INTERNATIONAL GEOLOGICAL CONGRESS
XXI SESSION NORDEN 1960

ALKALINE ROCKS AND MINERAL DEPOSITS OF SOUTHERN, CENTRAL, AND NORTHERN SWEDEN

GUIDE TO EXCURSION NO C 27

By

H. VON ECKERMANN, W. LARSSON, E. NORIN,
R. GORBATSCHEV, AND PERCY QUENSEL

The Swedish geological guide-books

are edited by

THE GEOLOGICAL SURVEY OF SWEDEN

INTERNATIONAL GEOLOGICAL CONGRESS
XXI SESSION NORDEN 1960

ALKALINE ROCKS AND MINERAL DEPOSITS OF SOUTHERN, CENTRAL, AND NORTHERN SWEDEN

Guide to excursion No C 27

By

H. von Eckermann, W. Larsson, E. Norin,
R. Gorbatschev and Percy Quensel

The Swedish geological guide-books
are edited by

THE GEOLOGICAL SURVEY OF SWEDEN

CONTENTS

Excursion No C 27: Aug. 25th—Sept. 1st, 1960

Excursion leaders:

Professor Harry von Eckermann
Edeby
Ripsa

State Geologist Walter Larsson
Geological Survey of Sweden
Stockholm 50

Docent Otto Brotzen
Mineralogical Institute
University of Stockholm
Stockholm Va

The Alkaline Rocks of Norra Kärr

By

H. von Eckermann

Norra Kärr is a small farm situated about 1 1/2 km from the eastern shore of Lake Vettern, about 15 km N.N.E. of the small town Gränna and 45 km N.N.E. of Jönköping. The alkaline rocks around the farm constitute an elongated area in a north-southerly direction of a length of about 1,200 m and a width of up to 400 m (Fig. 1). They were first described by Törnebohm (1906) as katapleite syenite, who found the schistosity to be parallel with that of the adjoining and enclosing Gothian Växjö granite. Gavelin (1912) assumed the schistosity to be secondary and due to the same regional movement which has affected the granite. Backlund (1932), v. Eckermann (1942), and Adamson (1944) found the structure at both ends of the alkaline body to run transversely to the regional schistosity (disclaimed by Koark 1960) and conformably with the granite contact. Adamson drew attention to the surrounding fenite zone and claimed the schistosity to be primarily protoclastic. Part of the schistosity may, however, be due to a secondary tectonic disturbance. At present the alkaline occurrence is being reinvestigated (H. v. Eckermann and H. Koark) and the results are expected to be communicated at the excursion.

The main alkaline rock, by Adamson termed grennaite (= Törnebohm's katapleite syenite), occupies about 90 % of the area and is composed of katapleite and eudialyte crystals — according to Adamson phenocrysts — in an aphanitic matrix of alkaline feldspar, nepheline, aegirine, eudialyte, katapleite, and accidentally natrolite. In some types of grennaite eudialyte occurs in the groundmass only, and in others the katapleite may be totally missing. The usually grayish green grennaite grades marginally into a white facies due to a lighter colour as well as decreasing amount of aegirine. At the very contact towards the granite the nepheline is replaced by natrolite and the aegirine by biotite and occasionally by amphibole, while the feldspar remains unchanged. Some fluorite is added.

Within the grennaite vein- and lens-like pegmatitic "schlieren" occur, by Adamson described as segregations. They are composed of the same minerals with the exception of the feldspars, which in the grennaite are anorthoclases and in the schlieren microcline and albite.

At Norra Kärr and at a short distance from the north-western boundary of the alkaline area fairly narrow bands of coarse-grained rocks are found within the grennaite. At their southern end Adamson called them pulaskite, at their northern lakarpite. They are both albite-amphibole-nepheline syenites, the amphibole of the former being a sodic hornblende and of the latter an arfvedsonite. Both types contain the rare zirconium mineral rosenbuschite. Current survey (v. Eckermann) indicates a grading of the pulaskitic type into the more sodic lakarpite further north. Adamson is of the opinion that these rocks are older enclosures within the grennaite, but new exposures of the rocks rather suggest a slightly younger age. Their conformity to the direction of foliation in the grennaite, claimed by Adamson, does not seem to be a general one.

Another rock, occurring within the grennaite, is the kaxtorpite (Adamson), which occupies one larger area in the central part of the alkaline rocks S.W. of Norra Kärr and a smaller one close to the north-eastern boundary. It consists of the following main minerals: large grains of soda-microcline in a matrix of albite, pectolite, eckermannite, aegirine, and nepheline. Accessorily both optically positive and negative titanite is found, the latter mostly in kaxtorpite rich in pectolite. The amounts of pectolite and nepheline vary and one or both of the minerals may be locally wanting. In the kaxtorpite no zirconium minerals have been found according to Adamson, who considers the kaxtorpite to be older than the grennaite. The current reinvestigation of the central kaxtorpite area (Koark) has so far indicated a structure of greater complication than the parallel schistosity of grennaite and kaxtorpite observed by Adamson, and, in consequence, the age relationship of the two rocks may not be definitely settled.

The alkaline area is according to previous investigators (Törnebohm, Adamson) an intrusion surrounded by a fenite zone of 25—100 meters width. The Växjö granite, which in places is more or less dioritic and transversed by mylonitization zones parallel to the downthrow faulting of Lake Vettern, is transformed into syenitic and quartzsyenitic rocks. Close to the alkaline contact the biotite and hornblende of the granite is transformed into aeririne-augite and aegirine. Of special interest are the narrow bands of fluorite, which occur in increasing amount towards the contact. The fenitization involves a recrystallization of the feldspars and a replacement of the microcline by albite close to the contact. The essential difference between the fenitization processes at Norra Kärr and Alnö (v. Eckermann) is the mode of formation of aegirine-augite. While at the former locality the biotite remains stable during the major part of the fenitization process and decomposes with the formation of pyroxene very close to the alkaline contact, the same process at Alnö starts with the replacement of biotite by pyroxene and the formation of the latter around the quartz grains. The reason for this diversity may be the absence of Ca and CO_2 in the metasomatic exchange reaction at Norra Kärr (Adamson).

The age of the alkaline rocks of Norra Kärr has been the subject of discussion since the discovery of the locality. The estimates include: "not older than the beginning of the Jurassic period but possibly younger" (Törnebohm 1906), "pre-Cambrian" (Gavelin 1912), "definitely younger than the deformation of the Växjö granite" (Adamson 1944), and "Permian" (Magnusson 1958). As an age determination on radioactive basis is included in the program of the current re-survey a more precise determination may be arrived at later. At present an eo-Cambrian age, or the same age as the Alnö intrusion, seems to be the best guess.

The composition of characteristic minerals

Eckermannite	$W_4(XY)_4(Z_4O_{11})_2(O, OH, F)_2$ in Berman's symbols with 11.30 weight % Na_2O, 2.41 weight % K_2O, and 2.59 weight % F.
Eudialyte	$Na_3Ca(Fe^{II}, Mn, La)_2Zr(Si^3O_9)_2(OH, F, Cl)_2$ with La = 0.92 weight %
Katapleite	$(Na_2, Ca)ZrSi_3O_9 \cdot 2H_2O$
Nepheline	$(Na, K)_2Al_2Si_2O_8$ with Na: Na + K = 88.5 weight-ratio.
Pectolite	$Ca_2NaHSi_3O_9$ with 2.2 weight % MnO.
Rosenbuschite	$Na_2Ca_3((Si, Zr, Ti)O_4)_3$, not analyzed so far.

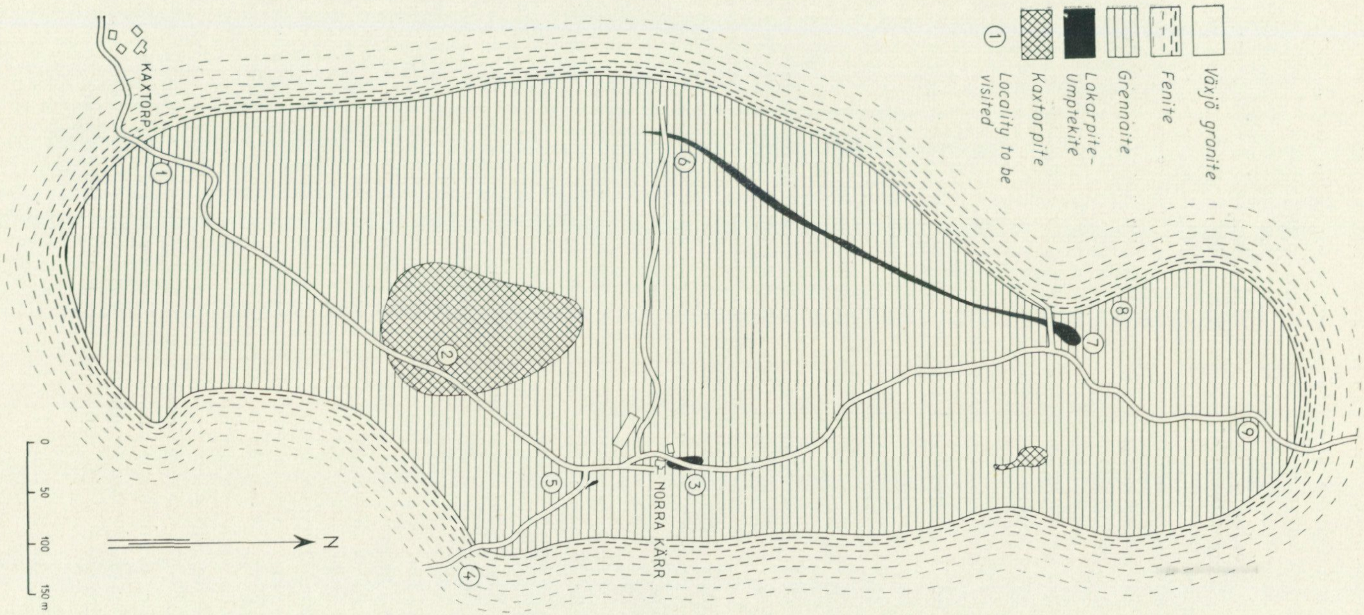


Fig. 1. Geological sketch-map of the Norra Kärr alkaline area.
För spridning godkänd i Rikets allmänna kartverk den 27 april 1960.

Localities to be visited by the excursion (Cfr. map Fig. 1)

1. A quarry in grennaite with phenocrysts of katapleite and eudialyte.
2. The central occurrence of kaxtorpite, rich in pectolite.
3. Lakarpite at outcrop at Norra Kärr farmhouse.

4—5. The Växjö granite W. of the farm and a heap of boulders and blasted blocks of different types of the alkaline rocks, available for sampling.

6. The excursion leaves the busses and walk to an outcrop of pulaskite.

7—8. An outcrop of lakarpite. To the north-west a quarry at the very contact between the marginal facies of the grennaite and the fenitized Växjö granite.

9. Grennaite with phenocrysts of katapleite at the northern boundary, where the structure may be studied. The excursion returns to the busses.

The Titaniferous Iron-Ore Deposit of Taberg

By

Walter Larsson

Taberg is situated 12 km S.S.W. from the town of Jönköping in the middle of S. Sweden. The iron ore (magnetite-olivinite) forms practically the whole mountain (Fig. 2 and 3) and is surrounded by hyperite, the mother rock of the ore. The hyperite has intruded into an acid, schistose granite of Gothian age (Barnarp granite), the schistosity of which is due to tectonic movements along the boundary zone between the southwestern gneiss area of Sweden and mainly granites to the east.

The iron ore of Taberg has been mined intermittently probably from the Middle Ages. The highest output was reached during World War II (1943: > 200,000 metric tons) due to the increased demand for vanadium, which metal was once (by Sefström in 1830) discovered in rod-iron made of Taberg ore. The mining has chiefly been done in open cuts, only during the last mining period to a small extent by underground working.

The *magnetite-olivinite* occurs in two types, one poor in plagioclase and one containing plagioclase tables, sometimes in parallel arrangement indicating a flow-structure, sometimes accumulated in star-like groups. The former type contains ab. 58.5 % by volume of olivine, 35 % titano-magnetite, 4.5 % plagioclase, and 2 % amphibole. The plagioclase-porphyritic form has up to 25 % plagioclase, somewhat more amphibole, and correspondingly less content of olivine and titano-magnetite. According to chemical analysis the olivine has the composition $Fo_{65}Fa_{35}$. The titano-magnetite, which generally makes up an anhedral filling between the olivine crystals, consists of magnetite with small lamellae of ilmenite and somewhat coarser lamellae of a common Mg-spinel, generally in octahedral and cubic arrangement, respectively. Sulfide minerals (pyrite, pyrrhotite, pentlandite, chalcopyrite) occur sparsely as small grains or narrow veins. The plagioclase — phenocrysts as well as interstitial filling — is a labradorite with 50—57 % An. Pale green or colourless amphiboles form reaction rims of varying width between plagioclase and olivine + titano-magnetite. Biotite, pyroxene, and apatite are highly subordinate minerals in the magnetite-olivinite.

Sequence of crystallization in the magnetite-olivinite without phenocrysts: Olivine (+ apatite) — titano-magnetite — plagioclase. In the type richer in plagioclase the labradorite tables are of early crystallization. In chemical and mineralogical composition the magnetite-olivinite presents striking similarities with the cumberlandite of Iron Mine Hill in Rhode Island. According to five drill holes from Taberg (Fig. 3) the Fe-percentage of the unaltered ore varies between 28.0 and 33.8 %, being on an average 31.4 %.

Coarse-grained magnetite-olivinite occurs as a dike in the northern part of the mountain. As it differs only slightly in mineral composition from the main rock it may be interpreted as an off-shoot from a deeper, not yet solidified part of the magnetite-olivinite magma being somewhat enriched in mineralizers. Besides the ilmenite and spinel lamellae the ore mineral of this dike contains a component, the nature of which has not yet been definitely settled.

In tectonically influenced zones the magnetite-olivinite has been more or less altered. The olivine then gives rise to a confused mass of serpentine, carbonate, poor in CaO, amphibole, chlorite, and secondary magnetite. In the titano-magnetite the spinel disappears and the ore mineral is broken into pieces, kept together by the secondary minerals. Garnet, biotite, orthorhombic amphibole, prehnite, and apatite are subordinate.

The *hyperite,* generally surrounding the ore body and also occurring as inclusions in the magnetite-olivinite, is a medium-grained, blackish brown olivine-dolerite. The An-percentage of the plagioclase is a trifle higher and the olivine somewhat richer in iron than the same minerals of the magnetite-olivinite. The anhedral clinopyroxene is evidently pigeonitic. Reaction rims of amphibole between plagioclase and olivine as well as titano-magnetite are frequent. The last-mentioned mineral is very similar to the titano-magnetite of the magnetite-olivinite. Solitary ilmenite grains also occur. Small grains of chalcopyrite and pyrrhotite with pentlandite are more common than in the magnetite-olivinite. Apatite and alkali feldspar are primary, biotite and garnet secondary minerals of the hyperite, all in low percentages. The crystallization of the chief minerals of the hyperite was completed in the following sequence: Olivine — apatite — titano-magnetite — labradorite — clinopyroxene — alkali feldspar. Peripherically, the hyperite has generally been altered into a more or less schistose *amphibolite,* the olivine and pyroxene having been replaced by chlorite and amphibole. Contemporaneously the plagioclase becomes poorer in lime. Occasionally biotite, epidote, titanite, and quartz enter into the mineral composition of this hyperite-amphibolite.

In the magnetite-olivinite there occur fragments of a greyish, medium-grained *anorthosite* of a gabbro-like texture. In addition to the predominating plagioclase (labradorite with 50—62 % An) small amounts of olivine (richer in iron than that of the magnetite-olivinite), clinopyroxene (pigeonitic), and titano-magnetite as well as, subordinately, biotite, apatite, alkali feldspar, ilmenite, pyrrhotite, and pentlandite are to be found in this rock. Sequence of crystallization of the chief constituents: Labradorite — olivine — titano-magnetite — clinopyroxene.

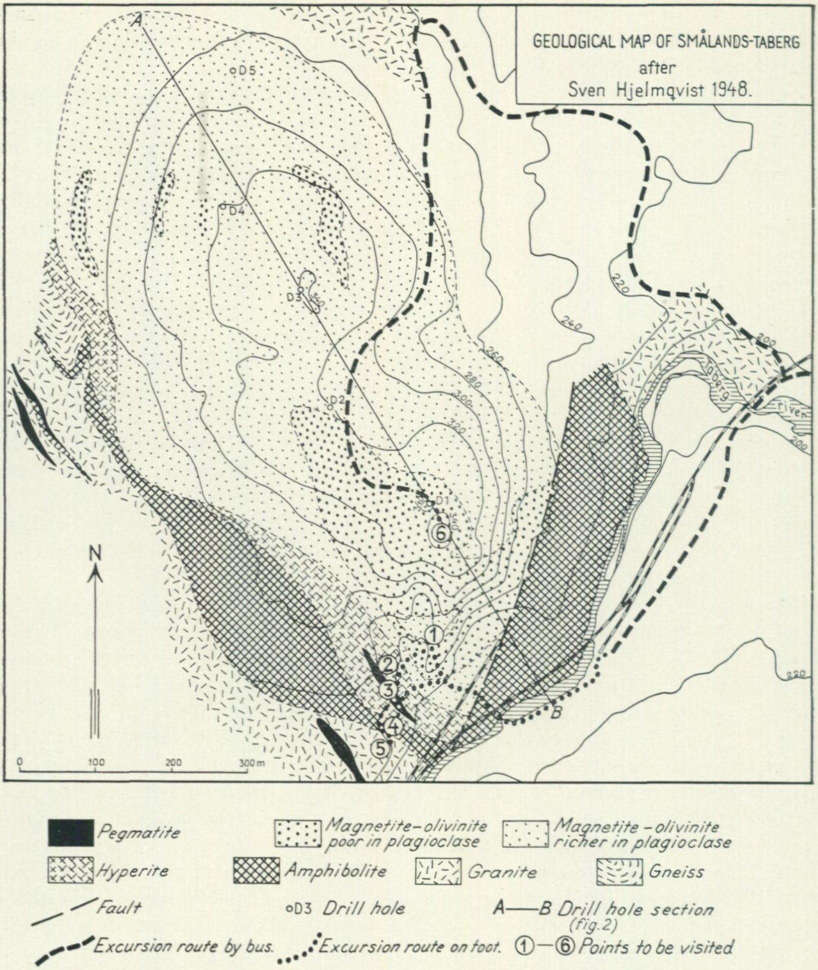


Fig. 2. Smålands Taberg.

För spridning godkänd i Rikets allmänna kartverk den 27 april 1960.

On the S.W. slope of Taberg the hyperite is cut by a 10—15 m wide dike of *pegmatite,* striking N.N.W.—S.S.E. The pegmatite has acquired a partly distinct parallel structure in consequence of tectonic deformation. It consists mainly of pale reddish albite and quartz, partly in graphic intergrowth. Muscovite, microcline, and magnetite are present in small amounts.

The Archean rocks surrounding the hyperite and magnetite-olivinite intrusion include grey, fine-grained gneiss, amphibolite, a reddish grey, somewhat gneissose granite and aplite.

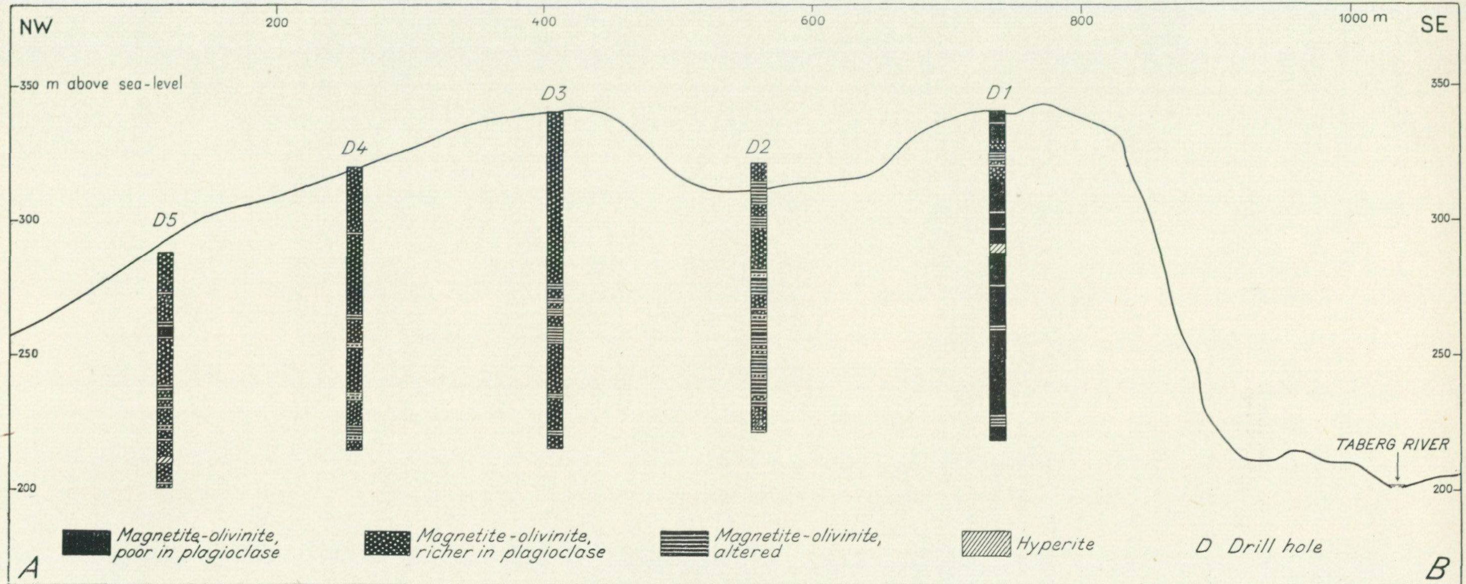


Fig. 3. Section through Taberg from N. W. to S. E.
Scale of height = twice the scale of length.

The relations between the rocks of Taberg (magnetite-olivinite, hyperite, anorthosite) are in favour of a common origin from an intruding, crystallizing hyperite magma by gravitational differentiation, plagioclase crystals moving upwards forming anorthosite, olivine and titano-magnetite sinking downwards and remelting to form a magma, which later intruded upwards into the hyperite and anorthosite already solidified. The age of the Taberg intrusion seems to be Late Gothian or Early Dalslandian.

Localities to be visited by the excursion (Fig. 2): —

1) Open cut in magnetite-olivinite of different types. Fluidal structure. Inclusions of hyperite and anorthositic hyperite. Alteration zones. Fissure fillings.

2) Hyperite, unaltered.

3) Pegmatite (see above).

4) Marginal zone of hyperite, altered into amphibolite.

5) Reddish grey, medium- to coarse-grained, porphyritic, gneissose granite of Gothian age, surrounding the Taberg intrusion.

6) Top of the mountain, 343 m above the sea-level. Magnetite-olivinite poor in plagioclase. Outlook over the Archean plateau of Småland, intersected by fault lines. To the north the fault depression of Lake Vättern with the Visingsö sedimentary series.

Data on Smålands Taberg mainly in accordance with S. Hjelmqvist: The titaniferous iron-ore deposit of Taberg in the south of Sweden. SGU C 512, Stockholm 1950.

The Alkaline Rocks of Almunge

By

E. Norin and R. Gorbatschev

The alkaline rocks of Almunge, described in P. D. Quensel's classical monograph of 1914, occupy an area of about 16 sq. km some 30 km east of Uppsala in a region of Archean (Svecofennian) granites and gneisses (Fig. 4). These include gray granodiorite ("gray Uppsala granite"), red microcline granite (Vänge granite), and gabbroid rocks. The granodiorite is rich in fragments and strips of metabasites and leptitic gneisses. All these rocks have become more or less intensely fenitized within the borders of the alkaline massif.

The boundary is fairly well defined on the west, being a zone of dislocation in which the Archean rocks have been extensively crushed to mortar-structure and subsequently recrystallised into rocks with aplite-like texture. From Stora Ellringe southwards, this zone is marked by several parallel, echelonating bands of fine-grained, streaky fenitic gneisses and nepheline gneisses which extend, albeit with interruptions, as far as Oppgården, curving gradually to the south-east and east in a manner suggestive of a quadrant of a ring dike (Locs. 1 and 4). Numerous dikes, veins, and veinlets of reddish syenite-aplite extend along the boundary zone, locally intersecting the streaky nepheline gneiss.

In the north the boundary is irregular and ill defined; traces of a marginal, migmatized nepheline gneiss are, however, to be found c. 500 m west of Ryggestalund. Northwest of Ryggestalund a broad lobe of umptekite protrudes from the centre of the massif northwards. In the south and the east, the boundary is also less conspicuous and rather irregular; it is marked by a series of dislocations along which the Archean rocks retreat stepwise eastwards, being replaced by fenitized rocks and umptekites, thus producing a roughly oval shape of the alkaline region. Numerous fractures with north-southerly trend marked by crush zones and streaks of mylonite also intersect the Archean red granite outside the eastern boundary and are locally accompanied by fenitization. A conspicuous feature of this part of the map is a long, apparently boudinaged dike-like body of massive canadite, striking N. 10° W., which extends from near Andersberg in the south to Ryggestalund and beyond in the north and from which the canadites and associated felsic nepheline syenites between Sågen and Byske extend laterally over a large area.

Amongst the multitude of rocks within the alkaline area, the following principal types may be distinguished:

1. An assemblage of mainly basic alkaline rocks which represent the oldest members of the alkaline suite. They are predominantly of canaditic type ranging from *felsic nepheline syenites* to *theralites* and are composed principally of albite (grading into oligoclase or andesine in the mafic varieties), nepheline, cancrinite, alkali hornblende, aegirine-augite, and biotite; amongst the accessories the common occurrence of vesuvianite should be emphasized. These rocks are partly gneissic, partly massive. The string of usually streaky, sometimes granulitic, gray nepheline gneisses which extend along the western and southwestern border of the area, may represent parts of an uncomplete ring dike intruded at an early stage of the tectonic development of the area. Similar rocks, often with trachytoidal texture, occur in the interior of the alkaline region. Thus, several disconnected streaks of canaditic and theralitic rocks as well as of nepheline syenite-pegmatite extend with north-easterly trend across the central part of the area (Loc. 5). In the basic alkaline group is probably to be included a solitary occurrence of hornblende gabbro of essexitic affinity at S. Norrby near the northern boundary of the massif.

The large canadite field in the middle eastern part of the area (Loc. 7) consists of a large number of irregular bodies of canadite of all sizes, each, as a rule, surrounded by a broad aureole of white nepheline syenite which generally is coarse-grained and often pegmatitic. This white syenite grades into the adjoining umptekite, into which the whole complex is immersed; umptekite also appears as irregular outcrops inside the canadite field. Outside the western border of the canadite area, patches of white syenite, a few sq. m in size, are very common. In many cases these patches constitute a thin crust on the umptekite only.

2. Under the general term of *umptekites* may be grouped a complex of perthite-hastingsite syenites of much variable texture and mineral proportions composed mainly of perthitic feldspars, albite or oligoclase-albite, a usually hastingsitic amphibole, biotite (often siderophyllitic), ± quartz and accessorily calcite, fluorite, zircon, apatite, and titanite. The rocks have generally a migmatitic appearance, being very inhomogeneous with the mafic minerals tending to cluster together into patches or strings. The umptekites differ from the fenitic migmatites, described below, mainly by a reduction or disappearance of the aplitic textured groundmass. The transition into fenitic migmatites is therefore gradual.

In certain places, the massive umptekite contains *bodies of red granite,* rich in quartz, ranging in size from a few metres to hundreds of metres, without any defined boundary towards the umptekite. These granitic bodies are most common along the marginal parts of the umptekite field in the south-east and the north-west, but they are also quite common in the interior. In the neighbourhood of Johannesdal a gradual passage of such red massive granite into the ordinary Archean reddish granitic gneiss, exposed along the main road, can be traced. Intimately associated with the fenites and the umptekite are numerous dikes and veins of syenite-aplite which intersect the former.

3. *Fenitic gneisses* (a) and *fenitic migmatites* (b) formed by alkali metasomatosis of the brecciated and cataclastically deformed Archean rocks which, thus, have lost their primary features partially (a) or entirely (b) without being homogenized. Characteristic of these rocks is a largely aplitic development with saccharoidal crystals of albite (usually dusty in the fenitic gneiss, more clear in the migmatite), an intergranular film and irregular crystals of clear microcline, brown or green (siderophyllitic) biotite, ± quartz, and alkali hornblende, more rarely diopside or aegirine; fluorite and calcite are nearly constant accessories. In this groundmass occur porphyroblasts of alkali feldspar in varying proportions exhibiting, with advancing metasomatosis, all transitions from only slightly perthitic microcline into string-perthites, patch-perthites, and antiperthites, the latter often developed as very long, narrow, jagged laths, occasionally with a fan-like grouping (middle part of section, Loc. 2).

4. Bodies, often of large dimensions, of *Archean rocks,* still recognizable as such to the naked eye. These rocks exhibit mortar-structure, healed by recrystallization. The metasomatosis is in evidence by partial sericitization of the plagioclase, partial replacement of the primary hornblende by a pale brownish biotite, soaking of the rock with intergranular potash feldspar, and abundant formation of titanite. Such xenoliths are most abundant in the western and southern parts of the massif forming, together with the fenitic gneisses and migmatites, a gigantic agmatitic breccia. They are intersected by veins and dikes of syenite-aplite, in part of pneumatogeneous nature (Loc. 3).

Concerning the sequence of emplacement, the canadites are the earliest members of the alkaline complex. They differ petrographically and magmatectonically fundamentally from the umptekites. Their mode of emplacement is not always obvious because the invasion of the umptekite is often that of a migmatitic front which has given rise to peculiar hybrid rocks of much variable texture.

Fragments of canadite included in the umptekite testify to the younger age of the latter, which is further confirmed by the occurrence of dikes of umptekites or nordmarkites in the canadites. The occasional occurrence of fluidal arrangement of the feldspar porphyroblasts in the umptekite shows that the rock had passed into a rheomorphic state capable of mobility. They are all traversed by veinlets, veins, and dikes of red or pink syenite-aplite. The youngest intrusive formation is a generation of dikes and veins of grayish quartz with a conspicuous cherty appearance in handspecimen.

Quensel (1914) arrived at the conclusion that the alkaline area represents

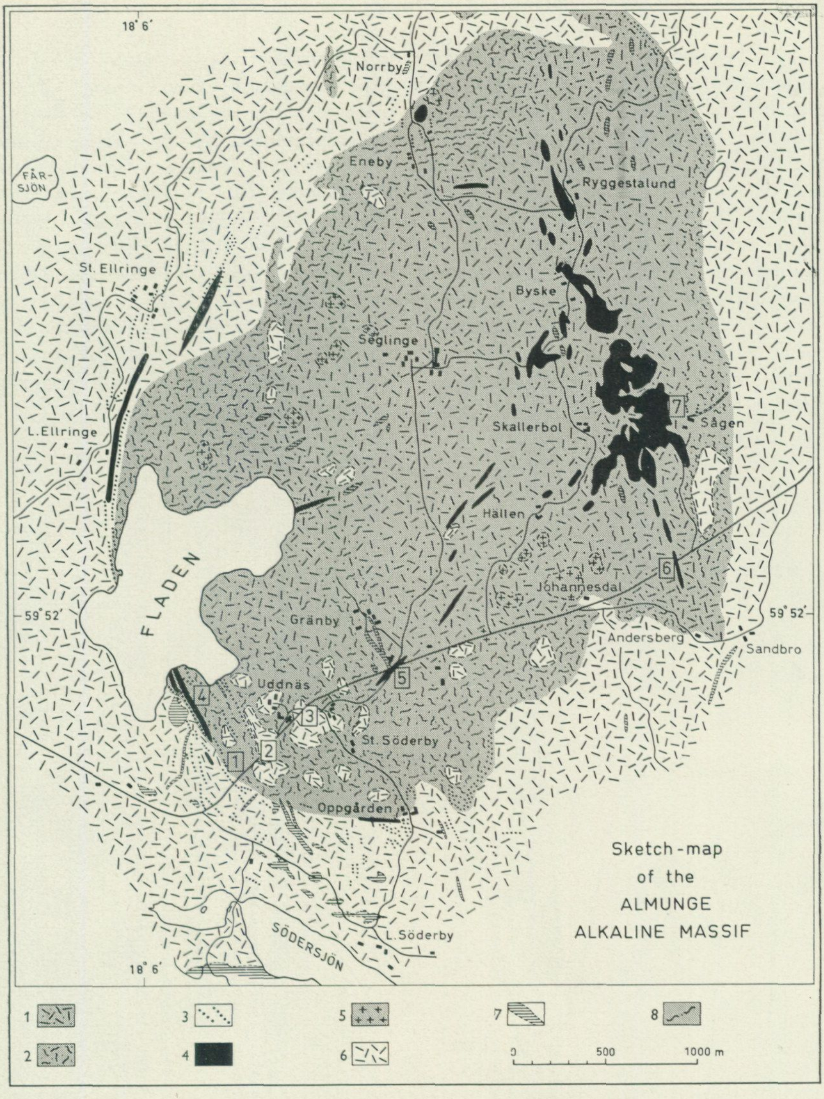


Fig. 4. Almunge alkaline masssif.

1. Umptekites
2. Fenites
3. Aplites
4. Canadites and theralites
5. Red granite transitional into umptekite
6. Archean granodiorite and granite
7. Metabasites and amphibolites
8. Leptites and quartzites

För spridning godkänd i Rikets allmänna kartverk den 27 april 1960.

a section at great depth of an old volcanic channel or neck, the superstructure of which has been entirely removed by denudation.

The detailed investigation of the area during the last decade has revealed the important role played by metasomatic processes in the development of the alkaline complex. In our opinion the only primary magmatic rocks in the alkaline area are the early basic alkaline intrusives, represented by the canadites and the theralites, the mother magma of which may have intruded from a deep-seated source at an early stage in the development of the massif in connection with a subsidence of the present alkaline area, in principle of cauldron type. These intrusions seem to have had originally the form of dikes and sills in the pre-existing Archean rocks. The displacement of the latter was accompanied by thorough and intense brecciation of the dislocated rocks. Emanations rich in *int.al.* CO_2,F, and H_2O ascended from the magma in the depth, soaking the rocks by way of cracks and intergranulars, inaugurating metasomatic alterations of the mineral assemblages, and eventually originating a rheomorphic magma. The metasomatism has embraced also the early basic alkaline intrusives.

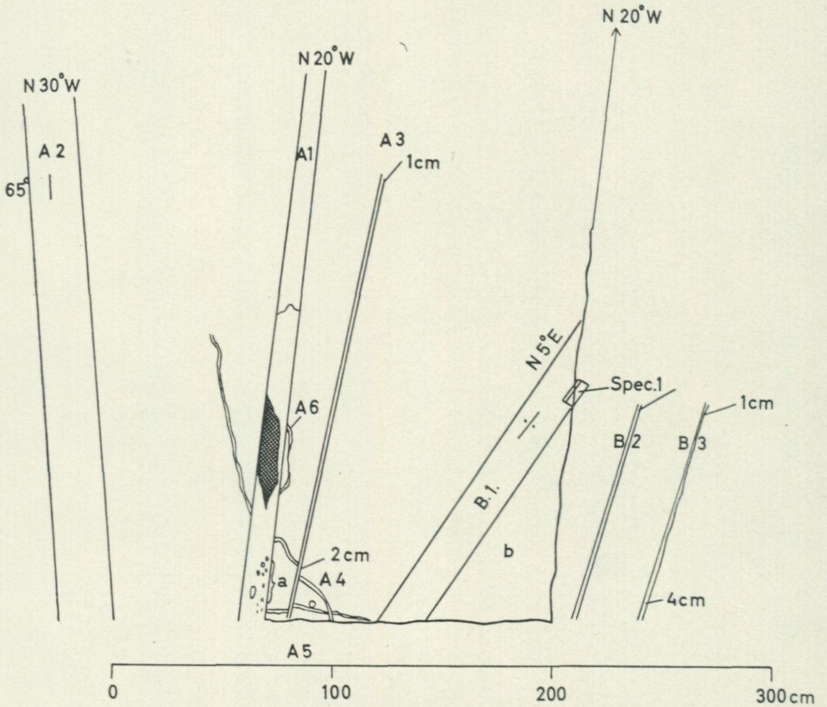


Fig. 5. Veins in the granodiorite, Loc. No. 3.
Veins A. 1 — A. 3 : syenite-aplite; A. 4 — A. 6 : pegmatitic; B. 1 — B. 3 : felsic granodiorite; black: quartz nodule.

Description of Localities

Locality No 1

General view of the alkaline massif.

Contact zone between the alkaline rocks and the Archean. In the road cutting is exhibited the gradual passage from cataclastic but still recognizable gray granodiorite, which forms the wall-rock, into streaky fenitic gneisses with veins and dikes of syenite-aplite conformable to the boundary.

Locality No 2

The section exhibits further stages in the process of fenitization with transition from cataclastic, gray granodiorite in the western part into fenitic gneisses and fenitic migmatites. Inlayers of paragneisses are represented *int.al.* by fenites rich in diopside. In the middle part of the section, the various types of porphyroblasts of perthitic feldspars are well represented and the gradual replacement of their potash feldspar by albite can be followed.

The granodiorite constitutes part of a very large xenolith grading into fenites all around.

Locality No 3 (Fig. 5)

Another large body of gray granodiorite surrounded by fenitic gneisses with gradual transition. The granodiorite is intersected by dikes and veins of aplite of pneumatogeneous nature.

The syenite-aplite A1 contains a large nodule of quartz which partly occupies the whole width of the dike.

In the area a, no defined boundary exists between the granodiorite and the aplite, a gradual transition is taking place, the principal stages being: 1) replacement of the amphibole by pale brownish biotite, titanite, and quartz, disintegration and myrmekitization of the plagioclase; 2) disappearance of the biotite, abundant formation of potash feldspar, decalcification and recrystallization of the plagioclase; 3) disappearance of the quartz and reduction of potash feldspar leaving a residue consisting mainly of saccharoidal albite.

Locality No 4 (Fig. 6)

Streaky fenitic gneisses and nepheline gneiss in the zone of tectonic disturbance which here delimits the alkaline massif. The neighbouring Archean rocks comprise red granite with inlayers of supracrustals and a few sizeable bodies of gabbro. According to the analyses available, the nepheline gneiss differs from normal canadite in being much richer in K_2O and extremely low in MgO. Dike-like bodies of aplites composed of 70—95 % vol. albite with some microcline and magnetite extend conformably to the foliation of the gneisses. The fenitic rocks transitional between macroscopically still recognizable Archean and the umptekite are medium- to fine-grained, frequently markedly foliated, and composed of perthitic feldspars, microcline, albite, hastingsitic amphibole, and siderophyllite. The contents of flucrite, calcite, and zircon are usually

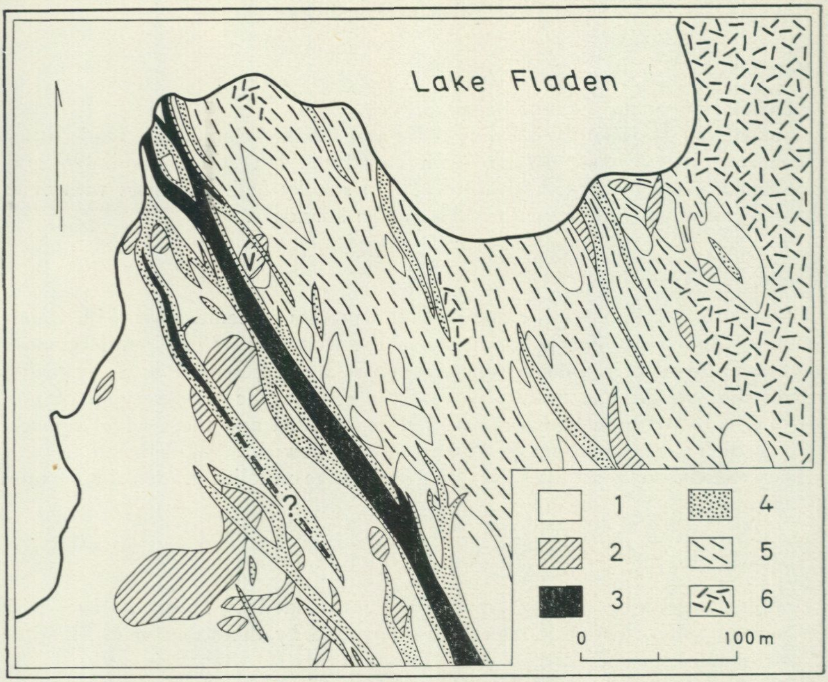


Fig. 6. The western boundary of the alkaline massif, south of Lake Fladen; Loc. No. 4.

1. Archean granite and supracrustals, in part fenitized
2. Archean amphibolites and amphibole-gabbro
3. Nepheline-gneiss
4. Albite-aplite
5. Fenitized marginal rocks transitional between Archean and umptekite
6. Umptekite

V. Vesuvianite-bearing fenitized amphibolite

För spridning godkänd i Rikets allmänna kartverk den 27 april 1960.

higher than in the umptekites. The latest alkaline rocks represented here are quartz-bearing pegmatites and fine-grained quartz-feldspar-aegirine-alkali-amphibole rocks rich in potash.

Locality No 5

The umptekite, which here grades into fenitic migmatite with many fragments and large inlayers of supracrustal rocks, encloses an elongated body of canadite (90 × 10 m exposed). Except for the northern parts of this body, which are much altered and disrupted by the umptekite, the canadite has the appearance of a dike with distinct contacts. The strike is similar to that of a number of analogous canadites stretching from Hällen towards the southwest.

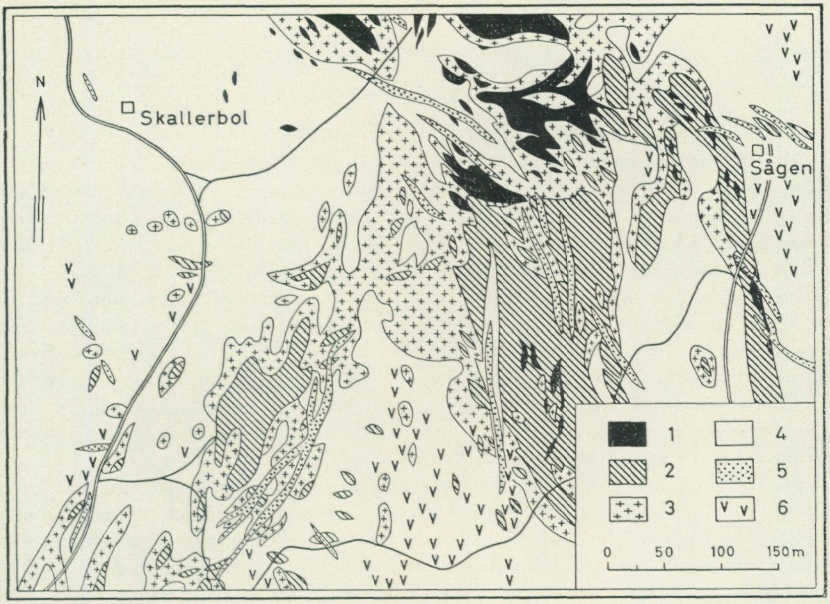


Fig. 7. Detail map of the Skallerbol—Sågen Area, Loc. No. 7.

1. Canadite, predominantly theralitic
2. Canadite, predominantly normal
3. White syenites
4. Umptekites
5. Lestivarite-porphyry and albite-aplites
6. Inclusions of Archean rocks

För spridning godkänd i Rikets allmänna kartverk den 27 april 1960.

Locality No 6

Section across a dike-like body of rather typical canadite enclosed in fenitic migmatite and umptekite.

Locality No 7 (Fig. 7)

Within this area, most varieties of the nepheline-bearing rocks are well represented. They comprise dark, mostly trachytoidal theralites, normal canadites, felsic sodalite-bearing canadite brecciating theralite, and finally canadite-pegmatite. White syenites transitional between canadite and umptekite are common throughout the area. Umptekite-pegmatite and dikes of albite-aplite grading into lestivarite-porphyry also occur here. Remnants of Archean in the umptekites include granite, amphibolite, and supracrustals (predominantly quartzitic paragneisses).

The Alnö Alkaline Region

By

Harry von Eckermann

Alnö Island lies in the Baltic N.E. of the city of Sundsvall. It is on its western side separated from the main land by a narrow sound, following one of the big faults marking the downthrow of the Baltic sea-floor. The alkaline rocks cover about 8 km^2 of the N.E. part of the island. The major part and the centre of the intrusion are located under the sea north of the island (Fig. 8).

The country rock of the region is a migmatitic gneiss-granite composed of supracrustal biotite schists, more or less homogeneous gneiss-granites, and pegmatites. It is sparsely intersected by Jotnian dikes of quartz-porphyric, porphyritic and doleritic compositions. At the time of the alkaline intrusion, viz. at the most 562 million years ago (von Eckermann and Wickman 1956), the present surface was covered by sediments, mainly of Jotnian age and of an estimated thickness of about 2,000 meters.

The original intrusion seems to have consisted of a kimberlitic magma, rich in fluorine and carbonic acid but comparatively poor in water, which through differentiation, reaction with the surrounding acid rocks, and autometamorphic alterations produced an astounding variety of rock types. The genesis of the kimberlite itself may be connected with a concentration of carbonic acid and fluorine in an underlying basaltic magma, although the origin of this concentration remains obscure.

When the intrusion pushed upwards it was headed by an almost pure dolomitic-ankeritic differentiate of very high internal CO_2-pressure. At a level where this pressure exceeded the external pressure of the overlying rock-roof the latter burst asunder, conical as well as radiating fractures being formed. Some of these were immediately filled by quickly congealing carbonatite magma, while others got lined with carbonatite but filled centrally by the following kimberlitic magma, thus producing composite dikes. Still other fractures, issuing from levels below the carbonatite or formed later were filled by kimberlitic magma only, rising in the wake of the carbonatite. The kimberlite must have remained fluid some time as evidenced by a gravitative settling of the olivine crystals towards the lower parts of the dikes.

The fractures having been sealed by the congealing dikes, the CO_2-pressure rose again and the intrusion proceeded towards higher levels, where the same sequence of events was repeated. Altogether three main centres of fracturing have been located at about 10, 5, and 3 km below the surface of rocks and sediments existing at the time of the intrusion, viz. about 2 km less below the actual surface of today (Fig. 9). At higher levels the carbonatites have been found to be increasingly calcitic and the contemporaneous varieties of kimberlites, melilitites, and alnöites increasingly carbonatitic. The two latter dike rocks were largely altered into ouachititic types through the decomposition of melilite into garnet, calcite, and clay minerals and the crystallization of a secondary generation of micas. Generally, phlogopite dominates within the dolomitic-ankeritic carbonatites (beforsites) and biotite within the calcitic ones (alvikites).

During the intrusion the chemical exchange between the carbonatitic parts of the magma and the gneiss-granite led to the formation of a fenite-zone which at the present rock surface has a width of several hundred meters. While the magma has deprived the acid rocks of their silica and soda, it has in return enriched them in lime, carbonic acid, and potash. In consequence, the gneiss-granite grades into quartz syenite and syenite, rich in potash, which in turn grades into nepheline syenite-fenite, formed "in situ" and retaining many of the original structural features of the gneiss-granite, enhanced by the replacement of lightly coloured mica by deeply coloured pyroxene. In the case of the dikes only the strongly carbonatitic ones display fenite-zones within the adjoining gneiss-granite and the fenitization generally does not proceed beyond the potash-syenitic stage. Only in the case of a few very large dikes nephelinitization has been observed within the fenite. On the other hand the formation of nepheline (mostly altered into natrolite) within the dikes close to their contacts is quite common.

Between the fractioning centres the syenite- and nepheline syenite-fenite has in increasing amount upwards been mobilized and turned into a magma at a temperature sufficiently high to admit of a regular agpaitic differentiation leading to rocks ranging from ultra-potassic borengite and leucocratic juvites to melteigites, malignites, and ultrabasic jacupirangites. At the time of the last uppermost fractioning of the overlying rocks the carbonatitic magma occupying the upper part of the volcanic conduit, consisted of almost pure calcite with small remains of magnesia and iron in the form of olivine (serpentine), mica, and magnetite as well as a varying amount of apatite. Barium, niob (columbium), thorium, tantalium and uranium are also concentrated in the sövite, although never in large quantities except barium, which occurs as 2—3 meters wide dikes of barite with marginal zones of fluorite and calcite.

Comments to the Excursion Program (Cfr. map Fig. 10)

First Day Excursion

The excursion follows the main road from Sundsvall to the North, then a smaller road to the sea and by ferry across to Alvik and Alnö Island, where the following localities are visited (Fig. 8):

1. The sövite quarry at Smedsgården

Sövite containing biotite and apatite was quarried until a few years ago and sold as a Ca—K—P-fertilizer to the farmers along the coast. The mill, where the rocks were crushed and grounded to powder, is shut down temporarily. The strongly fluorite-impregnated fine-grained fenite-contact is exposed at the N.W. end of the quarry. In the outcrops around the quarry occur sövites containing pyroxenes, biotite, phlogopite, and apatite. From one large nepheline-syenitic fenite fragment within the sövite, still visible in the N.E. wall of the quarry, samples are still obtainable among the tailings to the N.W. of the mill. A pile of impure barite from the contacts of the barite dike at Pottäng also remains at the mill.

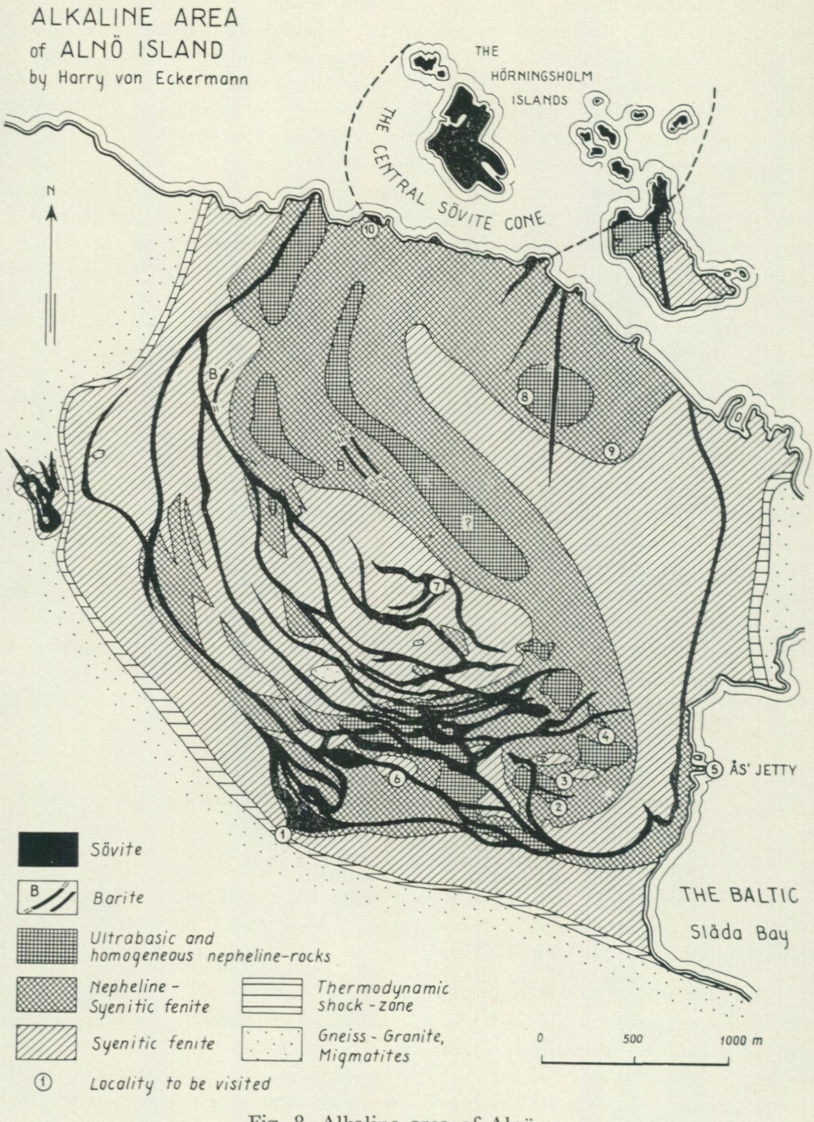


Fig. 8. Alkaline area of Alnö.

För spridning godkänd i Rikets allmänna kartverk den 27 april 1960.

2. Road-cutting East of the quarry

The cutting to the West of the road shows leucocratic and melanocratic nepheline-syenite and melteigite intersected by a sövite dike and illustrates the speedy weathering of the latter.

3. The iron mine at the road West of Ås' Jetty

The mine is located to the West of the road and waterlogged. A heap of tailings remain East of the road and is made up of jacupirangite rich in apatite. The iron ore consists of magnetite concentrations within the jacupirangite, and good samples are found at locality No 5.

4. A quarry West of Ås' Jetty

About 200 meters from the main road and to the North of a smaller road leading down to the Jetty the contact between fenite and mobilized homogeneous melteigite is exposed. Large prismatic aegirine-augites have crystallized perpendicularly to the contact. Between the pyroxenes melanite and titanite crystals are conspicuous.

5. The Ås' Jetty and adjoining sea-shore

In the mole of stone boulders leading out to the demolished jetty samples of almost every rock of the region are found, even of those not exposed anywhere

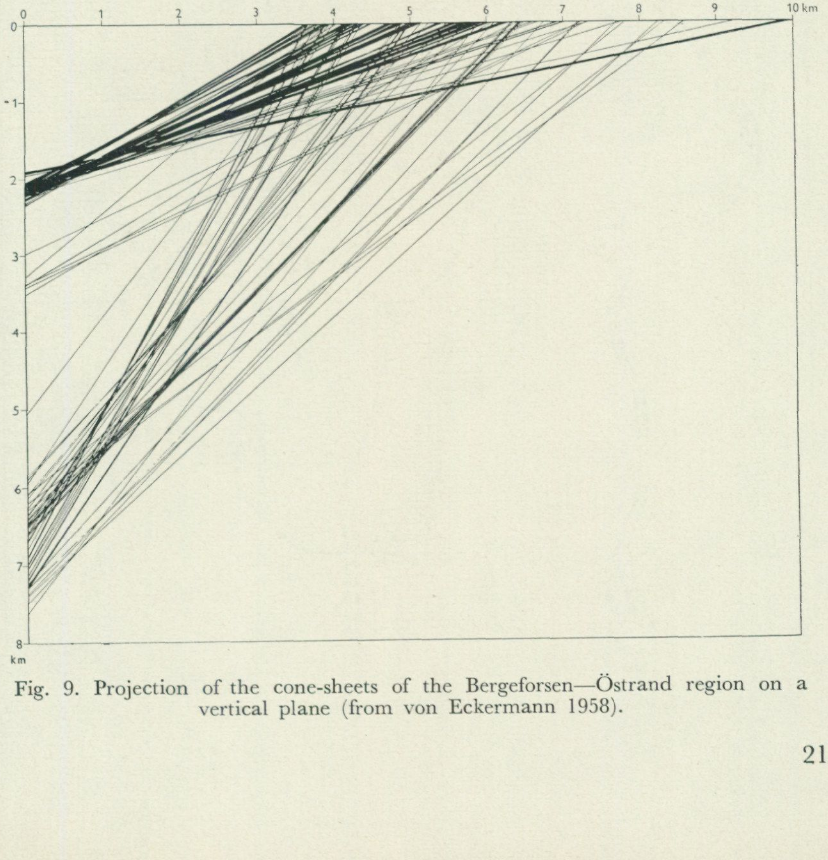


Fig. 9. Projection of the cone-sheets of the Bergeforsen—Östrand region on a vertical plane (from von Eckermann 1958).

to-day, although uncovered by drillholes and now inaccessible diggings during the survey of the alkaline area. A short walk southwards along the sandy shore shows numerous boulders and at the turning-point a small promontory of nepheline-syenitic fenite brecciated by numerous dikes.

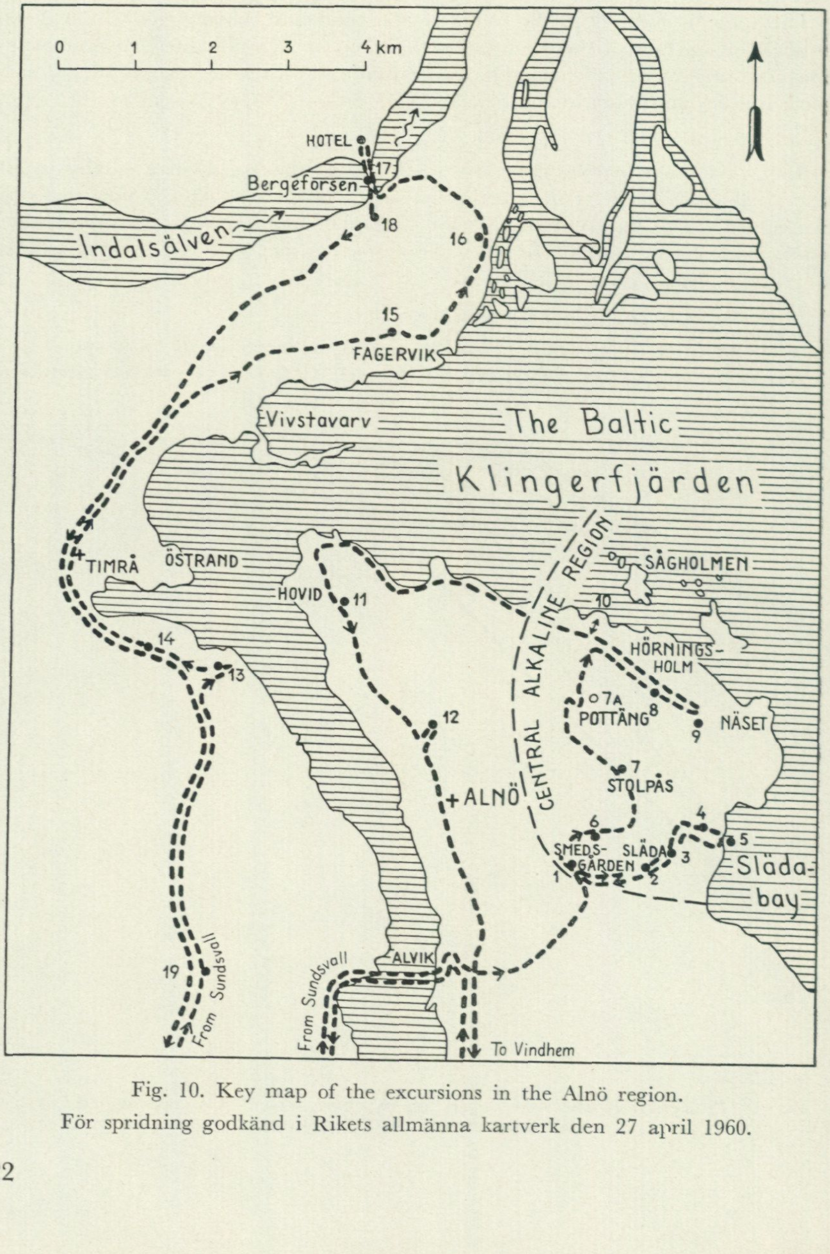


Fig. 10. Key map of the excursions in the Alnö region.
För spridning godkänd i Rikets allmänna kartverk den 27 april 1960.

6. Pyrochlore-bearing sövite dike East of Smedsgården

A half meter wide zone at the centre of the dike contains scattered crystals of pyrochlore, magnetite, and phlogopite. The pyrochlore contains up to 68 % Nb_2O_5, 3 % ThO_2, 1 % Ta_2O_5, and 0.04 % U_2O_5.

7. The sövite-pegmatite at Stolpås

The pegmatite occurs partly as an almost pure sövite, visible at the farmhouse South of the road, and partly containing aegirine-augite, nepheline (natrolite), apatite, and soda-orthoclase. The latter occurrence is exposed to a length of about 1 km with a maximum width of 3 meters in the pasture ground North of the road.

8. The quarry at the school South-East of Hörningsholm

Juvite was quarried here to be used as a flux in smelting processes. The experiment turned out a failure on account of the high potassium content. The juvite, consisting of nepheline and soda-orthoclase, exemplifies a rheomorphic and differentiated product of the fenite. Radiating aegirine-augite crystals at its contact towards the overlying fenite are similar to those of locality No 4.

9. The Alnöite West of Näset

This is the classic locality where the alnöite was first discovered and described as a melilite basalt (Törnebohm 1882).

10. The shore North-West of Hörningsholm

In outcropping rocks along the shore line runs the contact between the central sövite of the volcanic intrusion and the adjoining melanocratic nepheline-syenite fenite. The sövite contains at this level fragments of the gneiss-granite roof, which represent the ultimate stage of fenitization, viz. pyroxenites, the leucocratic components having all been removed.

Looking towards the North-East skerries and islets are composed of sövite with similar fenite fragments, which, however, gradually decrease in number downwards. Drillhole soundings have met pure sövite at a depth of about 60 meters. On the small skerries N.N.E. of locality No 10 the sövite is strongly radioactive due to the presence of pyrochlore minerals.

On a submerged rock-ridge between those skerries and the island to the east of them some large boulders of a volcanic breccia were pushed up by the ice a few winters ago. Rounded boulders of sövite, fairly rich in pyrochlore-perowskite minerals occur within a mafic matrix of more or less dolomitic carbonate, olivine, and magnetite.

11. The alnöite breccia at Hovid

The breccia occurs in a road-cutting and contains angular as well as rounded fragments of country rocks, Jotnian sandstones, rapakivigranite, and dolerite. Conspicuous are the perfectly rounded dolerite boulders, indicating a considerable hiatus and erosion between the intrusion of the Jotnian dolerite and the alnöite.

The alnöite contains spectacular crystals of barkevikitic hornblende and is intersected by a couple of radiating as well as cone-sheet dikes of carbonatitic composition.

12. The potassic dike (borengite) at Båräng

This previously unknown type of dike was uncovered during road-building a few years ago. It is of beautifully trachytoidal texture and is the most potassic rock ever found in Sweden, containing 14.08 % K_2O and only 0.18 % Na_2O. The rock has recently been described under the name of "borengite", an anglicizing of Båräng (Eckermann 1960).

Second Day Excursion

The excursion follows the main road to the North from Sundsvall to Östrand pulp mill, then a smaller road passing the pulp mills of Vivstavarv and Fagervik to Bergeforsen, returning by the main road to Sundsvall.

13. Road-cutting at Sund

Radial and cone-sheet dikes of tinguaitic, ouachititic, and carbonatitic compositions occur in the cutting.

14. Road-cutting South of Östrand pulp mill

Several Alnö dikes intersect the groundrock, which is composed of supracrustal mica schists (= metamorphosed graywackes), pegmatites, and a partly tectonized old amphibolite dike(?). Two chlorite-phlogopite-alvikite cone-sheets occur in the northern rock-wall. A radial carbonatite dike is cut by the lower one. A big vertical radial dike runs right across both sides of the cutting and is on the northern side split in two, containing lots of groundrock fragments.

15. Outcrop immediately North of the Fagervik pulp mill

Carbonatitic dikes on a low flat rock-surface indicate the dip of cone-sheets towards the volcanic centre north of Alnö Island and display distinct fenitization phenomena at the contacts.

16. Quarries North-East of the pulp mill

A steep rock-wall illustrates the mode of occurrence of intersecting cone-sheets. As, however, the quarries are worked, the section through the dikes changes daily and a description of then observable dikes will be given at the excursion.

17. The hydraulic power station at Bergeforsen

Two Alnö carbonatite dikes at the entrance to the power station illustrate their mode of weathering. The marginal parts are the first to desintegrate due to the free CO_2-content in the most quickly congealed parts of the dikes. If subject to percolating water some of the dikes may alter into clay within a few months. In order to delay the decomposition until the leakage has been stopped by cement injection, saturated lime-water is constantly forced into the groundrock below the power station and adjoining dams, thereby increasing the Ca-ion concentration and counteracting the formation of soluble lime-bicarbonate.

In the boardroom of the power station a transparent plastic model of the rockground shows the emplacement of the Alnö dikes, and a small collection of rock-samples demonstrate the types of dikes encountered during the blasting of the underground part of the power station and the 8 km of tunnels.

To the power station is attached the largest salmon-culture establishment in Sweden.

18. Road junction immediately South of the power station

The outcrops on both sides of the road contain a great variety of dikes. A beforsitic radial dike is rather radioactive, due to pyrochlore minerals. This dike intersects an older Jotnian porphyritic dike. The Western side of the cutting gives an illustration of the fenitizing power of a rather thin carbonatite dike, originally very rich in CO_2.

19. Quarry at Råsta, North of Sundsvall

Across the quarry runs a vertical foyaite-porphyrite dike surrounded by bright-red fenite borders, drenched with fluorite at the contacts. The marginal parts of the dike are brownish while the centre is darkish green on account of increased aegirine-augite-content. At the bottom of the quarry occurs a radial vertical ankeritic carbonatite-dike.

The Varuträsk pegmatite

By

PERCY QUENSEL

The Varuträsk pegmatite is situated 22 km S.E. of the Boliden mine and 15 km from Skellefteå town on the Baltic coast. It is assumed to be genetically connected with the so called Skellefte granite, representing a fine-grained variety of the more widespread Revsund granite.

The pegmatite forms a trough-like to tabular body, striking N.N.E.—S.S.W. In the eastern wing the dip is about 30° W.N.W., whereas the western wing lies all but horizontal. The exposed outcrop is about 350 m in length. The thickness varies from some few meters up to 30 meters, bounded both above and below by an amphibolitic rock (cp. Fig. 11).

The parts of the pegmatite, containing lithium-bearing minerals, are separated in two lenses, intersected by a part, devoid of these minerals. The two lenses lie about 50 m apart.

Four stages in the mineralogical development of the pegmatite can be distinguished. The first, named *the pegmatitic stage,* is taken to represent the original zonal structure of the pegmatite body, formed by fractional crystallisation from the walls inwards. This is assumed to have taken place in a closed system under epimagmatic conditions, *i.e.* above 600°.

The second stage, named *the pneumatogenic stage,* is taken to include all replacement units, succeeding the pegmatitic stage. Subsequent alterations, due to activity of thermal water of hypogene origin, are attributed to a third *hydatogenic stage*. A final development, due to the activity of percolating ground water or to superficial weathering, can be included as *a stage of supergene alterations.*

In the following, the principle minerals, representative for each of these stages will be given.

The pegmatitic stage can be divided into four divisions, the border zone, the wall zone, the intermediate zones and the core, denoting the sequence of fractional consolidation.

The mineral assemblage of the *border zone* is simple and uniform. The only minerals of primary origin are a fine-grained assemblage of quartz and muscovite. This zone seldom attains more than some 10 cm in thickness, often it is less than a few cm thick.

The *wall zone* may vary from some 5 dm to several meters in thickness. In one sense one may say that the border zone and the wall zone co-ordinate, inasmuch as the bulk mineral composition is the same, though the minerals of the wall zone are developed in large individuals. Muscovite can now occur in large silvery white books, up to one dm in width. Additional minerals of this zone are black tourmaline and beryl, the former a characteristic mineral of this stage and principally restricted thereto. Beryl crystals up to several dm in length have been found. Löllingite is found in some amount in one locality within the wall zone (between H2 and K in the centre of the map).

The *intermediate zones* include the zonal development of the pegmatite between the wall zone and the core. At Varuträsk, as is the case in most other complex pegmatites, it forms the greater mass of the pegmatite. A sub-division into two phases can be made, denoted as an outer and an inner intermediate zone. The difference is that the outer zone has a simpler mineral composition than the inner zone.

The difference between the mineral assemblage of the wall zone and the outer intermediate zone is that microcline perthite now enters as the dominant mineral, developed in crystals or anhedral masses of great size. A single crystal measured 3 m in length and was then only partly exposed.

In the inner intermediate zone the mineral assemblage is the same as in the outer zone with the addition of some pronounced lithium-bearing minerals, evidently due to a content of lithium in residual solutions of the pegmatitic stage. The essential minerals in this respect are spodumene and amblygonite (montebrasite), both present in large amounts.

Attention may be called to the considerable amount of rubidium in the microcline perthite. The medium of nine analyses from the eastern wing of the pegmatite gave 1.55 % Rb_2O (maximum 3.3 %). In other respects the outer and inner intermediate zones show no further dissimilarities and grade imperceptibly into each other.

As recorded from many other zonal pegmatites the *core* of the Varuträsk pegmatite is not centrally located but displaced towards the southern foot wall of the eastern wing, where it occupies a lens-formed body, about 50 m in length and 15 m in breadth. The core is almost exclusively composed of pure milky quartz. Though surrounded by mineral assemblages of later replacement units and locally intersected by minerals of the same, the core on the whole shows but insignificant signs of replacement by invading solutions of succeeding phases of mineralisation.

The pneumatogenic stage is used to denote the phases of replacement which followed the zonal consolidation of the pegmatite. Whereas the temperature prevailing during that stage was taken to have exceeded the 600° limit, the replacement units of the pneumatogenic stage are postulated to have taken

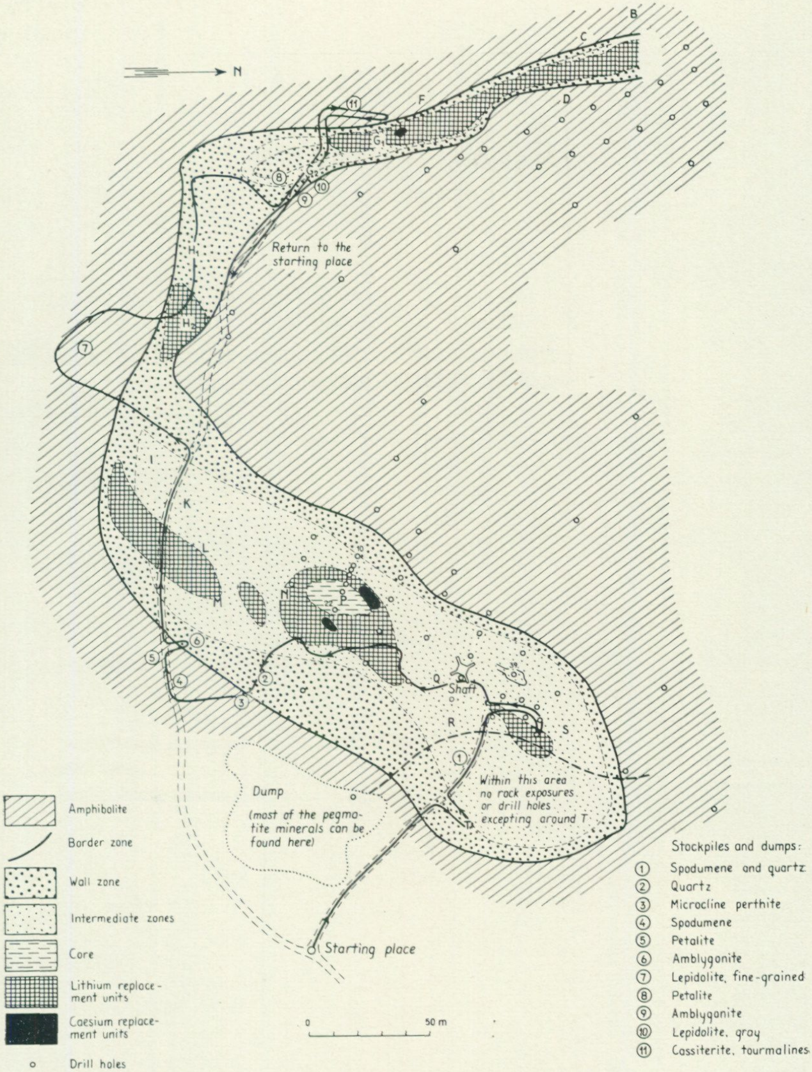


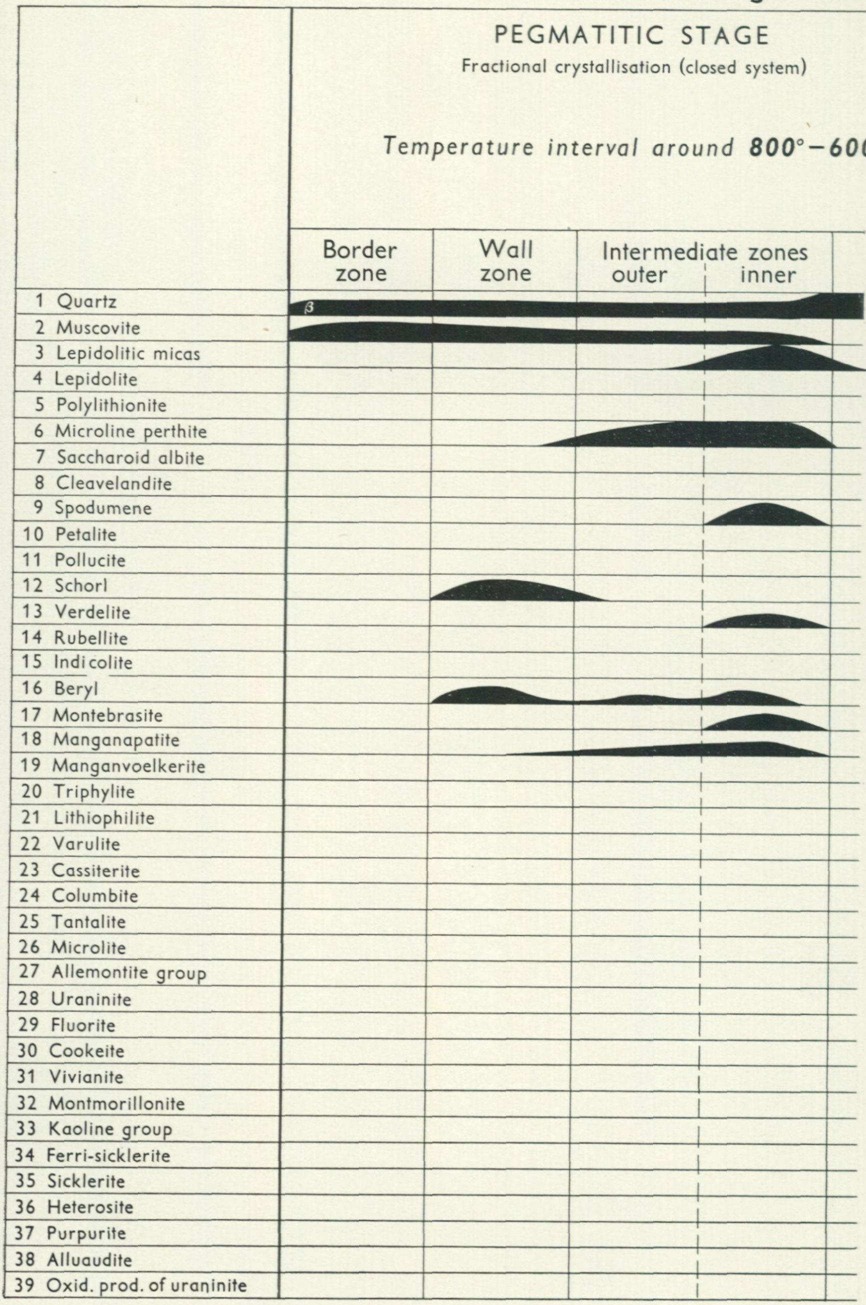
Fig. 11. Geological map of the Varuträsk pegmatite.

För spridning godkänd i Rikets allmänna kartverk den 27 april 1960.

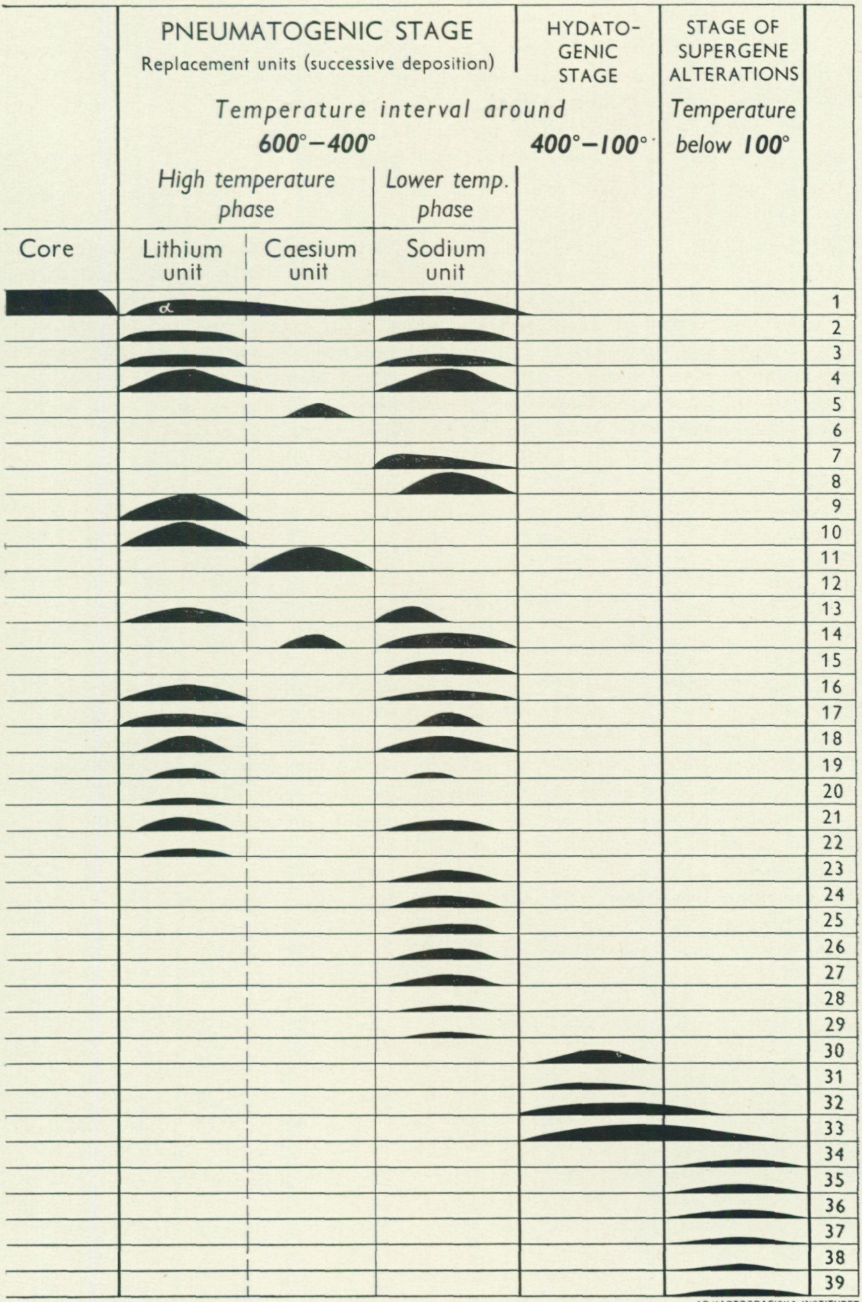
place between this limit and the critical temperatures of the co-operating solutions, *i.e.* between approximately 600° and 400°. This stage has been divided into a higher and a lower temperature phase, each characterized by its own mineral assemblages.

Table I

THE VARUTRÄSK
Paragenesis of



PEGMATITE
the minerals



AB KARTOGRAFISKA INSTITUTET

The higher temperature phase has again been sub-divided into two stages, the lithium replacement unit and the caesium replacement unit, each characterized by specific mineral assemblages.

The lithium replacement unit is taken to represent the first epoch of renewed mineralisation after the final consolidation of the pegmatitic stage. The name is, however, only meant to indicate that the main concentration of lithium occurs within this unit, verified by the abundant occurrence of lepidolite, petalite, and a second generation of spodumene.

The greatest concentration of lepidolite is found in the form of a mauve-coloured fine-grained massive rock in the western wing together with some manganapatite (quarry H_2 on the map). Inclusions of pure white beryl with a vitreous lustre and granular texture, very different from the beryl of the pegmatitic stage, can there be found. The lepidolitic rock is in parts speckled with small grains of cassiterite and invaded by cleavelandite, pertaining to replacements of the lower temperature phase of this stage.

Together with lepidolite, petalite is the most abundant mineral of this unit. Though in general of rare occurrence in other lithium pegmatites, it is present in great quantities at Varuträsk.

The third lithium silicate mineral of quantitative importance in this unit is a second generation of spodumene. When now recurring in this unit, it is developed in an obviously different habit. Instead of the tabular masses of the pegmatitic stage, the mineral now occurs in the form of compact slender laths, which when uncontaminated, are semi-translucent. It is not unusual that the spodumene of this unit is highly altered to a mixture of clay minerals (rotten spodumene) which is never found to be the case with the earlier generation of the mineral in the pegmatitic stage.

Other minerals of this unit only occur in small quantities. They consist of a second generation of montebrasite, manganapatite, and of green tourmaline. A new type of beryl now is found in the form of small vitreous crystals.

The great masses of pollucite in the Varuträsk pegmatite seem to call for a separate replacement unit within the high temperature phase of the pneumatogenic stage. It seems hardly plausible that solutions of the same phase in some parts of the pegmatite have carried lithium as the main alkali component and close by have deposited great amounts of caesium in the form of the mineral pollucite. The localized distribution of the largest deposit along the core margin likewise seems indicative of new replacement channels. The quartz core has, however, not succumbed to any replacement by the invading solutions of this unit.

The lower temperature phase of the pneumatogenic stage expressively indicates that a further break in the mineralisation of the pegmatite now occurred. The solutions of this unit are universally found to traverse and replace all earlier mineral assemblages. Furthermore the mineralisation of this unit includes many minerals not before represented in the previous zones or units. With regard to the content of alkalies, sodium now enters as the principle component. As a result thereof the dominant mineral of this unit is an almost pure albite, predominantly in the form of cleavelandite, generally developed in spheroidal bursts or large radiating sheaves. In other parts, principally restricted to the peripherical parts of the pegmatite, the mineral can occur in the form of a fine-grained s a c c h a r o i d a l b i t e.

Next in importance of the minerals of this unit are several different modifications of mica minerals. Remarkable are the large purple crystals of lepidolite, up to 2 cm in breadth, principally to be found around a small prospecting pit in the eastern wing (T on the map). Other modifications are a delicately rose-coloured to nearly colourless lepidolite, forming concentric bundles as well as a medium-grained gray lepidolite, found as veins and in accumulated masses. Muscovite recurs, now in the form of a fine-grained rose-coloured species as well as in a cryptocrystalline form (oncosin), often traversing larger masses of pollucite.

The red and blue tourmalines (r u b e l l i t e and i n d i c o l i t e) are characteristic minerals of this unit. Rubellite is often found in zonal development with the green tourmaline (verdelite). In that case the red type forms the core with an outer green shell. The red core is often completely altered to cookeite or replaced by albite.

Manganapatite recurs in this unit in the same aspect as in previous phases. The rare mineral *manganoan voelckerite* seems, however, to be restricted to this unit, connected with the gray lepidolite. It can easily be distinguished from manganapatite on account of that, on exposed surfaces, it is always found to occupy well-defined cavities, in contrast to manganapatite yielding to weathering.

The Li—Fe and Li—Mn phosphates are represented by the minerals *triphylite* and *lithiophilite*. They are, however, not found coordinated in the field. The natural cause is that triphylite is restricted to such occurrences where iron-containing solutions have circulated, whereas lithiophilite is found in connection with manganese concentrations in the replacement units.

Triphylite has been rarely encountered in replacements within the wall zone. The usual occurrence of lithiophilite has on the other hand only been found in a small prospecting excavation (G_1 on the map) together with cleavelandite and its mineral assemblage. It is, however, there mostly altered to sicklerite → purpurite.

It has now been proved that the new mineral v a r u l i t e itself is an alteration product of lithiophilite in replacements within the wall zone.

In the same small excavation, where lithiophilite was first found (G_1 on the map), many other minerals occur. A third generation of beryl as well as c a s s i t e r i t e are there relatively abundant. The only occurrence of u r a n i n i t e is this locality. It mostly occurs in minute, generally oxidized crystals. Only one larger specimen has been found.

The rare minerals a l l e m o n t i t e and s t i b i o t a n t a l i t e also belong to this unit, only found in an excavation near G_1. Several large specimens of both these minerals have been disclosed there.

C o l u m b i t e and t a n t a l i t e also belong to this unit. Columbite is not uncommon, though generally only found between cleavage planes of cleavelandite. Tantalite was seldom found during earlier stages of mining operations. Later large quantities of the mineral came to light in underground workings around the shaft in the eastern wing of the pegmatite, together with some few specimens of m i c r o l i t e.

F l u o r i t e has only been found in two small vugs. As vugs are in the pegmatite all but absent this may explain the scarcity of fluorite. The want of fluorine in such minerals as montebrasite, voelckerite, and hydroxyl-apatite indicates that at no time during the deposition of the minerals of the pegmatite was there any excess of fluorine present.

The hydatogenic stage is taken to represent all processes, which may be ascribed to the influence of ascending hydrothermal water percolating throughout the consolidated mineral assemblages of the previous stages. During this stage the juvenile water seems not to have introduced new material of any importance. The residual fluids of the preceding stages have apparently concluded the transfer of soluble matter.

The most pronounced feature of the minerals pertaining to this stage is their high content of hydroxyl radicals.

A characteristic mineral of this stage is m o n t m o r i l l o n i t e, mostly found as an alteration product of petalite. The decomposition of the younger generation of spodumene to k a o l i n i t e and to other kaolin minerals is also to be referred to this stage. Pollucite has in underground working also been found to have succumbed to an intense alteration to a soft white clay substance.

The alteration of the red core of the zonal tourmaline to c o o k e i t e should also be attributed to the thermal activity of this stage as well as to the formation of cookeite in independent depositions. The lower temperature prevailing during this stage would favour the formation of cookeite rather than the less hydrous micas.

The rare mineral m a n g a n - h y d r o x y l a p a t i t e, assumed to be a decomposition product of varulite, contains 2.56 % H_2O+ against about 1 % in the host mineral varulite. This would represent a typical example of hydration during the hydatogenic stage.

The stage of supergene decomposition represents an oxidation of selective minerals due to superficial weathering or to the action of phreatic water.

A good example of such processes is the successive oxidation of triphylite, lithiophilite, and varulite. In a first phase the bivalent iron ions in these minerals become trivalent, whereas the manganese ions remain bivalent, resulting in the formation of the minerals f e r r i a n s i c k l e r i t e — m a n g a n o a n s i c k l e r i t e, and m a n g a n o a n a l l u a u d i t e. Ultimately both the iron and the manganese ions become trivalent, forming the fully oxidized minerals h e t e r o s i t e and p u r p u r i t e.

A r s e n o s t i b i t e (arsenian stibionite), an oxidation product of the alloy allemontite, must also be considered as an alteration product of this stage.

There hardly remain any further alteration products, than a frequent incrustation of manganese oxides on minerals containing manganese in their composition or on adjacent minerals. It must, however, be taken into consideration, that glacial erosion may have removed many products of weathering on exposed outcrops, which otherwise might have increased the mineral assemblage of this stage.

Attempts have been made to determine the age of the Varuträsk pegmatite. A determination of the lead isotopes in a specimen of uraninite has given an approximate age of 1.70×10^9. A determination with the Rb/Sr method gave an age of 1.74×10^9. The two determinations tally well within the limits of experimental error. On the other hand a determination on lepidolite with the K/Ar method gave an age of 2.06×10^9 and on the same material with the Rb/Sr method likewise 2.06×10^9. This is a singularly good correspondence, but of some reason probably giving a co-equal too high age.

The approximate age of the pegmatite is taken to be around 1.80×10^9 years, which would correspond with approximate ages, found in equivalent formations in middle Sweden.

In Table I the paragenetic association of the minerals is recapitulated. In Table II a list of the minerals is given in order after Strunz' tables (with the exception of alteration products, placed after their host mineral). Names in spaced types indicate those minerals which can be readily found.

Table II. List of described minerals from the Varuträsk pegmatite, in numerical order after Strunz' tables (with the exception of alteration products, here given after host mineral).

Elements: allemontite, stibarsen (alteration product: arsenostibite).

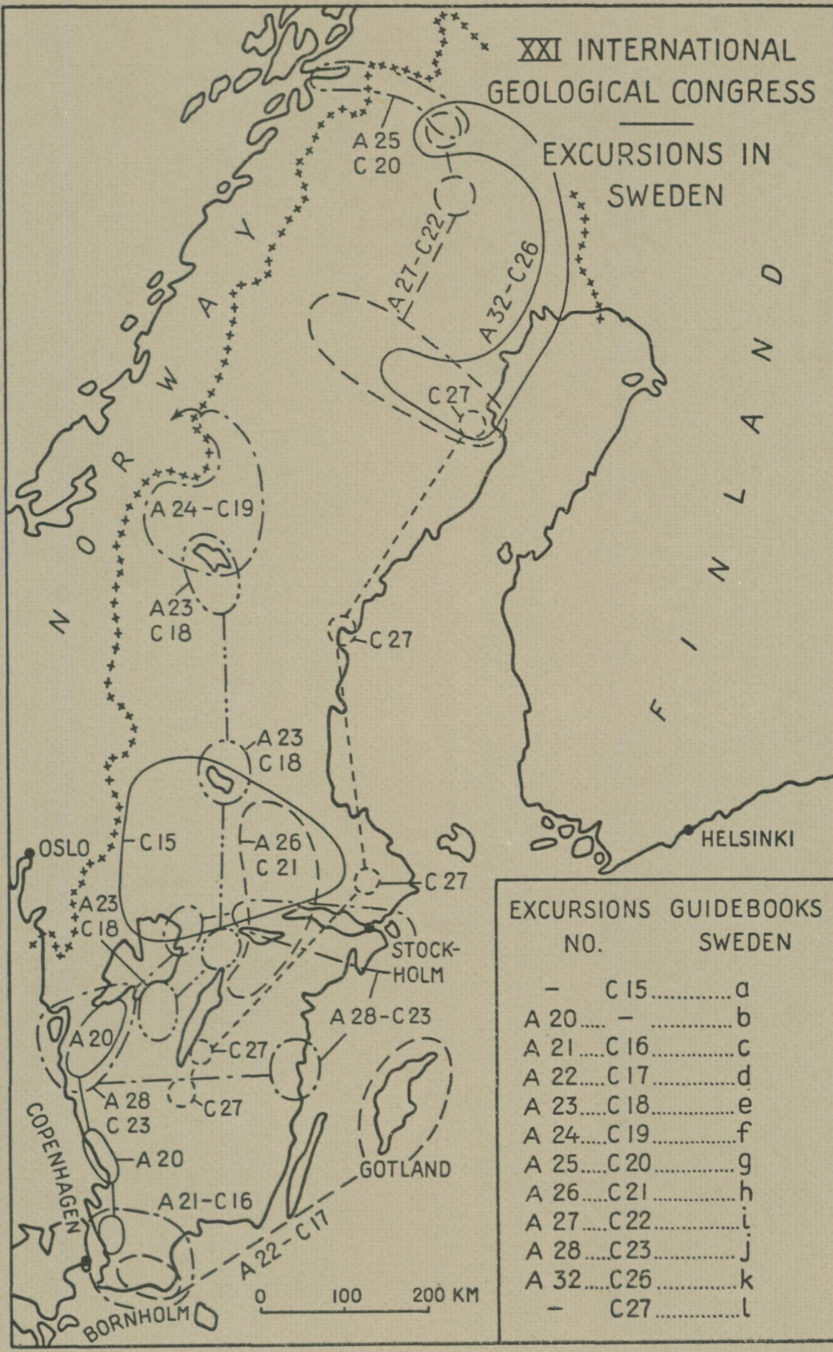
Sulphides: löllingite.

Halides: fluorite.

Oxides: quartz, cassiterite, columbite, tantalite, stibiotantalite, microlite, uraninite.

Phosphates: triphylite (alteration products: ferrisicklerite, heterosite), lithiophilite (alteration products: manganosicklerite, purpurite), varulite (alteration products: alluaudite, purpurite), triplite, amblygonite (var. montebrasite), manganapatite, mangan-hydroxylapatite, mangan-voelckerite, vivianite.

Silicates: beryl, tourmaline (green, blue, and red; alteration product in red kernel of zonal tourmaline: cookeite), spodumene (alteration product: kaolin minerals), muscovite (white and red), lepidolite (pink-gray, and white), cookeite, petalite (alteration product: montmorillonite), pollucite, albite (cleavelandite and saccharoid), microcline perthite.



XXI INTERNATIONAL
GEOLOGICAL CONGRESS
EXCURSIONS IN
SWEDEN
NORWAY
FINLAND
A 25
C 20
A 27-C 22
A 32-C 26
C 27
A 24-C 19
A 23
C 18
C 27
A 23
C 18
C 15
A 26
C 21
C 27
OSLO
A 23
C 18
STOCK-
HOLM
HELSINKI
A 28-C 23
A 20
C 27
C 27
A 28
C 23
COPENHAGEN
A 20
GOTLAND
A 21-C 16
A 22-C 17
BORNHOLM
0 100 200 KM
EXCURSIONS NO. GUIDEBOOKS SWEDEN
– C 15 .... a
A 20 ..... – .... b
A 21 ..... C 16 c
A 22 ..... C 17 .... d
A 23 ..... C 18 .... e
A 24 ..... C 19 .... f
A 25 ..... C 20 .... g
A 26 ..... C 21 .... h
A 27 ..... C 22 i
A 28 ..... C 23 .... j
A 32 ..... C 26 .... k
– C 27 l

SWEDEN

Guide-book I

Key map, see inside of this cover

Price 4 Sw. crowns