptitic, mafic greywacke of types 3–4 (cf. pp. 8–9). It is composed of plagioclase (An_{20-25}), which looks pinkish in the microscope, some potash feldspar (very seldom with quadrille structure), rather much biotite, and some quartz; subordinately epidote (very small needles and equidimensional grains), clinozoisite, and a few grains of garnet which include several other minerals; accessorily ore and very few grains of apatite.

(*c*) Immediately W of the Svarteberg farm, on the south-eastern shore of Ölme Bay, only a few metres from the contact between the Väse gneiss and the hyperite, the outcrop pictured on Fig. 28 was studied. The northern part of the exposure consists of an aplitic rock, very similar to the adjoining Väse gneiss, protruding wedge-like into the hyperite. It was not possible to ascertain whether the former represents an isolated inclusion in the hyperite or a flake of *Väse gneiss*, still connected with the gneissous fundament. A similar flake of Väse gneiss is shown on Fig. 29 (here delimited by chalked lines on three sides).

The inclusion shown on Fig. 28 consists mainly of oligoclase-albite (An_{14}) with a greyish pigment, relatively few crystals of quadrille-structured microcline, solitary scales of muscovite, some biotite with pleochroic haloes around both zircon and small crystals of garnet. Crystals of orthite reach about 1 mm in size. The biotite is partly replaced by chlorite.

(*d*) In the road crossing, 1.4 km N of the railway station at Ölme, several inclusions of typical *Ölme gneiss* occur. The largest inclusion measures 4 × 2 m.

Fig. 28.

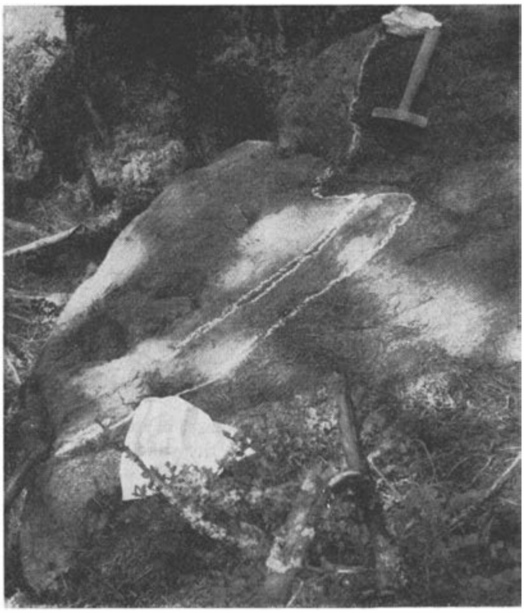


Fig. 29.

Fig. 28. Inclusion of Väse gneiss (hammer on this rock) in hyperite. Stripes of biotite in the hyperite are marked by chalk-lines parallel to the spade.

Fig. 29. Flake splitt off from the Väse gneiss and partly bordered by hyperite, Svarteberg. Immediately S of the locality pictured in Fig. 28.

C. *Marginal Zones of the Hyperites*

On several occasions the marginal part of some bodies of hyperite exhibits a peculiar development with "eyes" of large crystals of plagioclase, microcline-perthite, and some patches of quartz, which give the rock a *porphyroblastic appearance* in a hand specimen. Such is the case with the hyperite bodies at Trefors,[1] Stubberud, and Bergstaten, and less typical at Kartåsen. A similar porphyroblastic development has also been observed along the margin of the dikes AA and QQ (Pl. A). North of the farm of Öna (Pl. A) the hyperite body carries, instead of porphyroblasts, only solitary small patches of granophyre. In many of the zones the eyes are rather densely distributed.

Hyperites with holoblastic margins have been observed both in the *granitic* (inside QQ and AA) and in the *gneissous regions* (Pl. A). In the latter, holoblastic zones appear near the Trefors farm (15 km NW of Kristinehamn), at Stubberud (3 km SE of the former zone), at Bergstaten (8 km NNW of Kristinehamn), at Kartåsen (2.2 km SSW of Trefors), and at Öna (10 km due W of Kristinehamn). The dike QQ is situated 5 km E of the town and AA 3.5 km NNE of it, both in

[1] The "tre" in Trefors means "three"; it is not "trä" (= wood). Three rapids (forsar) really exist here. On maps one usually finds Träfors.

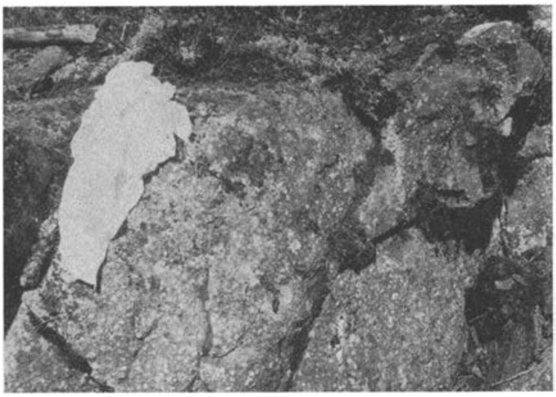


Fig. 30. Holoblasts of plagioclase, cryptoperthite, and quartz in the marginal zone of hyperite QQ. South-eastern margin of the dike, N of the farm of Sätterbron, 5 km E of Kristinehamn.

the granitic region (Pl. A). In the more or less gneissous hyperitic marginal zones, the holoblasts of plagioclase have pushed the scales of biotite and certain other minerals aside.

(*a*) *Holoblastic zone of the doleritic hyperite-amphibolite QQ*, 5 km E of Kristinehamn. Along the south-eastern margin of the doleritic rock a narrow zone of holoblastic ampibolite, 20 m long and 2–10 m wide, is intimately associated with the main body of the hyperite dike. Holoblasts (Fig. 30) of both plagioclase and microperthite, as well as of quartz have been found in the marginal zone.

Some of the smaller crystals of *plagioclase* are partly, quite locally, myrmekitic. A dense albite twinning is locally faintly discernible in the holoblasts of plagioclase, but elsewhere the plagioclase host crystal looks homogeneous. It also encloses irregular skeletons of amphibole and often small scales of biotite. The holoblasts are occasionally studded with small crystals of clinozoisite. Other large ovoid eyes of cm-size consist of aggregates of smaller rounded grains of plagioclase (An_{20}), 0.1–0.5 mm in size, each grain often crowded with minute droplets of quartz (Pl. II, Fig. 9).

Holoblasts of *microperhithe* (or cryptoperthite, $2V_\alpha$ = about 54°) appear with very fine-meshed networks of oligoclase (Pl. II, Figs. 10–11). The droplets in these networks consist of oligoclase, because they have been observed to extinguish simultanously with larger enclosed crystals of typical oligoclase. The holoblasts of microperthite are occasionally surrounded by a nearly complete zone of myrmekite (Pl. II, Fig. 12). Not only the plagioclases, but also the microperthites enclose skeletons of amphibole (Pl. III, Fig. 13). Goldschmidt (1916, Fig. 6, Taf. III) has described an oligoclase-microperthite, somewhat similar to the one mentioned above, in mangerite of the Jotun rock province in the central Caledonides of Norway (cf. N.H. Kolderup, 1940, p. 90).

The groundmass (grain-size 0.03–0.5 mm) of the marginal zone of QQ consists of sometimes lath-shaped plagioclase (An_{20}), quartz, biotite, amphibole, titanite, clinozoisite (often in the plagioclases), calcite, apatite, and ore. Among the mafics, biotite, partly altered into chlorite, is the most common mineral, but in one thin-section almost only hornblende occurs, but still here both skeletons of hornblende and scales of biotite appear in the holoblasts of plagioclase.

In a gneiss block enclosed by hyperite and derived from the adjoining gneiss at Hökås (Scania), P. LJUNGGREN (1959) has studied the reactions which have taken place in certain minerals of the block. One conspicuous feature is the extensive myrmekitization of the feldspar (Fig. 2, p. 81), very similar to those of Pl. II, Fig. 9 and 12. The holoblasts of the hyperite QQ probably also originate from its wall rock.

The holoblastic rock of QQ is intersected by pinkish *veinlets of an aplitic appearance*, the texture of which is very peculiar. Under the microscope the rock is seen to consist of more or less anhedral grains (averaging 1 mm in size) of quartz, microperthite, and plagioclase (An_{17}) in order of frequency, separated by a mesostasis of interlocking minute grains of feldspar and quartz and scattered crystals of biotite of hornfelsic appearance. Many crystals of microperthite are intersected by thin veinlets of the same extremely fine-grained aggregate as forms the mesostasis. The large plagioclases exhibit only very faint albite twinning or none at all. The quartz is only faintly undulous, but is divided into fields with different optical orientation.

The *potash feldspars* are microperthitic; locally the albitic component becomes predominant, eventually leaving potash feldspar only as smaller patches in the host crystal. The microperthite is not quite similar to the one of the above zone in hyperite QQ. The microperthitic crystals of the aplitic rock are usually marginally intergrown with quartz (Pl. III, Fig. 14). Again, other potash feldspars are bounded by a more irregular rim of myrmekite with lobate contact (Pl. III, Fig. 15).

The *plagioclases* (An_{17}) are usually only slightly stained with decomposition products, but occasionally the larger holoblastic plagioclases are studded with small crystals of clinozoisite and minute laths of biotite. The larger plagioclase crystals are sometimes surrounded by a marginal zone of potash feldspar intergrown with quartz (Pl. III, Fig. 16). Sometimes these plagioclases, with their micropegmatitic margins, are entirely enclosed in quartz, which in part displays the same optical orientation as the quartz in the micropegmatite. Thus both kinds of quartz are closely related genetically. The interstices between the grains are occupied by isometric grains of feldspar and quartz, the latter of which extinguishes contemporaneously over considerable areas.

Reactions of a similar nature have also been active in an *inclusion* (0.6 × 0.3 m) *of holoblastic gneiss*, rich in biotite, enclosed *in the northern part of the hyperite-amphibolite HH*, 5 km SE of Kristinehamn (Fig. 31). This inclusion resembles the marginal rock of the hyperite-amphibolite QQ in hand specimens.

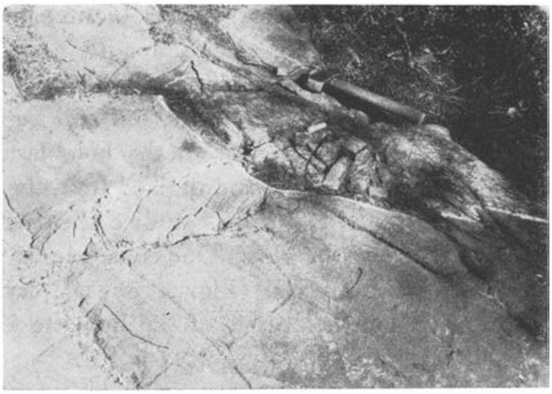


Fig. 31. Holoblastic ovoid-shaped inclusion (delimited by chalked lines) in the northern part of the doleritic hyperite-amphibolite HH.

The rock is composed of numerous rounded or subrounded holoblasts of brick-red *plagioclase* (An_{10-16}) in a groundmass of smaller plagioclases, which are often lath-shaped and much stained with sericite and calcite, dirty-brown biotite, which is usually extensively altered into chlorite, younger clear and anhedral grains of plagioclase and quartz sometimes myrmekitically intergrown, and accessorily calcite, apatite, zircon, and ore. The holoblasts of plagioclase have a very peculiar appearance, being patchily and densely penetrated by dense networks of quartz in a cryptogranophyric manner (Pl. III, Fig. 17). As to mineral composition, the complex holoblasts are closely related to myrmekite, but the textural pattern is rather that of a graphic intergrowth ("schriftgranitisch"). The holoblasts carry skeletal remnants of amphibole (Pl. III, Fig. 18) and scattered scales of biotite.

About 350 m SSW of the holoblastic inclusion inside hyperite HH, in the railway cutting intersecting the southern end of the hyperite HH, another inclusion or protruding wedge (2 m across) of a somewhat gneissous rather typical Kristinehamn granite (1–1, Pl. A) appears in the hyperite HH. This inclusion is not similar to the holoblastic rock present in the northern part of the hyperite.

(*b*) *Holoblastic zones of the hyperites at Trefors, Stubberud and Bergstaten.* At *Trefors* (also Träfors), about 15 km NW of Kristinehamn, the eyed marginal zone of the hyperite is about 5 m wide, grading to the north into typical unmetamorphosed hyperite, and bordering to the south on reddish Ölme gneiss with vertical dip. Two thin-sections from a larger exposure 500 m W of the Trefors farmstead have been studied.

The rock may be classed as a fine-grained garnetiferous amphibolite with large holoblasts of plagioclase. It is composed of common hornblende, brown biotite partly replaced by chlorite, irregular grains and large holoblasts of rather fresh andesine, scapolite, garnet, and clinozoisite; accessorily calcite, apatite, titanite, and ore. The ore is represented by both an oxide (ilmenite?) with a titanite border, and by pyrite.

Larger twinned ***holoblasts of plagioclase*** ($An_{26\text{-}33}$) in an amphibolitic groundmass are studded with numerous, often lath-shaped crystals of clinozoisite, sometimes arranged in winding strings; further the holoblasts carry small crystals of biotite, in part lath-shaped and with an orientation more or less parallel to (001). In some cases the plagioclase is partly surrounded by a marginal zone of several rhombdodecaeders of garnet, poikilitically intergrown with plagioclase of the same optical orientation as the eye (Pl. IV, Fig. 19). Consequently, the holoblasts can hardly represent primary phenocrysts of a basaltic rock. Apart from all these minerals, the holoblasts also contain larger irregular amoeboid patches of nearly fresh *scapolite* (Pl. IV, Fig. 20) with $n \gg 1.55$ and $\omega - \varepsilon = 0.03$, which corresponds to 60 mol% of meionite (WINCHELL, 1951, p. 353). The scapolite contains clinozoisite crystals similar to those in the plagioclase and, besides, also small patches of probably secondary calcite.

BRÖGGER (1934–35, p. 122) has found scapolites in hyperitic ödegårdites of Norway with the composition of Ma 77.54, Me 12.57, and MeK 10.64 (= 100.75 %), which is then more marialitic than the scapolite of Trefors. He mentions (p. 124) that the scapolite has essentially been formed at the expense of "the feldspars", thus, here plagioclase.

Along the eastern margin of a hyperite 0.3 km SW of Stubberud, about 3 km SE of the Trefors locality, a holoblastic, somewhat skarn-like zone is exposed in an area of 20 × 5 m. The rock is composed of holoblasts of plagioclase (An_{26}) less ovoid in shape than at Trefors, lath-shaped crystals of plagioclase, equidimensional grains of myrmekite, clinopyroxene, pale-green amphibole, bluish-green hornblende, reddish-brown mica, clinozoisite, titanite, garnet, and ore. In spite of the common occurrence of myrmekitic plagioclase, no potash feldspar has been found. The holoblasts only reach 1 cm. Larger crystals of amphibole include larger and smaller diablasts of plagioclase. Intergrowths composed of ore and biotite and of ore and plagioclase occur also (Pl. IV, Fig. 21).

A similar holoblastic zone in the hyperite as at Stubberud is observed 0.5 km ENE of the farms of Bergstaten, about 8 km NNW of Kristinehamn. The zone has been followed over a length of 100 m, and carries, with the exception of clinopyroxene, the same minerals as the Stubberud zone.

(*c*) *Along the margin of the olivine-bearing hyperite AA* (3.5 km NNE of Kristinehamn) solitary large holoblasts of plagioclase (Figs. 32–33) appear within a narrow zone with a length of about 400 m and a width of 4–10 m, along the north-western part of the dike. The marginal hyperite contains holoblasts of plagioclase (An_{39}), very few remnants of bronze-coloured orthopyroxene, light-green amphibole ($c/\gamma = 11°$), brown biotite, clinozoisite, garnet, zircon, and ore. The holoblasts (10–30 mm), which are partly studded with needles of clinozoisite, have pushed aside the biotite scales especially; the margin of one of the porphyroblasts encloses a crystal of garnet (cf. Trefors). As the schistosity of the hyperite has developed after the intrusion of the rock, the holoblasts

Fig. 32. Large holoblasts of plagioclase in the marginal zone of the north-western part of the hyperite dike AA. Johannesberg, N of Kristinehamn.

must be still younger, especially because they include secondary garnet. The grain-size of the groundmass varies between 0.07 and 1.5 mm.

A short distance further south thin aplitic veins intersect the hyperite. These veins are composed exclusively of plagioclase stained by sericite and some quartz. The plagioclase is partly myrmekitic. Some few scales of chlorite and calcite occur in fissures.

(*d*) On the western side of the Ölme Bay, the Väse gneiss borders on a fairly large area of hyperite; *the marginal zone* is exposed 300 m N of Öna. The contact between the two rocks is sharp, running NNW. The hyperite body is locally

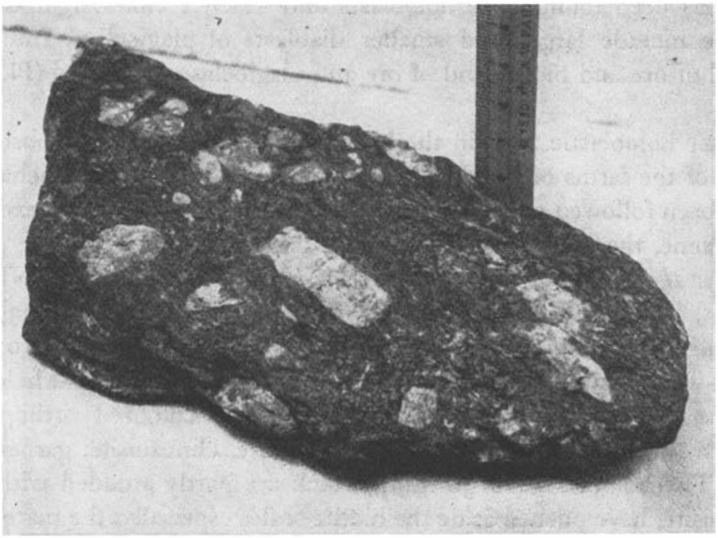


Fig. 33. Large holoblasts of plagioclase in a hand specimen collected in the marginal zone of the hyperite dike AA on the same locality as pictured in Fig. 32.

penetrated by dikes of pegmatite. The marginal part of the hyperite carries scattered very small, reddish patches or dots of granophyre (2–3 mm) hardly noticed by the naked eye; they occur as far as 10–20 m from the contact.

The marginal zone of the hyperite mentioned carries holoblasts of plagioclase (An_{38} in the kernel), partly rather distinctly zonally built. The individuals are sometimes rounded, sometimes lath-shaped. Occasionally needles of clinozoisite appear in the former. Other constituents are bronze-coloured orthopyroxene, bluish-green hornblende ($c/\gamma = 18°$), brown biotite, garnet, apatite, titanite, and ore. In smaller and larger patches the minerals have partly been enclosed in perthite, antiperthite, quartz, and granophyre, the latter being composed of quartz and perthite (Pl. IV, Fig. 22) with striped to spool-shaped albite. The grain-sizes of the rock vary (0.2–3.0 mm), and the patches of granophyre may reach 3.0 mm. The optical data of the orthopyroxene are: $2V_\alpha = 77°$, $\alpha' = 1.692$, $\gamma-\beta = 0.005$, and $\beta-\alpha = 0.008$, which indicates $FeSiO_3$ 20–30 mol% (WINCHELL, 1948).

Such patches of potash feldspar and quartz might develop by partial assimilation (cf. KROKSTRÖM, 1937, p. 273) of the felsic Väse gneiss, but an immigration of potash feldspar and quartz into the hyperite is also possible.

D. *Veins and Dikes of Aplite and Pegmatite Intersecting the Hyperites*

Excepting the aplitic veins (p. 47) intersecting the holoblastic marginal zone of hyperite QQ and the thin veinlets of aplite (p. 50) cutting the hyperite AA south-east of its holoblastic marginal zone, other aplites and also pegmatites intersect certain hyperites.

Two aplitic dikes intersect the hyperite on the southernmost end of the island of Killingen in Lake Vänern. Similar aplitic dikes with an almost leptitic appearance seem to cut the hyperite N of Uddebytorp, which is situated W of Varnum Bay, W of Kristinehamn. Undoubtedly true aplites intersect the hyperite NW of the island of Saxholmen at the entrance of Ölme Bay. Pegmatites penetrate rather large areas of the hyperites in the south-western part of the region. Also on the island of Vålön, 7 km SSW of Kristinehamn, and on other adjacent islands in the Kristinehamn archipelago, a multitude of veins and dikes of aplite and pegmatite intersect the amphibolites here, but because the hyperitic nature of the latter is doubtful, they have not been included in the present survey.

The hyperite of the northern part of the small island of Killingen is of the normal olivine-bearing type; in its southern part, near the Väse gneiss, it becomes somewhat gneissous. The contact between the hyperite and the Väse gneiss runs N 35° E. Almost perpendicularly to the contact and partly below both the beach gravel and the water of Lake Vänern two discordant (Fig. 34) dikes of aplites occur.

One of the dikes is more than 13 m long, and 1–2 dm wide. The dikes do not

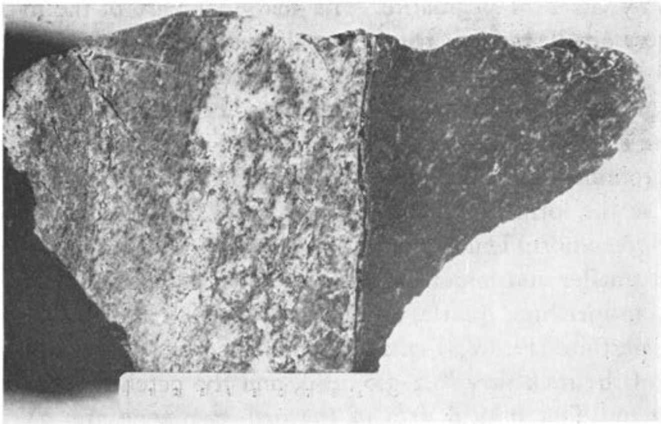


Fig. 34. Hand specimen of aplite (to the left) from the island of Killingen, Lake Vänern, cutting discordantly the gneissous hyperite (only present to the right).

intersect the adjacent Väse gneiss, which is nicely exposed 2–3 metres from visible hyperite.

The aplitic dikes of Killingen may be classified as *garnetiferous oligoclase aplites.* The rock is composed of plagioclase (An_{15-20}), which is not always twinned and often carries rounded diablasts of quartz, further rather much quartz and garnet, some few scales of brown biotite, also filling cracks in the garnet, and then sometimes replaced by an optically positive chlorite. The garnet also contains inclusions of plagioclase (Pl. IV, Fig. 23), quartz, ore, and biotite. Accessorily appear iron oxides and pyrite. Potash feldspar is absent. In the coarser varieties the grain-sizes generally reach 0.3 mm, but the crystals of garnet reach 2.6 mm. In one thin-section of a more greyish-red variety of the rock, amphibole appears with pleochroic haloes (radii = 0.016 mm) around zircon. In the scales of brown biotite rather large crystals of zircon are surrounded by haloes with radii of 0.020 mm.

The content of garnet is uncommonly high. This may depend on the presence of adjacent hyperite which is, at the contact, composed chiefly of plagioclase, amphibole, reddish-brown mica, and garnet.

In a hyperite 200 m N of the farmstead *Uddebytorp*, two aplite-like dikes appear quite near each other. One of them is boudinaged (Fig. 35, the right one). One of the dikes is similar to a leptite with a grain-size between 0.05–0.20 (–0.60) mm, but in another dike some grains attain a size of 1.3 mm. In the field the aplite-like rocks give more the impression of aplitic dikes than of rectangular inclusions of leptite, especially the left-hand one in Fig. 35.

Besides occasional perthite ($\perp \gamma : \alpha / P = +8°$) and antiperthite the supposed aplites of Uddebytorp are generally composed of plagioclase (An_{9-14}) and quartz; subordinately brown and brownish-green biotites of hornfelsic appearance, chlorite, and garnet; accessorily orthite and ore.

Fig. 35. Two dikes of aplite-like rock intersecting the hyperite N of Uddebytorp, S of Gustavsvik (NW of Kristinehamn). The dike to the right is boudinaged. Joints and contacts of the aplites have been chalked.

These aplitic dikes differ from those of other localities, in that they carry an abundance of potash feldspar, whereas potash feldspar is rare or absent in other aplites of the region. One of the aplites at Uddebytorp is rather rich in garnet, and encloses solitary thin (1 cm across) bands of a *hornfelsic garnet-biotite-quartz-schist* (Pl. IV, Fig. 24) composed of brown scales of biotite, streaks of garnet, and quartz. The latter encloses garnet stained abundantly with a biotitic dust (Pl. V, Fig. 25) mainly in the central parts of the crystals. It is rather astonishing to find bands of hornfels in the aplite, because the wall rock seems altogether to be composed of typical hyperitic amphibolite with still preserved hyperitic features.

Three rather similar, light-coloured or white bodies of aplite, NW of the island of Saxholmen have been investigated. They are only a few metres long and about one metre wide. In relation to the planes of schistosity of the hyperite wall rock, they appear both concordantly and discordantly. However, one of the aplites appears to have impregnated the hyperite, because thinner minute stripes of hyperite remnants appear in the aplite.

The aplites are saccharoidal (0.2–2.0 mm) and are composed chiefly of partly sericitic plagioclase (An_{18} in kernels; $An_{9\text{-}13}$ in margins) and varying amounts of quartz, which is however, sometimes altogether absent. Sometimes the quartz grains form stripes. Subordinately scales of pale brown biotite, chlorite, muscovite, some few grains of calcite, titanite, and ore occur. In certain instances stripes of amphibole, representing relicts of hyperite, occur inside the aplites. The aplites may be classified as oligoclasites. Potash feldspar is absent.

Fig. 36. Pegmatite dike cutting schistose black amphibolite-hyperite W of the island of Saxholmen, at the entrance of the Ölme Bay, Lake Vänern.

Pegmatites in the hyperites—and some pegmatites in older rocks. At least 53 dikes of pegmatite, intersecting the hyperites, have been observed. Many of them are probably sodic (10 representative species of pegmatites have been investigated), but in others, e.g. in a muscovite-pegmatite at Östra Ulvsjö (1.5 km SE of Ölme church), microcline-perthite is almost the only feldspar present, apart from small crystals of albite (An_{04}). Thus, also potassic pegmatites occur.

The strike of the dikes varies greatly, but the dip is more or less vertical. The hyperites, which occupy large parts of the wide land tongue between the bays of Hagelsviken and Lunnerviken in the west and Ölme Bay in the east, are penetrated by dikes of pegmatite (for instance, Fig. 36) extending in a north-southerly direction from Lake Vänern in the south towards the church at Ölme in the north. From the Svarteberg farm (5 km W of Kristinehamn) about 1 km southwards, at least six dikes of pegmatite cut the rather small hyperite body here.

Several pegmatite dikes intersect the amphibolitic hyperite on the island of Härön outside the south-western corner of the Kristinehamn area. Also on the western shore of Varnum Bay (Krogsvik) similar dikes cut the hyperites. On the island of Saxholmen, at the entrance to Ölme Bay, quartz veins (1–2 dm wide) carry some scattered feldspar crystals and cut the hyperite, which is here in part very garnetiferous. Also 1 km NNE of the Kummelön farm, 7 km WNW of Kristinehamn, pegmatites intersect the hyperite.

At Ulvsjö, 1 km S of the church at Ölme, between Skråckvik and Öna, S of the Ulvsjö region, and also on the Väner shore N of Skråckvik several dikes of pegmatite appear at the western part of Ölme Bay (as regards pegmatites intersecting hyperites, cf. the observations on the map-sheet of Karlstad and those made between Jönköping and Ulricehamn by MAGNUSSON, 1933 b and 1933 a, p. 617).

In the road section, immediately E of the Gässlösa farm, 3 km SSE of Ölme church, the pegmatite forms a pocket or lump (5 m across) in the hyperite. Dark packets of biotite are especially abundant in the peripherical part of the pegmatite. The pegmatite carries scattered rather large crystals of albite (An_{11}) and quartz in a coarse groundmass with biotite and a few crystals of zircon. Some clinozoisite is also present. The crystals of albite and quartz measure 5 mm. No potash feldspars appear in the thin-sections.

Pegmatites and veins of quartz are very scarce outside the hyperite areas of Pl. A, and veins or dikes of quartz with varying quantities of feldspar have, in the granitic areas, been observed only in the south-western part of Kristinehamn (Djurgården) and N of Hult (10 km S of Kristinehamn). Similar dikes occur in the Ölme gneiss at Marieberg, in the north-western part of the town.

Pegmatites only occur at some few localities in older rocks. At Lake Stora Vilången, a pegmatite cuts the leptitic greywacke discordantly. This pegmatite is rich in quadrille-structured microcline, the larger crystals of which are surrounded by small microcline grains.

About 3 m W of the contact between the Väse gneiss and the hyperite, but inside the Väse gneiss, 300 m N of the farm of Öna, a quartz dike appears. It is at least 20 m long and 1 m wide. It is partly pegmatitic and crops out near the granophyre-bearing hyperite described on p. 50. The pegmatitic part of the quartz dike is composed of quartz, plenty of both plagioclase (An_{07}) and microcline, myrmekite, biotite, and apatite; the latter rather coarse (0.2 × 0.1 mm). The size of the crystals of quartz and microcline vary between 0.2–4.0 mm and those of plagioclase between 0.2–1.0 mm.

Several pegmatitic to aplitic dikes cut the Bergsjö amphibolite, for instance at the south-eastern contact of the Bergsjö massif (Fig. 4, p. 10). The latter pegmatite is 1.5 m wide and is visible for a length of 3 m, cutting the eastern marginal variety of the Bergsjö amphibolite. It is rather fine-grained (0.5–3.0 mm) and carries, rather much perthite, antiperthite, and quartz, whereas plagioclase (An_{15}), biotite, muscovite, garnet, titanite, and ore enter only subordinately. The grains of the microcline generally have a size of 3.0 mm. The plagioclase crystals reach 1.5 mm and those of quartz 0.5 mm. Larger, rather equidimensional microcline crystals are often altogether surrounded by aggregates of very small crystals of the same mineral. The microcline crystals are rather extensively regulated.

III

Coarse Granite and Gneisses in the Eastern Area

The author has not succeeded in distinguishing the coarse Kristinehamn granite from another equally coarse granite which resembles the Filipstad granite, and which occurs in the area locally. This granite has therefore been classified as Kristinehamn granite, and is described below in section (*b*). The Kristinehamn granite is the predominant rock in the eastern part of the map (Pl. A). The rocks in this area are often rather gneissous, as indicated on the map by numerous signs for strike and dip. In some confined areas the rocks are more gneissous or medium-grained and seem to be somewhat different from the ordinary coarse granite petrographically. Such small areas of eyed or reddish gneisses have been indicated by Arabian figures. The eyed to medium-grained gneisses similar to the Kristinehamn granite have received the same signature as the latter on the map. The reddish Väse or Ölme gneisses, which may sometimes be rather similar, have been distinguished with special signatures (cf. pp. 4–5, and 33).

(*a*) *Eyed to medium-grained gneisses embodied in the Kristinehamn granite.* The granitic rocks, and also the granitic gneisses, certainly have a very complicated history and may be of diverse derivation. The dark rocks of Björneborg, Lindås, and Bergsjö have supplied some of the components of these gneisses, as is also indicated by agmatitic breccias, with which they are sometimes associated.

The eyed granitic gneiss 1–1 on Pl. A, 2.5 km ESE of Kristinehamn, has several features in common with the surrounding coarse granite. The plagioclase is the same (about An_{20}), and the dominant mafic mineral is a brown biotite. Other essential minerals are potash feldspar and quartz, solitary scales of muscovite, grains of garnet and ore as well as occasional orthite associated with epidote. Both in the gneiss 1–1 and in a layer of a granitic gneiss, marked 15–15 (Bäcketorp, SE of Kristinehamn) porphyroblasts of microcline-perthite (Pl. V, Fig. 26), enclose smaller grains of an earlier generation of microcline. In the gneiss 5–5 (Pl. A) porphyroblasts of plagioclase enclose smaller crystals of microcline unlike the antiperthitic inclusions of common type.

In the eyed gneiss of 1–1 (Pl. A), large porphyroblasts of microcline-perthite also carry small rectangular crystals of plagioclase. These crystals are partly parallelly arranged. At Bångtorp, 10 km ENE of Kristinehamn, a gneissous variety, too small to be entered on the map, also carries large porphyroblasts of microcline-perthite enclosing small rectangular crystals of plagioclase (Pl. V, Fig. 27). Here, the latter seem to have supplied some material for the ordinary spool-shaped albite of the microcline-perthite, because small protuberances of plagioclase radiate from the rectangular small crystals into the spools. The rectangular remnants of plagioclase at Bångtorp are rather similar to those present in porphyroblasts of microcline-perthite in the granitic gneiss N of Arvidstorp (p. 13), near the Bergsjö amphibolite.

(*b*) *The coarse granite.* In the Kristinehamn region the boundary between the Ölme gneiss in the west and the coarse granite in the east is extremely diffuse and transitional. Although several varieties of coarse granites occur in the region only the so-called Kristinehamn granite, typical of the Kristinehamn region, will be described below. This granite, first defined by A. E. Törnebohm 1881, has been described by N. H. Magnusson in his paper on "Persbergs

Malmtrakt" in 1925. The Kristinehamn granite is very seldom megascopically quite massive, a more or less gneissous development being the rule. A massive Kristinehamn granite appears in the road cutting immediately W of the hyperite AA north of Kristinehamn.

This granite is composed of plagioclase (An_{21-26}), microcline-perthite with a nice grating, bluish-green common hornblende (2 × 1 mm), brown biotite, and only some quartz (10.9% w); subordinately epidote, clinozoisite, garnet, and calcite; accessorily zircon, apatite, titanite, and ore. Myrmekite occurs occasionally at the contact between the plagioclases and the potash feldspars.

Solitary crystals of plagioclase show recurrent zoning; a plagioclase crystal, whose kernel is cut $\perp\gamma$ exhibits (from kernel towards margin) An_{22}, An_{26}, and An_{22}. A crystal of plagioclase enclosed in perthite has the composition An_{21}, and a diffuse plagioclase kernel inside a crystal of perthite, An_{26}. MAGNUSSON (1925, pp. 91–92), who has described the Kristinehamn granite in the neighbouring Filipstad region, has found An_{22-25} to be characteristic of this granite, and An_{15-21} of the Filipstad granite. Sometimes only goast-like remnants of plagioclase appear at the type locality of Kristinehamn. These remnants have then been replaced by potash feldspar (Pl. V, Fig. 28). The common hornblende of the Kristinehamn granite shows $c/\gamma = 15°$ (twins), γ = dark bluish-green, β = brownish-green, and α = yellowish-brown.

The crystals of hornblende contain more or less rounded inclusions of quartz and plagioclase. The crystals of plagioclase are either ovoid (6 mm), square (2 mm) or somewhat lath-shaped (1.0 × 0.3 mm). Smaller, more lath-shaped crystals of plagioclase in the *porphyroblastic* perthite (8 mm) are sometimes homoaxial with the latter. Some of the plagioclase crystals contain both epidote and clinozoisite. The Kristinehamn granite grades into quartz-diorites and quartz-monzonites, which are conspicuous at least immediately south of the Bergsjö amphibolite.

Several kilometres from any larger massif of amphibolites and hyperites, *mafic remnants*, generally 1–10 dm across, occur rather often in the coarse granite (Fig. 37). Megascopically almost all larger remnants, scattered here and there in the vast granite region, are megascopically similar to the mafic fragments of the agmatitic breccias with amphibolitic rocks of Björneborg and Lindås type; near the Bergsjö amphibolite the remnants seem to be identical with this rock.

IV

Main Conclusions

Many of the leptitic rocks described in Chapter I are developed as quartzites (p. 9), greywackes (p. 7), quartz-phyllites (p. 14), and mica schists (p. 14), and thus probably represent original sandy and clayey sediments. The epidosite

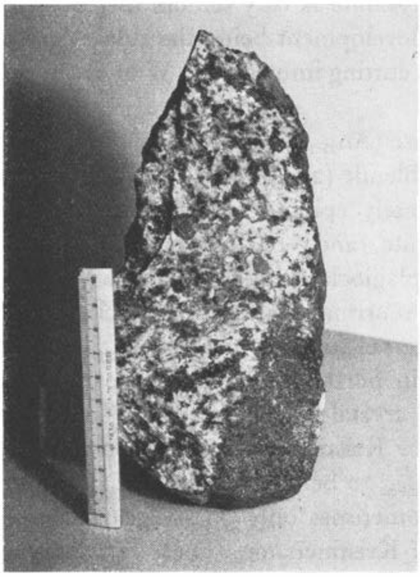


Fig. 37.

Fig. 38.

Fig. 37. Specimen of Kristinehamn granite with a mafic remnant. Heinola, between Lake Bergsjön and Kristinehamn.

Fig. 38. Porphyroblasts of pinkish feldspar have pushed the biotite scales aside in a coarse gneissous granite NE of the Kristinehamn region, N of the town of Karlskoga.

remnant (p. 12) W of Kvarntjärn may represent a calcic mother rock. The origin of the nodules in the amphibolitic rocks in the Björneborg area, composed of epidote, clinozoisite, and muscovite (p. 18), is doubtful, but may represent remains of calcic sediments associated with the amphibolite. The primary character of the Väse and Ölme gneisses is not known; however, at least the former may have been originally an arkosic sediment.

The agmatitic breccias west of Lake Bergsjön (p. 27), at Lindås (p. 22), and NNW of Björneborg (p. 18) represent stages in a process of migmatization. The formation of a quartz-monzonite similar to certain varieties of the Kristinehamn granite is evidently posterior to the intrusion of the hyperite. MAGNUSSON (1933 b, map-sheet no. 174, Karlstad, sketch-map, Fig. 2, p. 17) has shown how, east of the Tynäs inn, a quartz-monzonitic variety of the gneisses here intersects and encloses pieces of the hyperite, an observation which the present author could confirm during a visit to the locality. According to MAGNUSSON, the coarse granites on the map-sheet of Nyed (no. 144, 1929) have intruded at least the gneisses, but perhaps not the hyperite bodies associated with them.

Judging by their present appearance, the amphibolitic rocks may represent older volcanics or mafic greywackes, but the implication texture (p. 26) between plagioclase and ore in the coarse amphibolitic rock, an outlier of the Bergsjö amphibolite, possibly indicates an igneous nature of this amphibolite at least.

The presence of the more or less aplitic oligoclasites on the Väner shore W and WNW of the island of Saxholmen N of Uddebytorp, the presence of aplitic oligoclasite dikes on the island of Killingen, and the abundance of partly or chiefly sodic pegmatites in the region, indicate later sodic invasions in the more or less amphibolitic marginal zones of the hyperites in the western part of the region. It is often very difficult to distinguish decalcifications from true albitizations. This is especially the case in the Kristinehamn region, where epidote- and clinozoisite-bearing rocks are common.

Except by the presence of biotite, which replaces both olivine, pyroxene, and amphibole in several rocks, a subsequent invasion of potassium is indicated by several facts. *Potash feldspar*, crystallized at rather late stages, is of common occurrence in the investigated region. Possibly such secondarily formed potash feldspar may have been derived from pre-existing felsic sediments, traces of which are still left at many places, but many of the rocks may have originated from greywackes with a primary content of potash feldspar (Type 2, p. 8). Felsic rocks of probably sedimentary nature, which are rich in potash feldspar, occur near the mafic rocks, for instance, W of Lake Bergsjön (leptite, pp. 12–13) and NNW of Björneborg (for instance, those of 12–12 on Pl. A; p. 16).

The presence of solitary *holoblasts of microcline* in generally microcline-free mafic rocks of the region indicates that the holoblasts are strangers in these rocks. Such holoblasts occur, for instance, in the amphibolite in several varieties of the Björneborg amphibolites, at Östanmåsa (p. 22), in the Bergsjö amphibolite as solitary crystals (p. 23), in the Emtefalla amphibolite at one locality (p. 31), in the hyperite dike of QQ (p. 46), and as small patches of granophyre in the marginal zone of the Öna hyperite (p. 50).

The *holoblastic inclusion* in hyperite HH and the *holoblasts* in hyperite QQ are probably derived from former wall rocks. Other holoblastic marginal zones of the hyperites may also have the same origin, although no indubitable proofs of this can be procured.

The relationship between the crystals of plagioclase and potash feldspar is varied. For instance, rectangular to slightly rounded, partly twinned crystals of plagioclase are often enclosed in, and partly replaced by potash feldspar thus forming a kind of perthite or antiperthite. Porphyroblasts, of microcline-perthite also enclose small crystals of microcline (p. 56) in a gneissous variety of the Kristinehamn granite. Here, such small crystals of microcline (p. 56) are also enclosed in larger crystals of plagioclase.

The rectangular or slightly rounded crystals of plagioclase enclosed in microcline seem to represent the remains of larger crystals. Porphyroblasts of microcline-perthite in a gneissous coarse Kristinehamn granite at Bångtorp, rather typically exhibit all possible types of transitions from rectangular inclusions of plagioclase into ordinary spool-shaped albite. Similar relationship is also in evidence in the granitic gneiss at the south-eastern margin of the Bergsjö amphibolite (p. 14). The rectangular crystals seem to represent the remains of plagioclases, which have supplied the material of the spools of the microcline-perthite.

Rectangular crystals of plagioclase in holoblasts of microcline-perthite occur also in several other rocks. Such crystals appear for instance in the granitic gneiss which forms the matrix of the Björneborg amphibolite (p. 20), in the gneiss-granitic streaks in the Emtefalla amphibolite (p. 30), in a reddish gneiss (9469) near the greywackes of Vilångstorp (p. 8), in the partly eyed Ölme gneiss (p. 33), in gneissous varieties of the coarse Kristinehamn granite (p. 56), and also in typical Kristinehamn granite (p. 57). All the microcline crystals of these rocks also carry the ordinary spool-shaped albite.

In the quartz-monzonite (p. 27) and the intermediary quartz-diorite (p. 27) W of Lake Bergsjön both perthite and antiperthite appear, besides individual crystals of plagioclase. Some of the crystals of antiperthite here and in some of the other rocks grade into the above-mentioned holoblasts of microcline with sometimes larger amounts of rectangular crystals of plagioclase.

Holoblasts of potash feldspar include remnants not only of plagioclase, but also of other minerals, e.g. hornblende as at the northern and southern ends of the Östanmåsa amphibolite.

If the *myrmekite*, which occurs both inside, and at the margins of holoblasts of microcline-perthite, is related genetically to the rectangular remnants of plagioclase mentioned above is uncertain. Myrmekite is of common occurrence. The Killingen aplite (p. 52) and the aplite of the north-western margin of the Bergsjö amphibolite (p. 24), both of which intersect mafic rock bodies, exhibit only or chiefly droplets and not vermicules of quartz in the myrmekite. Similar droplets appear also in the plagioclase of an amphibolitic fragment (p. 18). In the aplitic veinlets intersecting the hyperite QQ, the droplets grade into vermicules (p. 47). Typical myrmekite occurs in the marginal zone of the hyperite at Stubberud (p. 49), in spite of the absence of potash feldspar in the thin-sections. According to, e.g., ESKOLA (1956), myrmekite, associated with potash feldspar, possibly indicates a potassium metasomatism.

The *fine-meshed quartz-nets* present in the holoblasts of plagioclase in the gneissous inclusion (p. 48) in hyperite HH, have been considered as graphic intergrowths ("schriftgranistisch") between plagioclase and quartz.

Holoblasts of potash feldspar have pushed probably secondarily crystallized biotite scales aside in for instance, leptites S and ESE of Kvarntjärn (p. 12), reddish gneiss (9469, p. 8), and a pinkish coarse granite (Fig. 38).

Many observations presented in the foregoing seem to indicate that rather basic plagioclases have been replaced by antiperthites and perthites without previous albitization of calcic plagioclases.

The replacement of plagioclase by potash feldspar has lately been described by EXNER (1951, pp. 111–130), EXNER and POHLE (1951, p. 17 and 36), KING and DE SWARDT (1949, p. 11), KING (1950, pp. 369–72), and COLLOMB (1951, pp. 622–23). The latter author shows (p. 622) how also a rather basic (An_{34}) plagioclase is replaced by potash feldspar. DRESCHER–KADEN (1948, p. 42) also elucidates such a transformation.

Some of the pegmatites in the Kristinehamn region, for instance, in the greywacke W of Lake Stora Vilången (p. 55) and in the hyperite at Östra Ulvsjö (p. 54), sometimes carry potash feldspar, although the aplites (pp. 51–54) and most of the pegmatites (pp. 54–55) generally seem to be sodic, at least in the hyperites. Exceptionally the aplites carry some potash feldspar, e.g. inside the hyperite N of Uddebytorp (pp. 52–53) and in the aplites intersecting (p. 47) the holoblastic zone of the hyperite QQ. The potassic aplites and pegmatites thus also indicate a late mobility of potash feldspars.

Certain facts seem to indicate low reaction temperatures. Clinozoisite and oligoclase appear together in the marginal zone of hyperite QQ (p. 46) indicating a temperature of about 400°C (H. RAMBERG, 1944). The clinozoisite-bearing rocks of the holoblastic marginal zones of the hyperites at Trefors (pp. 48–49), the one represented by AA (p. 49), and the marginal zone of the hyperite at Öna (p. 50) would have formed at about 500°C. Some of the older amphibolites, such as the clinozoisite-bearing amphibolites at Emtefalla (pp. 29–32, with An_{30-50}), Bergsjön (pp. 22–26, An_{50}) and Björneborg (pp. 17–20, An_{50}) would have recrystallized at about 500°C. The partly epidote-bearing Ölme gneiss (pp. 33–34) would have crystallized into its present state at about 300–350°C, considering its percentages of An being about 10 mol%. The coarse Kristinehamn (pp. 56–57) granite (An_{20}) would have received its present state at about 400°C.

Many of the petrological phenomena described seem to indicate a post-hyperitic (or hyperitic) metasomatism of the rocks, such as the presence of: (1) aplitic and pegmatitic veins and dikes (pp. 51–55), (2) the metamorphism of the hyperite-banded zone at Hållerud (pp. 36–37), and (3) the occurrence in the hyperite of possibly pre-granitic inclusions of clinozoisite-rich leptite (p. 43), greywacke (p. 44), and a band of hornfels (p. 53) in aplite intersecting the hypertite at Uddebytorp.

Especially from (2) one is tempted to consider the metamorphism as post-hyperitic, the above-mentioned felsic inclusions of (3) having been protected extensively by the hyperite from external action.

According to BRÖGGER (1934–35, p. 236 and p. 390), the sodic aplites and pegmatites, which intersect the hyperites in certain parts of Norway, represent the residual magmas of the hyperites.

Although several phenomena seem to indicate a late hyperitic or post-hyperitic metasomatism, other phenomena contradict such a supposition. Thus, the hyperites enclose blocks of both granitic Väse gneiss (p. 44) and Ölme gneiss (p. 44), and the olivine-bearing hyperite of JJ injects thin branching apophyses into (pp. 35 and 42) the crystals of the coarse Kristinehamn granite.

The doleritic hyperite-amphibolite HH encloses a stripe or a wedge of a gneissous variety (p. 48) of the Kristinehamn granite.

The contradictions seem at first to be diverted, if two sequences of hyperite intrusions are postulated, but then both must originate from the same magma because of the mineralogical and textural similarities in all the olivine-bearing hyperites of the region. One would then meet features indicating metasomatism both before the intrusion of certain hyperites and posterior to the intrusion of others. The lenticular hyperite bodies in the gneisses, intersected by aplites and pegmatites and possibly the dike-like sills with similar tectonical position in the granitic region would then, for instance, represent an earlier sequence, and true dikes, also partly or altogether amphibolitized (such as the doleritic hyperite-amphibolites of, for instance, GG and CC, pp. 39 and 42), would represent the later sequence. Thus, for instance, the hyperite dike JJ with branching microaphanitic apophyses (pp. 38 and 42), the certainly amphibolitic hyperite CC with a radiating longer doleritic apophysis (p. 42), and the hyperite bb (pp. 38 and 42) with a microaphanitic apophysis intersecting the eastern marginal variety of the Bergsjö amphibolite, would possibly represent the later sequence.

Acknowledgements

The late Professor H. G. Backlund inspired the author in many discussions and followed the results of the field observations and the microscopical investigation.

Professor Erik Norin has facilitated the work by placing at the author's disposal the equipment of his institute. He has critically discussed the methods and the conclusions of the present work.

The former Director of the Geological Survey of Sweden, Professor Nils H. Magnusson, who as early as 1925 guided the author in his studies of the hyperites and the felsic rocks north of the Kristinehamn area, later (1957) kindly discussed the problems of this area.

The late Dr Torsten Krokström (1946–50 professor in Alexandria, Egypt) with his pupils visited the Bergsjö area and the holoblastic margin of the hyperite dike AA (some of his pupils here) in the spring of 1945, and the author had the pleasure of discussing some granitization problems, stimulating further investigation.

In the summer of 1949 Mrs Doris Reynolds, visiting Uppsala, discussed in her inspiring way some problems of the Kristinehamn region with the author and studied some thin-sections of, *inter alia*, the Bergsjö amphibolite.

The amphibolite at Lindås, the sedimentary rock on the Vilången shore and the hyperite EE were made known to the author by the Royal forester, Mr Bernhard Blohm.

The Blomsterhult rocks and the garnetiferous aplite on the isle of Killingen were discovered by Mr Evert Nyqvist and Mr Helmer Wilkins respectively. The author wishes to express his sincere thanks to all the above-mentioned gentlemen. Mr Arne Svensson, without expense (to the author) showed him the smaller isles of the Kristinehamn archipelago.

Dr R. Blix has with his usual care made the chemical analysis of the quartz-monzonite. Mr J. Lukins has ably given the chemically determined weight percentages of quartz (and K_2O and Na_2O in one instance), which facilitated the classification of the rocks.

The microphotographs have kindly been made by Professor Erik Norin, Fil. lic. H. Lindholm, Mr G. Andersson, and Mr N. Hjort. The tracing of the maps has been conscientiously carried out by Mrs Ester Dreimanis.

The author wishes to thank Mr Gustav Andersson, Mr W. Plan, and Mr Olle Wallner for the skilful preparation of the thin-sections, most of which have been made by the latter.

The head of the British Institute in Gothenburg, Dr H. G. Gardner, has ably looked through the preceding pages from a stylistic point of view.

Kristinehamn–Uppsala
August 1960

References

B.G.I.U., *Bull. of the Geol. Inst. of Upsala, Sweden.*
B.G.S.A., *Bull. of the Geol. Society of America.*
G.F.F., *Geol. Föreningens Förhandlingar* (Geol. Society, Stockholm), Sweden.
N.G.U., *Norges Geol. Undersökelse* (Norwegian Geol. Survey), Oslo.
N.G.T., *Norsk Geologisk Tidskrift*, Oslo–Bergen.
S.G.U., *Sveriges Geol. Undersökning* (Swedish Geol. Survey), Stockholm, Sweden.

Asklund, B., 1950. Kosteröarna, ett nyckelområde för västra Sveriges pre-kambriska geologi. *S.G.U.*, Ser. C, No. 517.

Backlund, H. G., 1935. Zur genetischen Deutung der Eklogite. *Geol. Rundschau*, Bd. 27, H. 1.

— 1936. Der "Magmaaufstieg" in Faltengebirgen. *C.R. soc. géol. Finlande*, No. 9.

— 1937. Die Umgrenzung der Svekofenniden. *B.G.I.U.*, Vol. 8.

— 1938. The problems of the Rapakivi granites. *Journ. Geol.*, Vol. 46, pp. 339–396.

— 1940. Fennoskandias äldsta geologiska strukturelement. *Vetenskap av i dag.* 23–39453, p. 353. Stockholm.

— 1941. Gesteinsentwicklungen in Fennoskandia. *Zeitschr. f. Geschiebeforschung und Flachlandsgeologie*, Bd. 17, H. 3.

— 1941. Zum Aktualitätsprinzip. *Geol. Rundschau*, Bd. 32.

— 1941. Die ältesten Baustücke Fennoskandias im Lichte des Aktualitäts prinzips. *Zeitschr. d. Deutsch. Geol. Ges.*, Bd. 93, H. 6.

— 1942. Probleme der arktischen Plateaubasalte. *Veröffentlichungen d. Deutsch. Wissenschaftlichen Inst. zu Kopenhagen*, Reihe I: Arktis, No. 3, Berlin–Zehlendorf.

— 1943. Einblicke in das geologische Geschehen des Präkambriums. *Geol. Rundschau*, Bd. 34, H. 2–6.
— 1946. Om granit och gnejs och jordens ålder. *Kungl. Vet. soc. Årsbok.*
— 1946. The granitization problem. *Geol. Mag.*, Vol. 83, No. 3.
— 1950. The actualistic principle in geological research. *Från filosofiens och forskningens fält*, Uppsala.
— 1950. Some observations on homogenization and on geochemical discontinuities in granitic areas. *Intern. Geol. Congress.* Report of the 18th session. Part 3, Proc. Section B. London 1948.
— 1953. The granitization problem. *Rev. Est. Geol. Publ.* 17, Madrid.
BARTH, T. F. W., 1936. Structural and petrologic studies in Duchess County, New York. Part II. Petrology and metamorphism of the paleozoic rocks. *B.G.S.A.*, Vol. 47, pp. 775–850.
— 1947. The nickeliferous Iveland–Evje amphibolite and its relation. *N.G.U.*, No. 168*a*.
— 1948. Recent contributions to the granite problem. *Journ. Geol.*, Vol. 56, No. 3.
— 1952. Theoretical Petrology. New York.
BARTH, T. F. W., CORRENS, C. W. and ESKOLA, P., 1939. Die Entstehung der Gesteine. Berlin.
BEREK, M., 1924. Mikr. Mineralbestimmung mit Hilfe d. Universaldrehtischmethoden. Berlin.
BLOMBERG, A., 1903. Kartbladet Kristinehamn. *S.G.U.*, Ser. Aa, No. 122.
— 1904. Kartbladet Björneborg. *S.G.U.*, Ser. Aa, No. 124.
BRÖGGER, W. C., 1934 & 1935. On several archaean rocks from the south coast of Norway. II. The Norwegian hyperites & their metamorphism. *Skr. utg. av Det Norske Vid.-Akad. I. Mat-Nat.-Vid. Kl.*
BUGGE, J., 1940. Geological & petrological investigations in the Arendal district. *N.G.T.*, Vol. 20, p. 81.
— 1943. Geological & petrological investigations in the Kongsberg–Bamle formation. *N.G.U.*, No. 160.
CHAYES, F., 1948. A petrographic criterion for the possible replacement origin of rocks. Papers from Geophysical Laboratory, Carnegie Institution no. 1103. *Am. Journ. Sci.*, Vol. 256, pp. 413–25.
COLLOMB, P., 1951. A propos d'un phénomène de croissance secondaire des feldspaths potassiques dans une microgranulite filonienne. *Bull. soc. géol. France*, 6e série, tome I, fasc. 8, pp. 40–48. Pl. XX–XXV.
DRESCHER–KADEN, F. K., 1948. Die Feldspat-Quarz-Reaktionsgefüge der Granite und Gneisse und ihre genetische Bedeutung. Berlin–Göttingen–Heidelberg.
ESKOLA, P., 1956. Postmagmatic potash metasomatism of granite. Extrait des *C.R. soc. géol. Finlande*, No. 29, 9. *Bull. comm. géol. Finlande*, No. 172.
EXNER, CHR., 1951. Mikroporphyroblasten mit helizitischen Einschusszügen bei Badgastein, *Mitt. d. Österreichischen Min. Ges.*, pp. 11–130, Wien.
EXNER, CHR. and POHLE, E., 1951. Granosyenitischer Gneiss und Gesteins-Radioaktivität bei Badgastein. *Jahrb. d. Geol. Bundesanstalt*, Bd. 94, Wien.
GAVELIN, S., 1960. On the relations between kinetometamorphism & metasomatism in granitization. Some examples from the archean of Eastern Sweden. *G.F.F.*, Bd 82.
GEIJER, P., 1944. Omfattningen av termen leptit. *G.F.F.*, Bd 66.
GJELSVIK, T., 1952. Metamorphosed dolerites in the gneiss area of Sunnmöre on the West coast of Southern Norway. *N.G.T.*, Bd 30.
GOLDSCHMIDT, V. M., 1916. Geologisch-petrographische Studien im Hochgebirge des südlichen Norwegens. IV. Übersicht der Eruptivgesteine im Kaledonischen Ge-

birge zwischen Stavanger und Trondhjem. *Videnskapsselskapets Skrifter I. Mat.-Naturv. Klasse*, No. 2, Kristiania (Oslo).

— 1921. Die Injektionsmetamorphose in Stavanger-Gebiete in Geologische-petrographische Studien in Hochgebirge des südlichen Norwegens. Kristiania (Oslo).

GUIMARAES, D., 1948. La genèse des orthopyroxénes. *Bull. soc. géol. France*, tome 18, pp. 645–60.

HIRSCH, H. and DAWIHL, W., 1932. Die Einwirkung von Phosphorsäuren auf keramische Rohstoffe sowie gebrannt Erzeugnisse und ein neues Verfahren der rationellen Analyse von Tonen. *Ber. d. deutsch. Keram. Ges.*, Bd 13, pp. 54–60.

HJELMQVIST, S., 1950. The titaniferous iron ore deposit of Taberg in the south of Sweden. *S.G.U.*, Ser. C, No. 512.

HOLMQUIST, P. J., 1906. Studien über die Granite von Schweden. *B.G.I.U.*, Vol. 7.

HÖGBOM, A. G., 1910. Precambrian geology of Sweden. *B.G.I.U.*, Vol. 10.

— 1913. Fennoskandia. *Handbuch d. regionalen Geologie*, Bd 4, Abt. 3, pp. 197. Heidelberg.

IDDINGS, J. P., 1911. Rock Minerals. New York.

JOHANNSEN, A., 1931. A descriptive Petrography of the Igneous Rocks. Vol. 1, Chicago.

JOHANSSON, H. E., 1927. Hyperiternas geologiska och petrografiska ställning. *G.F.F.* Bd 49, p. 310.

JOHANSSON, S. and JOHANSSON, H. E., 1917. Kartbladet Furuholmarna. *S.G.U.*, Ser. Aa, No. 136.

KING, B. C., 1950. Some large felspar augen from near Ilorin Town, Nigeria. *Geol. Mag.* Vol. 84, No. 5, pp. 369–72.

KING, B. C. and DE SWARDT, A. M. J., 1949. The geology of the Osi area, Ilorin province (Nigeria). Kaduna.

KOLDERUP, C. FR. and KOLDERUP, N. H., 1940. Geology of the Bergen Arc System. *Bergens Museums skrifter*, No. 20.

KROKSTRÖM, T., 1932. On the ophitic texture and the order of crystallization in basaltic magmas. *B.G.I.U.*, Vol. 24.

— 1937. On the association of granite and dolerite in igneous bodies. *B.G.I.U.*, Vol. 26.

— 1944. Petrological studies on some basaltic rocks from East Greenland. *Medd. om Grønland*, Bd 103, No. 6.

— 1946. Felspathization and boudinage in a quartzite boulder from the Västervik area. *B.G.I.U.*, Vol. 31.

LANDERGREN, S., 1934. Några iakttagelser av berggrunden inom Lekebergs Bergslag i Örebro län. *G.F.F.*, Bd 56, pp. 323–34.

LARSSON, W., 1932. Chemical analyses of Swedish rocks. *B.G.I.U.*, Vol. 24, p. 80.

— 1940. Petrology of interglacial volcanics from the Andes of northern Patagonia. *B.G.I.U.*, Vol. 28.

— 1947. Några resultat av berggrundsgeologiska studier inom Dalformationens norra gränsområde. *G.F.F.*, Bd 69.

— 1956. Berggrunden i Beskrivning till kartbladet Vårvik. *S.G.U.*, Ser. Aa, No. 187.

LJUNGGREN, P., 1954. The region of Hålia in Dalecarlia, Sweden. Göteborg.

— 1957. Complete and incomplete granitizations. *G.F.F.*, Bd 78.

— 1957. Banded Gneisses from Gothenburg and their transformations. *G.F.F.*, Bd 79.

— 1959. Petrogenetic significance of gneiss blocks partly melted by hyperite magma. *Kungl. Fysiografiska Sällskapet i Lund Förh.*, Bd 29, No. 8.

— 1959. A magmatized magnetite. *G.F.F.*, Bd 81.

LUNDEGÅRDH, P. H., 1943. The Grovstanäs region. An ultrabasic gabbro massif and its immediate viscinity. *B.G.I.U.*, Vol. 29.

— 1957. The titaniferous ore-bearing gabbro of Helsingland, Central Sweden. *S.G.U.*, Ser. C, No. 549.
— 1958. Göteborgstraktens berggrund. *S.G.U.*, Ser. C, No. 553.
— 1959. Aspects of the term Old Gothian. *G.F.F.*, Bd 81.
— 1960. On the development of gneisses and granites in the Eskilstuna region to the West of Stockholm. *G.F.F.*, Bd 82.
MAGNUSSON, N. H., 1925. Persbergsmalmtrakt och berggrunden i de centrala delarna av Filipstads bergslag. *Kungl. Kommerskollegium.* Beskrivningar över mineralfyndigheter Nr 2. Beskrivning utarbetad av *Kungl. Kommersk.* och *S.G.U.*
— 1928. Aktuella problem från Värmlands gnejsurberg. *G.F.F.*, Bd 50.
— 1933*a*. Det mellansvenska urbergets åldersschema. *G.F.F.*, Bd 55.
— 1933*b*. Kartbladet Karlstad. *S.G.U.*, Ser. Aa, No. 174.
— 1934. Några åldersförhållanden inom det mellansvenska urberget. *G.F.F.*, Bd 56.
MAGNUSSON, N. H., and ASSARSSON, G. 1929. Kartbladet Nyed. *S.G.U.*, Ser. Aa, No. 144.
MAGNUSSON, N. H., LUNDQVIST, G. and GRANLUND, E., 1957. Sveriges geologi. Stockholm.
MISCH, P., 1949. Metasomatic granitization of batholitic dimensions. *Am. Journ. Sci.*, Vol. 247.
NORIN, E., 1958. Helge G. Backlund. Minnesteckning. *Kungl. Vet. Soc. Årsbok.*
OSANN, A., 1923. Rosenbusch, Elemente der Gesteinslehre. Stuttgart.
PERRIN, M. R., 1934. Extrapolation à la géologie des données métallurgiques. *Ann. Min.*, série 13, tome 6, pp. 135–70.
PERRIN, M. R. and ROUBAULT, M., 1947. Relation des granites, granulites et roches amphibolitiques de la côte de Bénodet (Finistère). *Bull. soc. géol. France,* 5 série, tome 17, pp. 233–48.
— 1949. On the granite problem. *Journ. Geol.*, Vol. 57, No. 4.
QUENSEL, P., 1951. The charnockite series of the Varberg District on the south-western coast of Sweden. *Arkiv. Min. o. Geol.*, Bd 1, No. 10, p. 321.
QUIRKE, T. T., 1927. Are some intrusions replacement deposits? *B.G.S.A.*, Vol. 38.
— 1927. Killarney gneisses and migmatites. *Ibid.*
RAMBERG, H., 1943. Vestrandens regionalmetamorfe bergarter. *N.G.T.*, Bd 23.
— 1944. Petrological significance of sub-solidus phase transitions in mixed crystals. *Ibid.*, Bd 24, pp. 42–74.
— 1946. Diffusion i de faste bergarter. *G.F.F.*, Bd 68.
— 1949. The facies classification of rocks. *Journ. Geol.*, No. 1, p. 18.
— 1952. The origin of the metamorphic metasomatic rocks. Chicago.
RASTALL, R. H., 1945. The granite problem. *Geol. Mag.*, Vol. 82, No. 1.
READ, H. H., 1943 and 1944. Meditations on granite. Part 1. *Proc. Geol. Ass.*, Vol. 54, Part 2, pp. 64–85. Vol. 55, Part 2, pp. 45–93.
— 1957. The Granite Controversy. London.
REYNOLDS, D. L., 1943. Granitization of hornefelsed sediments in the Newry granodiorite of Coraghwood quarry, Co. Armagh. *Proc. Royal Irish Acad.*, Vol. 48, Section B., No. 11.
— 1944. The south-western end of the Newry igneous complex. *Quart. Journ. Geol. Soc. London,* Vol. 94, pp. 205–46.
ROSENQVIST, I. TH., 1952. The metamorphic facies and the feldspar minerals. *Univ. Bergen Årsbok* 1952. Naturvitenskapelig rekke, No. 4.
SANDEGREN, R., HÖGBOM, A. and SVENONIUS, F., 1922. Kartbladet Väse. *S.G.U.*, Ser. Aa, No. 151.
SANDEGREN, R. and JOHANSSON, H. E., 1916. Kartbladet Otterbäcken. *S.G.U.*, Ser. Aa, No. 145.

SEDERHOLM, J. J., 1916. On synanthetic minerals and related phenomena. *Bull. comm. géol. Finlande,* No. 48. pp. 1–148.

SHAND, S. J., 1945. Coronas and coronites. *B.G.S.A.*, Vol. 56, Part 1, pp. 247–66.

SUNDIUS, N., 1944. Orogene Erscheinungen im südwestlichen Schweden. *G.F.F.*, Bd 66.

— 1947. Femisk leptit och slirgnejs. *S.G.U.*, Ser. C. No. 488, p. 27.

TÖRNEBOHM, A. E., 1877. Om Sveriges viktigaste diabas- och gabbroarter. *Kongl. Sv. Vet. Akad. Handl.*, Bd 14, No. 13.

— 1881. Beskrifning till Geologisk öfversiktskarta öfver mellersta Sveriges bergslag. Stockholm.

TRÖGER, W. E., 1956. Optische Bestimmung der gesteinsbildenden Minerale, Teil 1, 2. Auflage. Stuttgart.

WAHL, W., 1936. Om granitgrupperna och bergskedjeveckningarna i Sverige och Finland. *G.F.F.*, Bd 58, pp. 90–101.

WEGMANN, C. E., 1950. Transformations métasomatiques et analyse tectonique. *18th Intern. Geol. Congr., Rept. III:45–52. London 1948.*

WENTWORTH, CH. K., 1923. The improved recording micrometer for rock analysis. *Journ. Geol.*, Vol. 31.

WESTERGÅRD, A. H. and JOHANSSON, H. E., 1915. Kartbladet Töreboda. *S.G.U.*, Ser. Aa, No. 139.

WILKMAN, W. W., 1933. Über zwei Syenitvorkommen in Nilsiä, nördlich von Kuopio. *C.R. Soc. Géol. Finlande,* Vol. 6.

WINCHELL, N., 1948 and 1951. Elements of mineralogy. Part II. New York.

Plate I

Fig. 1. Symplektitic intergrowth between scapolite and plagioclase (?) in a leptitic remnant at the south-eastern margin of the Bergsjö massif, 4010:5 1 nic. ×23. (p. 14).

Fig. 2. Patch-antiperthite in an amphibolitic fragment in agmatitic breccia. 6075. 2 nic. ×60. (p. 18).

Fig. 3. Inclusions of plagioclase and hornblende in a holoblast of microcline in the Östanmåsa amphibolite. 6647. 1 nic. ×36. (p. 22).

Fig. 4. Holoblast of oligoclase (to the right) with droplets of calcic plagioclase (or quartz?) enclosing irregular grains of oligoclase with droplets of quartz. Aplitic layer or vein in the Bergsjö amphibolite (to the left) at the north-western contact. 7569. 2 nic. ×23. (p. 25).

Fig. 5. Intergrowth of ore and plagioclase in coarse-grained Bergsjö amphibolite (G in Fig. 4). Small grains of epidote appear at the contacts between the plagioclase and the ore. 6667 c. 1 nic. ×60. (p. 26).

Fig. 6. Double coronas around crystals of olivine bordering on plagioclase in typical hyperite at Lid. 6652. 1 nic. ×60. (p. 41).

Plate II

Fig. 7. Aphanitic to pilotaxitic apophysis from the hyperite dike JJ intersecting a feldspar crystal in the adjoining coarse granite. 4012:5. 1 nic. ×23. (p. 42).

Fig. 8. Partly disintegrated large lath of plagioclase in the amphibolitic western margin of the hyperite dike dd. 9879. 2 nic. ×60. (p. 42).

Fig. 9. Aggregates of smaller rounded grains of plagioclase with minute droplets of quartz. Marginal zone of the doleritic hyperite-amphinolite QQ. 8191 A. 2 nic. × 60. (p. 46).

Fig. 10. Droplets of plagioclase in a holoblast of microperthite. The same rock and the same locality as in Fig. 9. 8191 A. 2 nic. ×23. (p. 46).

Fig. 11. Detail of plagioclase droplets in microperthite. The same crystal as in Fig. 10. 8191 A. 2 nic. ×95. (p. 46).

Fig. 12. Myrmekite along the right margin of a holoblast of microperthite. The same rock as in Figs. 9–11. 8188 A. 1 nic. ×60. (p. 46).

Plate III

Fig. 13. Skeletal remnant of amphibole in holoblast of microperthite. The same rock as in Figs. 9–12. 8188A. 2 nic. ×62. (p. 46).

Fig. 14. Crystal of microperthite with marginal intergrowths of quartz with the same optical orientation as larger surrounding crystals of quartz (white), in a veinlet of aplite in the marginal zone of the doleritic hyperite-amphibolite QQ. 8188B. 2 nic. ×100. (p. 47).

Fig. 15. Crystal of microperthite bounded by a rim of myrmekite. The same rock as in Fig. 14. 8188B. 2 nic. ×100. (p. 47).

Fig. 16. Twinned crystal of plagioclase surrounded by a rim of potash feldspar micropegmatitically intergrown with quartz of the same optical orientation as the larger crystals of quartz (white) outside the rim. The same rock as in Figs. 14–15. 8188B. 2 nic. ×100. (p. 47).

Fig. 17. Net-like intergrowth of quartz in a holoblast of plagioclase occurring in an inclusion of gneiss in the doleritic hyperite-amphibolite HH. 7576. ×100. (p. 48).

Fig. 18. Skeletal remnants of amphibole in a holoblast of plagioclase. The same rock as in Fig. 17. 7576. 2 nic. ×62. (p. 48).

Plate IV

Fig. 19. Garnet poikilitically intergrown with plagioclase (white) with uniform optical orientation. Marginal zone of the hyperite at Trefors. 8186. 2 nic. ×24. (p. 49).

Fig. 20. Amoeboid crystal of scapolite (light greyish) in a twinned holoblast of plagioclase. The same rock as in Fig. 19. 8186. 2 nic. ×24. (p. 49).

Fig. 21. Intergrowths of ore and biotite and of ore and plagioclase. Marginal zone of the hyperite at Stubberud. 8192A. 2 nic. ×60. (p. 49).

Fig. 22. Granophyric intergrowths of perthite and quartz. Marginal zone of the hyperite at Öna. 8172. 2 nic. ×24. (p. 51).

Fig. 23. Micropoikilitic intergrowth of garnet and smaller grains of plagioclase and quartz in the aplite of Killingen Island. 8183. 2 nic. ×24. (p. 52).

Fig. 24. A short, narrow band of garnet-biotite-quartzschist in the aplite at Uddebytorp. Biotite dust in the garnet appears as black points. 8181. 1 nic. ×24. (p. 53).

Plate V

Fig. 25. Crystal of biotite-dusted garnet at the boundary between the schist and the aplite in Fig. 24. 8181. 1 nic. ×23. (p. 53).

Fig. 26. Part of large porphyroblast of microcline perthite (black) enclosing several crystals of microcline in the eyed gneiss of 1–1. 2803. 2 nic. ×28. (p. 56).

Fig. 27. Porphyroblast of microcline-perthite (greyish), enclosing a crushed square crystal of plagioclase (one of several in the same porphyroblast) with three protuberances or veinlets radiating from it. Gneissous variety of the coarse Kristinehamn granite at Bångtorp. 4212. 2 nic. ×92. (p. 56).

Fig. 28. Skeletal remnants of plagioclase (to the right) largely replaced by microcline-perthite. Typical Kristinehamn granite, W of hyperite dike AA. 9833. 2 nic. ×23. (p. 57).

Plate I

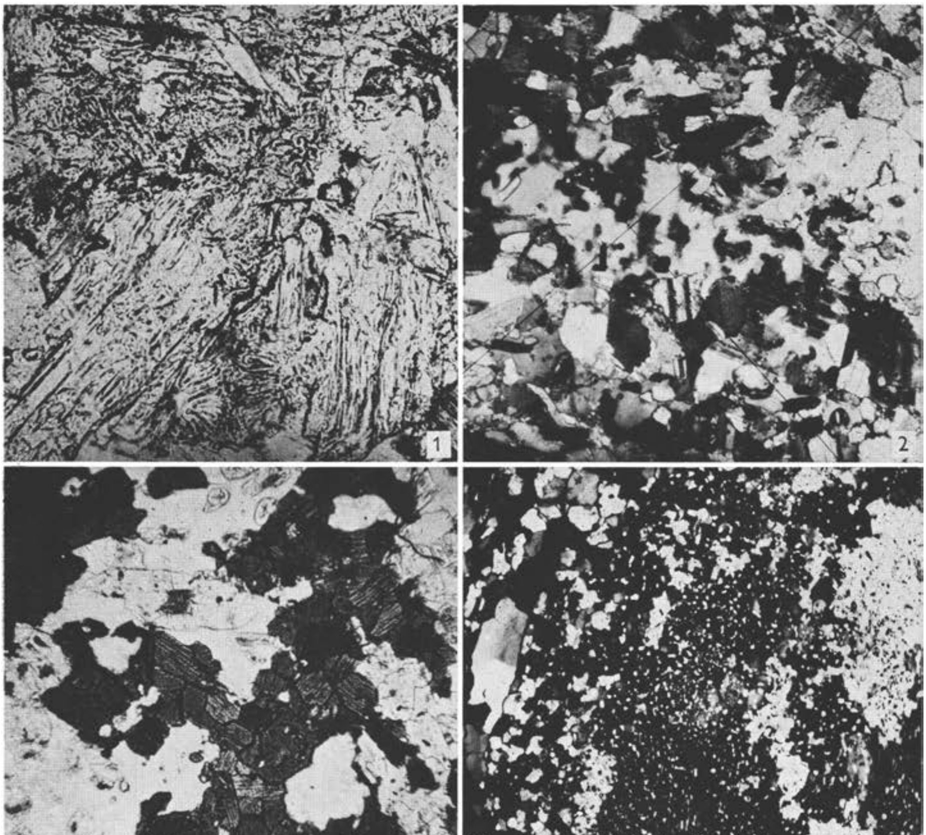
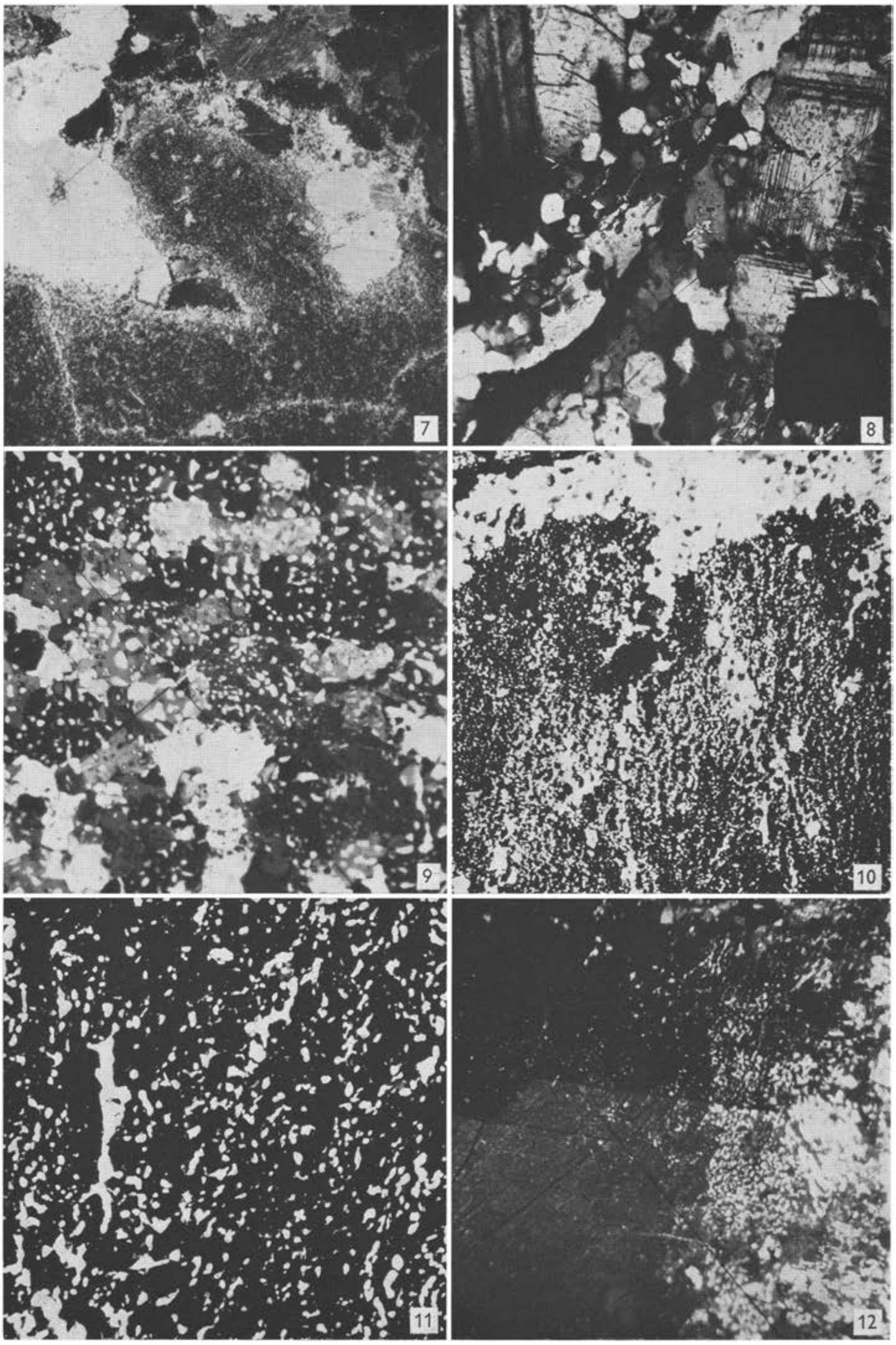
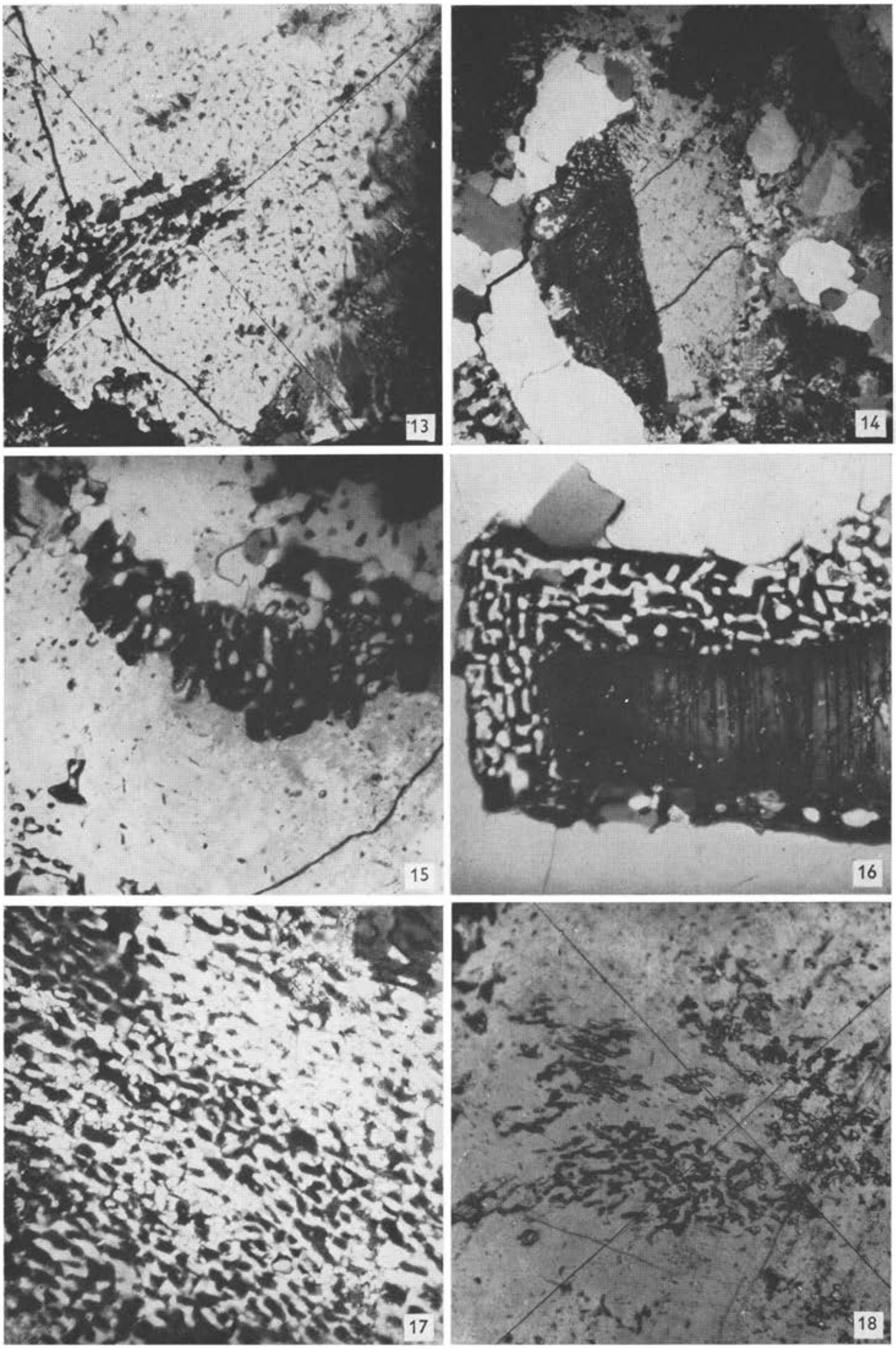
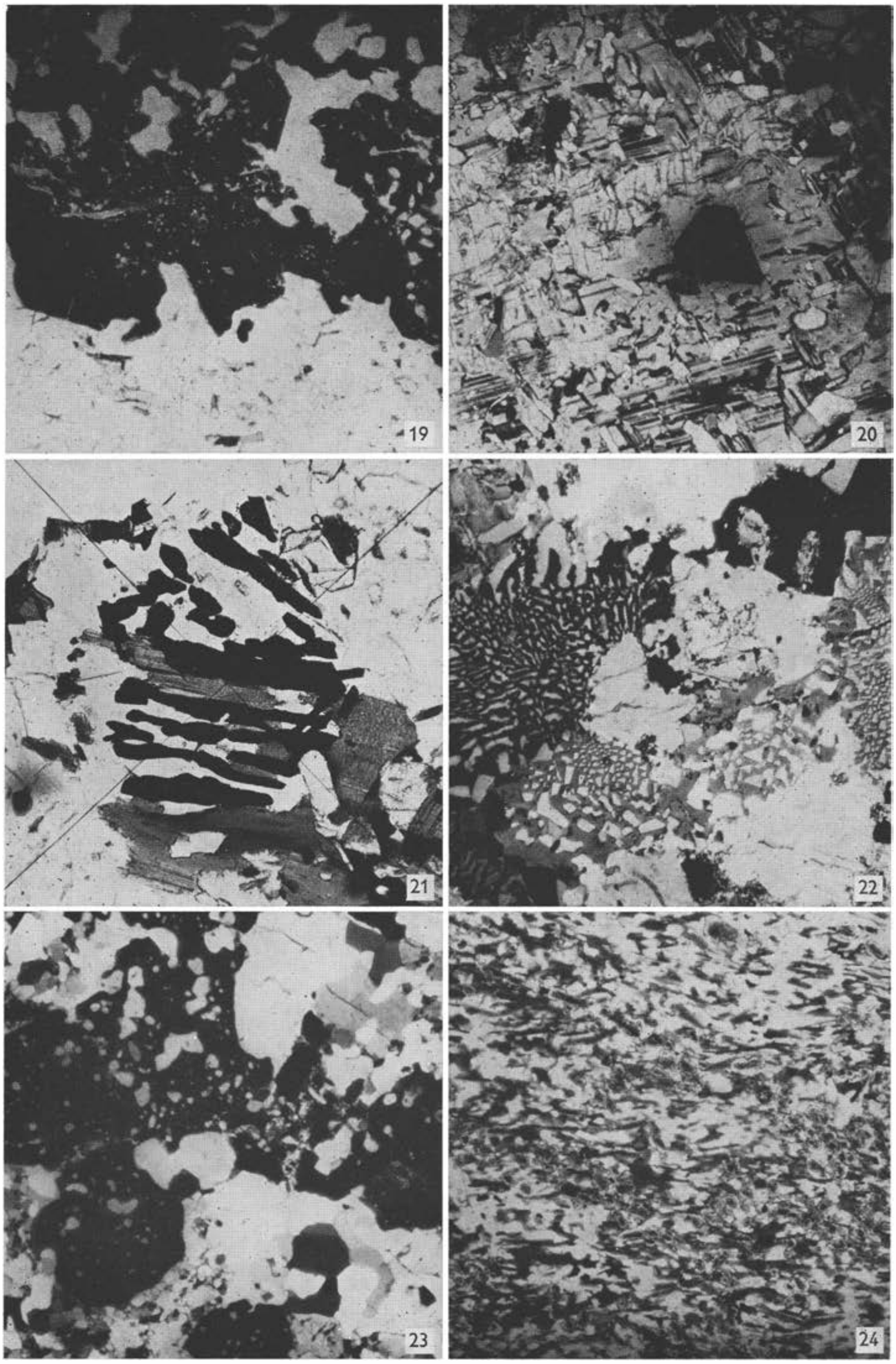
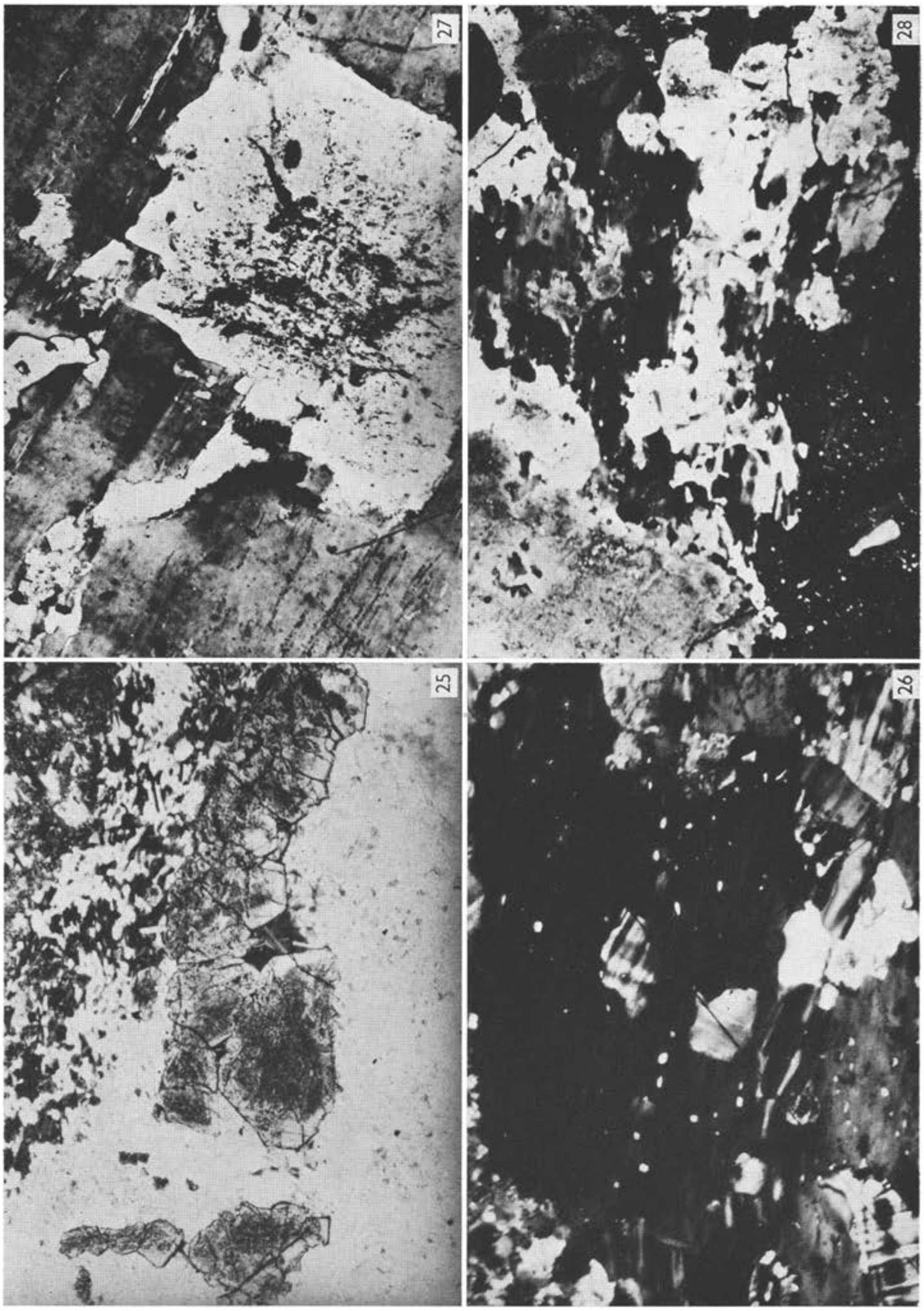


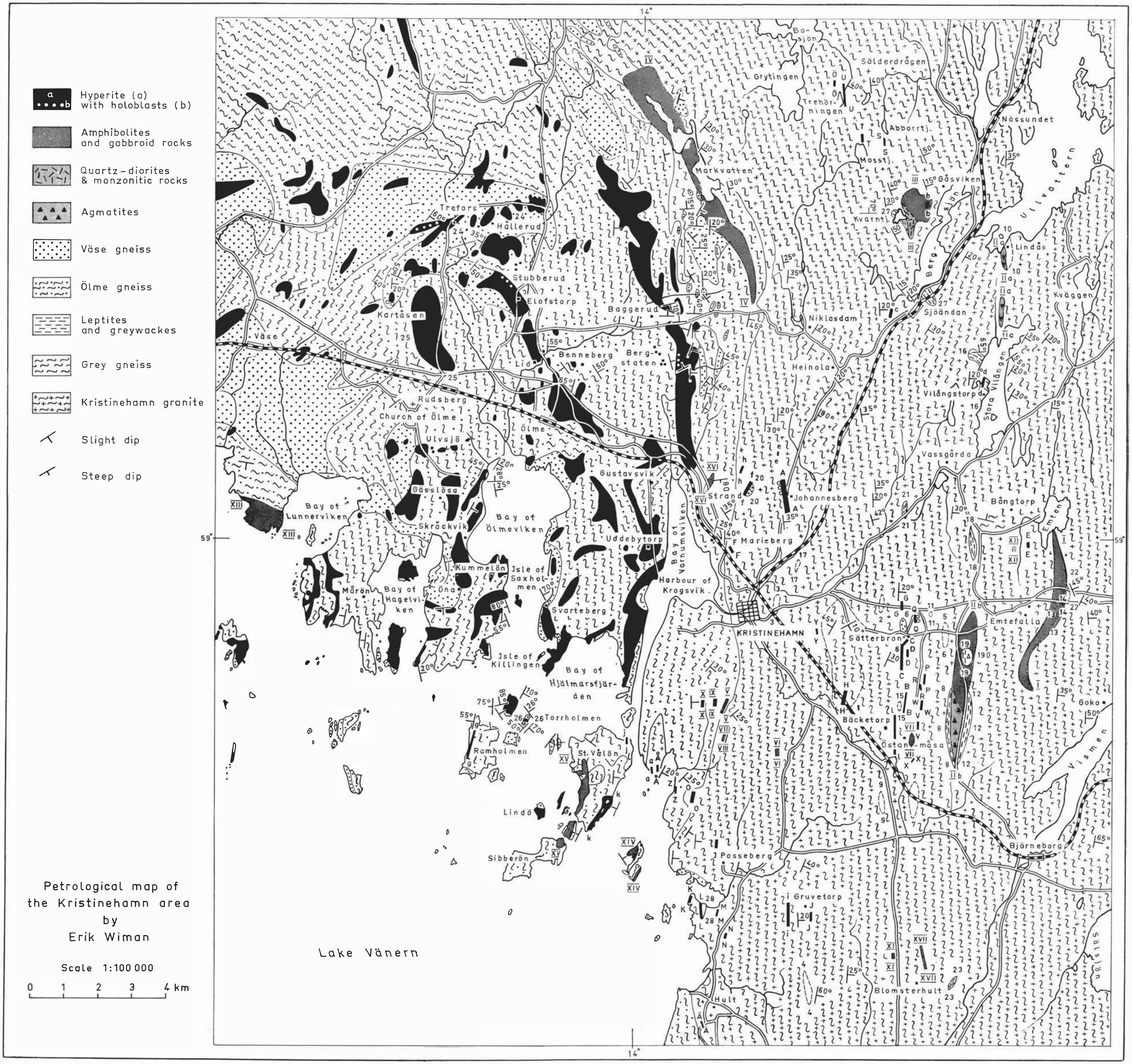
Plate II




13
14
15
16
17
18


19
20
21
22
23
24


27
28
25
26


Hyperite (a)
with holoblasts (b)
Amphibolites
and gabbroid rocks
Quartz-diorites
& monzonitic rocks
Agmatites
Väse gneiss
Ölme gneiss
Leptites
and greywackes
Grey gneiss
Kristinehamn granite
Slight dip
Steep dip
Petrological map of
the Kristinehamn area
by
Erik Wiman
Scale 1:100 000
0 1 2 3 4 km
Lake Vänern
KRISTINEHAMN
Väse
Trefors
Hällerud
Stubberud
Elofstorp
Baggerud
Kartåsen
Benneberg
Bergstaten
Lid
Rudsberg
Church of Ölme
Ulvsjö
Ölme
Gustavsvik
Gässlösa
Bay of Lunnerviken
Skråckvik
Bay of Ölmeviken
Uddebytorp
Bay of Varnumsviken
Harbour of Krogsvik
Kummelön
Isle of Saxholmen
Mårön
Bay of Hagelviken
Öna
Svarteberg
Isle of Killingen
Bay of Hjälmarsfjärden
Torrholmen
Ramholmen
St. Vålön
Lindö
Sibberön
Markvatten
Grytingen
Bosjön
Sölderdrågen
Trehörningen
Abborrtj.
Mosstj.
Kvarntj.
Gåsviken
Nässundet
Ullvättern
Lindås
Kvåggen
Sjöändan
Niklasdam
Heinola
Vilångstorp
Stora Vilången
Vassgårda
Strand
Johannesberg
Marieberg
Bångtorp
Emten
Emtefalla
Sätterbron
Bäcketorp
Östanmåsa
Goko
Visman
Björneborg
Posseberg
Gruvetorp
Blomsterhult
Hult
Sälsjön