

SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 768

AVHANDLINGAR OCH UPPSATSER

ÅRSBOK 73 NR 9

THOMAS LUNDQVIST

THE PRECAMBRIAN OF SWEDEN



UPPSALA 1979

SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 768

AVHANDLINGAR OCH UPPSATSER

ÅRSBOK 73 NR 9

THOMAS LUNDQVIST

THE PRECAMBRIAN OF SWEDEN

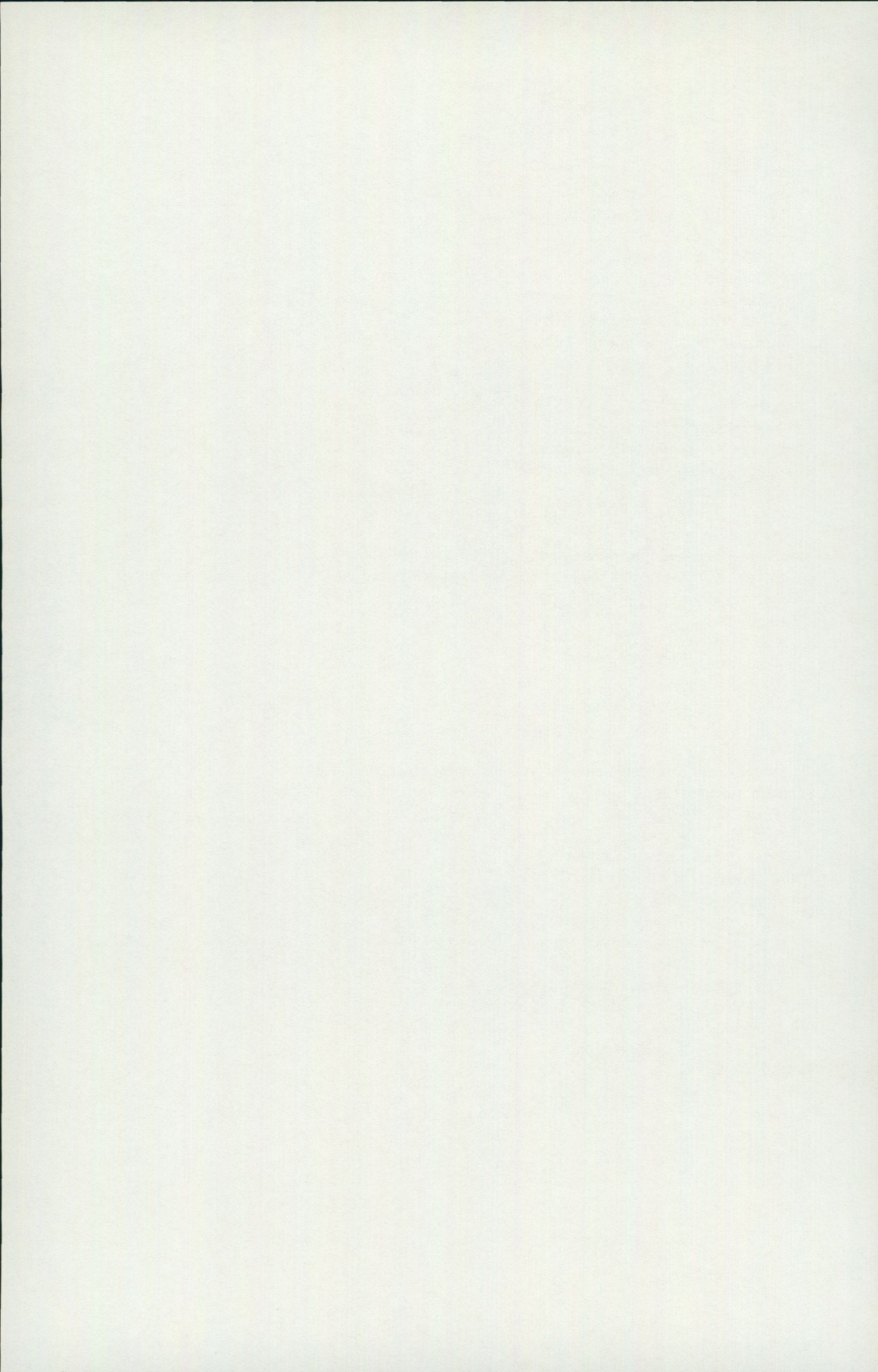
UPPSALA 1979

ISBN 91-7158-185-5

C. DAVIDSONS BOKTRYCKERI AB, VÄXJÖ 1979

CONTENTS

Preface	5
Introduction	5
The Precambrian of south-western Sweden	8
General features	8
The SW-Swedish gneisses	10
The Mylonite zone	11
Charnockite	12
Hyperite, hyperite dolerite and syenite	12
Stora Le-Marstrand formation	13
Åmål complex	14
Dalsland group	16
Bohus granite	17
Younger dolerites	17
Chronology of south-western Sweden	17
Region of Småland-Värmland intrusions	17
General features	17
Småland porphyries	18
Svecokarelian complexes	19
Småland-Värmland intrusions and younger rapakivi massifs	20
Shear zones at the western border of the Småland-Värmland intrusions	21
Almesåkra group	22
Visingsö group	22
Blekinge region	23
General features	23
Older granitoids	23
Västana formation and coastal gneiss	23
Karlshamn-Spinkamåla and Vånga granites	24
Dolerite dikes	24
The Svecokarelian orogenic belt with post- and anorogenic complexes	25
General features	25
Götaland and Svealand	27
Orogenic complex	27
Post- and anorogenic complexes	32
Norrland south of Västerbotten County	34
Orogenic complex	34
Post- and anorogenic complexes	36
Västerbotten County and southernmost Norrbotten County	38
Orogenic complex	38
Post- and anorogenic complexes	42
Norrbotten County	43
Orogenic complex	43
Post- and anorogenic complexes	46
Chronology	51
Alkaline complexes	51
Plate-tectonic aspects on the Swedish Precambrian	53
Acknowledgements	57
References	58
Figs. 5-39	67



PREFACE

The present survey comprises the Swedish Precambrian except for occurrences within the Caledonides. It is mainly based on the following works and appended maps: Magnusson et al. (1960 and 1963), Geijer (1963a) and Lundegårdh et al. (1974 and 1978). However, several papers have been published, which have changed or amplified views given in these publications.

The history of the Swedish Precambrian is still imperfectly known, our present knowledge in part being founded on observations from the 19th century. This is especially true for the south-western and southern parts of the country. New field work combined with radiometric dating will probably above all in these regions lead to a revision of earlier interpretations.

INTRODUCTION

In the 1930's a subdivision of the Precambrian of Sweden and Finland was established, which was founded on the concept of orogenic cycles. Three such cycles were thought to have existed: in chronological order the Svecofennian (or Svionian), the Gothian, and the Karelian (Wahl 1936). Each cycle comprised supracrustal rocks, which had been folded, metamorphosed and intruded in different phases by plutonic rocks. The term indicates that the processes were cyclically repeated. The rocks ascribed to the Svecofennian cycle occur in the eastern parts of south-central Sweden, and in the major parts of central and northern Sweden. The Precambrian of the southern and south-western parts of the country were referred to the Gothian cycle, whereas rocks of the Karelian cycle were limited to the eastern parts of northernmost Sweden. The Dalsland group (Dal formation) in south-western Sweden was correlated with the Karelian supracrustal rocks.

Later the SW-Swedish gneisses were detached from the Gothian cycle. These gneisses appeared to form the basement of the supracrustal rocks in the Gillberga synform (see p. 14), which were correlated with the Gothian supracrustals in south-eastern Sweden (Magnusson 1929; Magnusson et al. 1960). For this reason the SW-Swedish gneisses were termed Pregothian (Lundegårdh 1957a; Magnusson et al. 1960, 1963).

The Dalsland group and younger granites were subsequently referred to a separate cycle, the Dalslandian (Magnusson et al. 1957).

During the latest decades radiometric dating has created new possibilities for establishing a chronological subdivision of the Precambrian. Thus, it has been shown that there is no essential difference in age between the Svecofennian and Karelian

cycles. Accordingly, the term Svecokarelian has been recommended to replace the concepts Svecofennian and Karelian cycle or orogeny (Rankama and Welin 1972). Differences in lithology, deformation etc. between the latter two can be related to depositional environment (facies) of the supracrustal rocks. Karelian metasediments and metavolcanics are thus of epicontinental character (quartzites, conglomerates, etc.). In contrast, the major part of the Svecofennian supracrustals appears to be unrelated to a nearby continent, and acid metavolcanics, metagreywackes and meta-argillites are quantitatively important. The terms Svecofennian and Karelian can therefore be maintained to denote, in a general sense, this difference in supracrustal lithology (Rankama and Welin *op.cit.*).

Radiometric age determinations show that the Småland-Värmland intrusions and related rocks were formed closely after the end of the Svecokarelian orogeny, and thus probably do not belong to a separate Gothian orogeny (Welin *et al.* 1966; Lundqvist 1968). It has therefore been proposed that the term "Gothian" should be used in a purely chronological sense, for rocks formed in the interval 1 750–c. 1 400 Ma (Lundegårdh 1967), 1 750–1 150 Ma (Lundegårdh 1971), or 1 750–1 200 Ma (Zachrisson *et al.* in press). As the term is controversial, it has not been used below.

Modern views on the evolution of the Svecokarelian orogenic belt are roughly in accordance with the earlier cycle concept. Field evidence combined with radiometric dating has thus established the following sequence of events, which is in agreement with the scheme given by Welin (1970) for northern Sweden. In Proterozoic time, somewhat more than 2 000 Ma ago, various volcanic and sedimentary rocks were deposited on the pre-Svecokarelian crust. During an early phase of the Svecokarelian evolution magmas intruded, which gave rise to the primorogenic (early-orogenic, synorogenic or synkinematic) plutonics. These were subsequently deformed and metamorphosed together with the supracrustal rocks in the main, serorogenic phase of orogeny. The latter was characterized by intense folding, large-scale migmatization and generation of anatexic magmas. It came to an end at c. 1 750–1 800 Ma, although in northernmost Sweden more local migmatization and folding seem to have occurred later (p. 46). The anatexic magmas crystallized to the serorogenic (late-orogenic, late-kinematic) granites, accompanied by abundant pegmatites. Magmas, in part anatexic, subsequently reached the earth's surface and initiated extensive volcanicity, while weathering and erosion were active, giving rise to sedimentary formations. Radiometric dating shows that granite-forming processes continued until at least c. 1 300 Ma ago. Mainly unfolded rocks postdating the serorogenic granites but genetically linked with the Svecokarelian orogeny are called post-orogenic in this work, whereas the term anorogenic denotes a more independent origin. It is also possible that above all the younger post- and anorogenic igneous rocks of the Svecokarelian fold belt are genetically linked with orogenic processes in south-western Sweden (*cf.* Hjelmqvist 1973; see also p. 53).

The Precambrian history of south-western Sweden is not yet fully elucidated, but is definitely more complex than that of the Svecokarelian fold belt. A unifying feature is

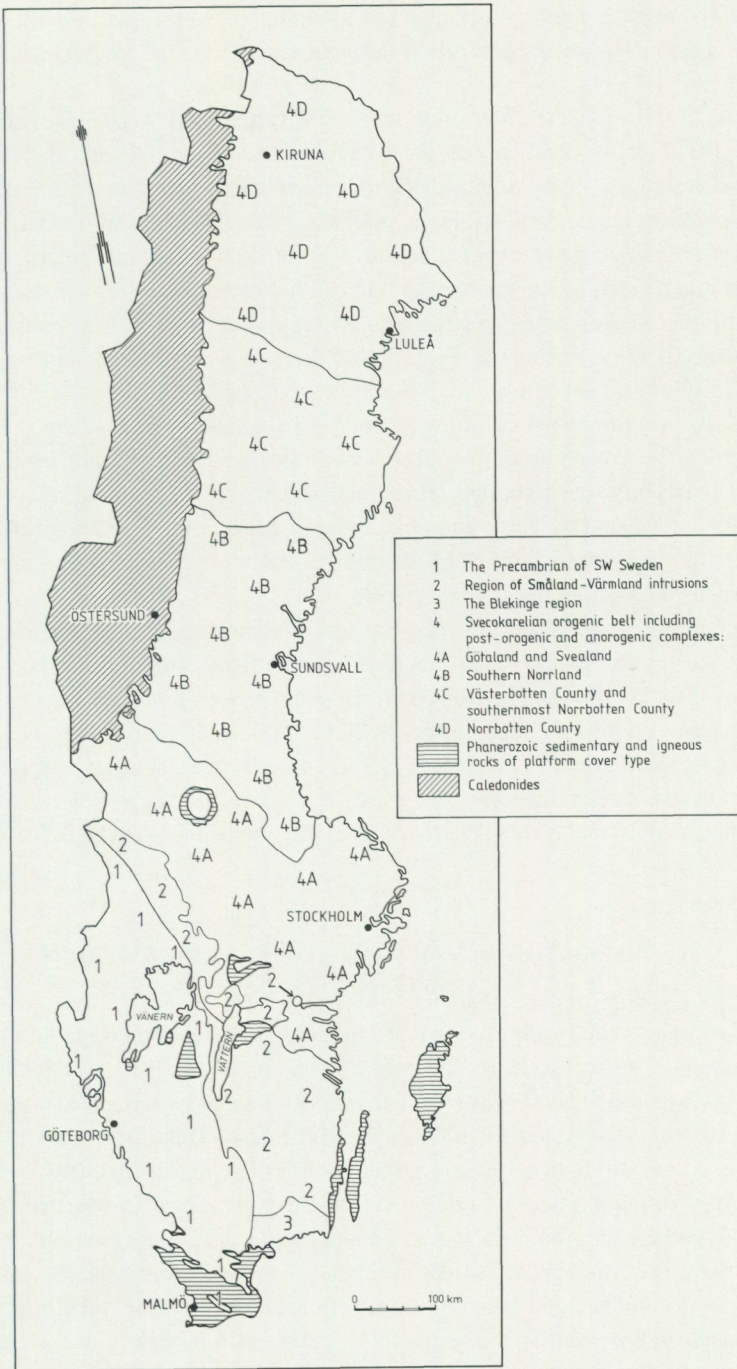


Fig. 1. The subdivision of the Swedish Precambrian adopted in the present work.

that K-Ar radiometric ages persistently fall around 1 000 Ma, due to what has been called the Sveconorwegian regeneration (Magnusson 1960a, 1970a; Magnusson et al. 1963).

At present two major tectonic units can be distinguished in the Precambrian of Sweden. The first of these is the Svecokarelian orogenic belt and its post- and anorogenic complexes. The Småland-Värmland intrusions and related volcanics can also be included here. A possible complication is northernmost Sweden, where post-Svecokarelian orogenic events may have occurred (see p. 47). The second major tectonic unit is formed by the gneisses etc. in south-western Sweden, which have been affected by the Sveconorwegian regeneration. A minor area of Precambrian rocks which are not readily attributable to either of the two main tectonic units occurs in Blekinge in southern Sweden.

For descriptive purposes the following fourfold subdivision is made in the present work (Fig. 1): the Precambrian of south-western Sweden, the region of the Småland-Värmland intrusions, the Blekinge region and the Svecokarelian orogenic belt. The latter is subdivided into orogenic and post- to anorogenic complexes, respectively.

Lithostratigraphic terms have been introduced for supracrustal sequences, if such terms were not adopted in the original papers.

Radiometric ages are given with the presently recommended decay constants according to Steiger and Jäger (1977). Recalculation by these constants has been carried out by Prof. Eric Welin, Stockholm, and the result has been kindly put at the author's disposal. A list of the new age figures will be published by Welin in *Geologiska Föreningens i Stockholm Förhandlingar* (GFF). Due to lack of analytical data some age figures have not been recalculated. In such cases the original age is given in italics.

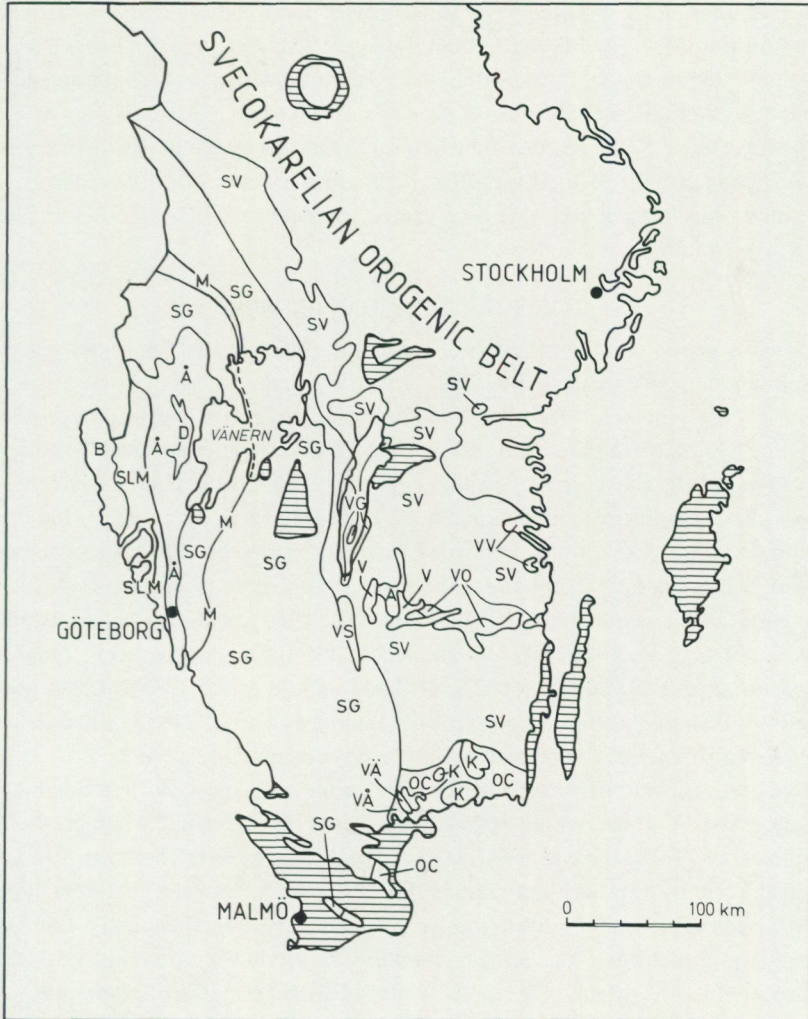
For technical reasons Figs. 5–39 are found at the end of the text (pp. 67–87).

THE PRECAMBRIAN OF SOUTH-WESTERN SWEDEN

GENERAL FEATURES

In south-western Sweden strongly foliated granitoid gneisses of plutonic origin generally predominate greatly over recognizable supracrustal gneisses. All these rocks, which by Lundegårdh et al. (1978) were termed gneiss-granites and gneisses, are in the present work collectively termed SW-Swedish gneisses. There are, however, some complexes, which differ from these gneisses in lithology and in intensity or style of deformation. Most important are the Åmål complex, the Stora Le-Marstrand formation, the Mylonite zone, the Dalsland group and the Bohus granite (see Fig. 2).

In south-western Sweden, especially in the SW-Swedish gneiss complex, deformation is generally intense and foliation and compositional banding very pronounced. Planar structures and fold axes usually show gentle or moderate dips. Amphibolite facies is the predominant metamorphic grade, and both intermediate and low pressure facies series are represented (Lundqvist 1978).




- | | | | |
|-----|--|---|--|
| A | Almesåkra group | V | Vetlanda supergroup |
| B | Bohus granite | VG | Visingsö group |
| D | Dalsland group | VO | Gneissose granites Vetlanda - Oskarshamn |
| K | Karlshamn - Spinkamåla granites | VS | Vaggeryd syenite |
| M | Mylonite zone | VV | Västervik formation |
| OC | Older granitoids and coastal gneiss | VÄ | Vånga granite |
| SLM | Stora Le - Marstrand formation | VÄ | Västana formation |
| SG | SW - Swedish gneisses | Å | Åmål complex |
| SV | Småland-Värmland intrusions and Småland porphyries |  | Phanerozoic sedimentary and igneous rocks of platform cover type |

Fig. 2. Index map showing important lithologic and tectonic units in south-western Sweden, the Blekinge region and the region of Småland-Värmland intrusions. Cf. Fig. 1.

The Precambrian of south-western Sweden was, as already mentioned, affected by regional heating c. 1 000 Ma ago (Grenville age). This heating, the Sveconorwegian regeneration (Magnusson et al. 1963), was approximately contemporaneous with tectonic deformation of the Dalsland group, i.e. with the Dalslandian orogeny (see Magnusson et al. 1957). The end of the latter was marked by the intrusion of the Bohus granite. The main part of the crystalline bedrock of south-western Sweden is, however, much older than 1 000 Ma, as revealed by recent isotopic age determinations (see below).

THE SW-SWEDISH GNEISSES

An extensive gneiss complex, the SW-Swedish gneisses, forms the major part of the Precambrian in south-western Sweden. An older term, referring to the magnetite content, is "iron gneisses" (*järngnejser*). According to earlier views on age relationships with "Gothian" supracrustal and plutonic rocks the gneisses have been denoted "Pregothian" (cf. above, p. 5). They have also tentatively been considered pre-Svecokarelian (or pre-Svecofenno-karelian; Zachrisson et al. in press). This opinion was founded on observations indicating that the gneisses dip gently below the Svecokarelian rocks near Töreboda, in the only area where the two complexes meet (Magnusson 1965; see map of Magnusson et al. 1960). The age relationship can, however, not be unambiguously determined in the field. Furthermore, radiometric dating contradicts the view of a pre-Svecokarelian age of the SW-Swedish gneisses (see below). It should also be mentioned that Lundegårdh et al. (1978) consider part of the SW-Swedish gneisses to be Svecofennoian (Svecokarelian).

The gneisses of south-western Sweden have, since early days, been divided into red and grey types. On the whole, the former occur in the east, whereas the latter predominate in the west. The SW-Swedish gneiss complex is, both on a large and small scale, characterized by a compositional banding between different types of foliated granitoids. Amphibolites (intrusive or supracrustal) abundantly take part in this banding. Foliation is, as already mentioned, often very pronounced, whereas migmatization varies in intensity. In some areas two generations of pegmatite veining can be observed (Lundegårdh 1953; Samuelsson 1978a).

The major part of the SW-Swedish gneisses appears to have been formed by intrusive rocks ranging in composition from granitic to tonalitic (Fig. 5). Granodioritic gneisses often carry microcline megacrysts. Ultrabasites, gabbros and diorites also occur. The chemical-mineralogical variations are thus of calc-alkali type.

Rb-Sr dating of tonalitic to granodioritic SW-Swedish gneisses from the Vänernsberg area has given a reference line of 1 700 Ma (Welin and Gorbatshev 1976a). It is, however, uncertain whether this represents an age of intrusion or of metamorphism. It has been possible to calculate a maximum intrusive age of 1 920 Ma from the initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio (Welin and Gorbatshev op.cit.).

Supracrustal rocks seem to be relatively subordinate within the SW-Swedish gneiss complex (Fig. 6). They are in many cases only distinguishable with difficulty from

gneisses of intrusive origin. Zircon morphology studies have been successfully adopted for this purpose in the Göteborg region (Samuelsson and Ahlin 1978). A more important supracrustal area has been observed on and to the east of Hammarön north of Lake Vänern (the Hammarö formation). Metagreywackes, feldspar quartzite, and intermediate to basic metavolcanics occur here (Lundegårdh et al. 1978). Other supracrustal occurrences are found in central Värmland and the adjoining parts of Norway. One example is the Kongsvinger group of Gvein 1967 and Gvein et al. (1974), including metagreywacke, schists (micaceous, basic and quartz-feldspar-rich), metarhyolite, greenstone, meta-arkose and conglomerate. A kyanite-rutile-lazulite-bearing quartzite occurs in the Hålsjöberget (Horrsjöberget)–Ruskåsen area (Geijer 1963b). Sedimentary gneiss and "leptitic", quartz-feldspar-rich gneiss are found on Romeleåsen, a horst rising above younger, Phanerozoic deposits in Skåne, southernmost Sweden (Hjelmqvist 1934).

The Hammarö formation is older than the granitoids among the SW-Swedish gneisses. Gvein et al. (1974) regard the Kongsvinger group as younger than these granitoids, but older than the hyperites (see below) and "Gothian" granites.

Lundegårdh (1977) describes the Gräsmark formation, situated within the SW-Swedish gneisses in western Värmland just north-east of the Mylonite zone discussed below. Metamorphosed basaltic, spilitic, andesitic and dacitic lavas and tuffs occur here. Rhyolitic metavolcanics have also been found, mostly as xenoliths in the more basic extrusives. The rocks are foliated, but in part moderately altered. The Gräsmark formation has been correlated with the post-Svecokarelian Dala volcanics (Lundegårdh *op.cit.*; cf. p. 33), but radiometric data are lacking.

The Västana formation in north-eastern Skåne is treated below (p. 23), in the chapter on the Precambrian of Blekinge.

THE MYLONITE ZONE

From the area north-east of Charlottenberg on the Norwegian border, towards south-east and south along the straight eastern shore of Värmlandsnäs, and further to northern Halland on the Swedish west coast runs a broad zone of strongly sheared and in part mylonitized rocks. According to older investigations the northern part of the zone includes quartzites, porphyries and granites similar to those of the Gillberga synform (see below, p. 14) and of the region dominated by Småland-Värmland intrusions. The rocks of the Mylonite zone were therefore considered to be a downfolded part of a once continuous complex including the Småland-Värmland intrusions and the rocks of the Gillberga synform (see Magnusson et al. 1963).

It should be noted that the Kongsvinger group of supracrustal rocks (Gvein et al. 1973; cf. above) occurs in the extension of the Mylonite zone in Norway.

Recent investigations (Lindh 1974) indicate that within the Mylonite zone in its northern part (Värmland) are found mainly those rocks that occur among the surrounding SW-Swedish gneisses. Particularly the red gneisses east of the zone are thereby

abundantly represented. The most intensive tectonic movements have taken place along the south-western border of the Mylonite zone, and postdate the intrusion of the Värmland hyperites (see below).

In the southern part of the Mylonite zone, near Göteborg (Gothenburg), two major phases of mylonite formation have been distinguished (Samuelsson 1978a). Both of these predate the latest, cross-cutting pegmatites and aplites of the region, and are thus probably older than c. 900 Ma (cf. Welin and Blomqvist 1964).

Lundegårdh (1977) has shown that several fault zones in Värmland run parallel to the Mylonite zone, and that mylonite is as a rule a subordinate rock in these zones.

CHARNOCKITE

Charnockites occur within the SW-Swedish gneiss complex in the region of the towns of Varberg, Laholm and Halmstad on the Swedish west coast. These rocks are rather massive, medium-grained, and consist of antiperthitic plagioclase, orthoclase, quartz, diopside, hypersthene, hornblende, garnet and oxide minerals in various proportions (Quensel 1951; Larsson 1966, 1968). The charnockites were formed by metamorphism of different, in part hybridic, plutonic rocks at high PT (granulite facies) and under exceptionally dry conditions (Quensel *op.cit.*). According to recent investigations (Hubbard 1975) an intrusive charnockite-granite association is an essential component of the Varberg region.

HYPERITE, HYPERITE DOLERITE AND SYENITE

Flat-lying and steeply dipping intrusions of hyperite occur in the SW-Swedish gneisses north and east to south-southeast of Lake Vänern, in Värmland and Västergötland. The hyperite is a doleritic rock, the main constituents of which are ortho- and clinopyroxene, dark-pigmented plagioclase, and most frequently olivine. Although the hyperite has evidently intruded into the surrounding gneisses when the latter were already metamorphosed, it is not unaffected by alterations. Especially in the marginal parts the hyperite has been transformed into more or less foliated amphibolite which frequently carries garnet. The hyperite bodies have been deformed by folding along gently plunging axes, the older of which strike E-W, and the younger N-NNW. According to Lundegårdh (1977) the E-W folding has developed complicated tectonic patterns in some hyperite bodies, and boudinage is common in tectonic zones running parallel to the Mylonite zone (see also Lundegårdh *et al.* 1978). During the final phase of Dalslandian tectonization part of the boudinated hyperite changed to chlorite-rich schists. However, the fact that many hyperite bodies are in part unmetamorphosed can be taken to indicate that they have only been affected by the last (Dalslandian) metamorphic event and have thus escaped much of the complicated evolution of the SW-Swedish Precambrian.

In southern Västergötland and further south in Halland true hyperites are lacking. Instead, basic intrusive rocks largely altered to garnet amphibolites occur.

So-called hyperite dolerites occur as N-S oriented, steep dikes in the shear zones from Lake Vättern to central Skåne. These dikes are intrusive into both Småland granite (see below) and SW-Swedish gneisses. The hyperite dolerites form elongated bodies wedging towards north and south, and in part show marginal foliation and alteration. Their shape has been interpreted as a boudinage structure (Lundegårdh 1971). The titaniferous magnetite ore of Smålands Taberg (the largest concentration of titanium and vanadium in Sweden; see Hjelmqvist 1950) occurs in one of these dikes. In several places the hyperite dolerites are quarried as ornamental stone ("black granite"). They are much more suitable for this purpose than the Värmland hyperites, as they are poor in, or lacking olivine (Lundegårdh 1971).

In northern Skåne the hyperite dolerites are accompanied by syenites and monzonites (Kornfält et al. 1978). A large syenite body, the Vaggeryd syenite, is situated in Småland, south of Lake Vättern (Quensel 1960).

On Kosteröarna, near the Norwegian border, occur the Koster "dolerites" as steeply dipping dikes (Fig. 7). They should properly be termed metadolerites, as they are largely amphibolitized. Relics of hyperitic character have been observed, however, and therefore the dikes have been correlated with the hyperite dolerites treated above (Asklund 1950; Lundegårdh et al. 1974).

The absolute age of the Värmland hyperites is not known. According to the above, metamorphic alterations in these rocks are probably due to the Dalslandian orogeny and the Sveconorwegian regeneration (Lundegårdh 1977). A K-Ar determination has yielded 1 521 Ma (Priem et al. 1968; Mulder 1971), but the significance of this is not clear. A similar figure (approximately 1 570 Ma) was obtained by Rb-Sr dating of the hyperite dolerites in northern Skåne (Klingspor 1976).

The syenites of northern Skåne have given an Rb-Sr age of 1 184 Ma (Klingspor 1976). A somewhat lower value (1 127 Ma) was obtained by the same method for the Vaggeryd syenite, and was interpreted as approximately the intrusion age (Patchett 1978).

STORA LE-MARSTRAND FORMATION

Supracrustal rocks predominate in a belt which extends from the Onsala peninsula (south of Göteborg) northwards through Bohuslän, Dalsland and south-western Värmland. They have been collectively termed the Stora Le-Marstrand formation (Larsson 1956; Lundegårdh 1958). The latter is composed of subgreywacke to greywacke gneiss with minor quartzitic layers, mica schist and basic to intermediate metavolcanics (Fig. 8). In part the Stora Le-Marstrand formation has been transformed into veined gneisses. According to an earlier view it has been supposed to rest on a basement of SW-Swedish gneisses (e.g. Magnusson et al. 1960). This is, however, contradicted by observations on Tjörn, where gneissic granitoids similar to the SW-Swedish gneisses were clearly formed later than the Stora Le-Marstrand

metasediments (Bergström 1963). The formation should probably be correlated with supracrustal gneisses occurring subordinately within the mainly plutonic SW-Swedish gneiss complex (see e.g. Samuelsson 1978a).

Supracrustal rocks which may perhaps be included in the Stora Le-Marstrand formation occur on the Kosteröarna Islands, near the Norwegian border. These rocks are fine-grained gneisses ('leptites'), the predominant feldspar of which is normally plagioclase, although, in some cases, it is microcline. They have been interpreted as volcanic metatuffs (Asklund 1950).

ÅMÅL COMPLEX

The Åmål complex (Åmål mega-unit of Gorbatshev 1975) is a southward narrowing belt of intrusive and supracrustal rocks, running from south-western Värmland to northern Halland. It is lithologically and tectonically not well separated from the SW-Swedish gneisses. Differences between the two complexes may be due to a relatively higher position in the crust for the Åmål complex during the strong deformation of the SW-Swedish Precambrian. This could explain the rather open folds in the Åmål complex as compared with the more intense folding, accompanied by migmatization, in the deeper section of the SW-Swedish gneisses (Gorbatshev 1971a, 1979a).

Supracrustal rocks, which are partially rather well preserved, occur in some regions west of Lake Vänern, in Dalsland and south-western Värmland. The predominating types are reddish or white quartzites (Åmål quartzite) together with acid and basic metavolcanics. Conglomerates also occur. These supracrustals, together constituting the Åmål formation, form part of the Gillberga synform (*Gillbergaskålen*). In the contact zone towards the underlying SW-Swedish gneisses a muscovite-rich zone has been found which was earlier interpreted as a metamorphosed, kaolin-weathered erosion surface. The Åmål supracrustals were thought to have been deposited on this surface in approximate structural conformity with the underlying gneisses (Magnusson 1929; Magnusson et al. 1960, 1963). Investigations by Zeck and Malling (1976), however, did not confirm this interpretation. Low-angle thrusting was instead considered to be important for the development of the Gillberga synform. In addition, it should be mentioned that muscovite-rich zones formed by intense tectonic movements have been demonstrated in the Göteborg region by Samuelsson (1978a) and by Samuelsson and Ahlin (1976).

Supracrustal rocks also occur within the Åmål complex in the Ellenö region in southern Dalsland (Gorbatshev 1971a, 1975, 1977). They include acid metavolcanics (porphyries), breccias and 'metagreywackes'. The latter are probably to be interpreted as arkoses, in which the original feldspar has been secondarily altered to mica. Fragments of gneissose granodiorites and granites have been found in the breccias. The supracrustal rocks display primary depositional contacts with plutonic rocks of the Åmål I group (Gorbatshev 1977; see below). According to Gorbatshev (op.cit.) the Ellenö supracrustals should be correlated with the Kappebo formation as

described by Sandell (1941) and Heybrook (1950). The stratigraphy of this formation is given in the following scheme:

- Quartzite sandstone
- "Kappebo greywacke" (breccia)
- Conglomerate
- Reworked quartz porphyry etc.
- Quartz porphyry and metagreywacke

The Kappebo and Ellenö supracrustals are younger than the Åmål formation, and separated from the latter by an intrusive phase (the Åmål I group; see below).

The major part of the Åmål complex is constituted by different intrusive rocks ranging in composition from gabbro via granodiorite (earlier: Åmål granite) to granite (earlier: Kroppefjäll granite). According to earlier views the intrusions form one differentiated suite (the Åmål-Kroppefjäll suite), but through recent investigations in the Ellenö region and by radiometric dating it has been shown that several generations are involved (Gorbatshev 1975). As mentioned above, gneissose granodiorites and granites occurred in the basement of the Ellenö supracrustals. The latter have been intruded by two generations of granite, the older of which has been called Ellenö granite (Rb-Sr age 1 375 Ma according to Skiöld 1976; cf., however, discussion in Gorbatshev 1977). The younger cross-cutting granite probably corresponds to the Bohus granite (see below).

In the Åmål region there are granites which are intrusive in the Åmål formation. Observations have also been made, which indicate that granites older than the Åmål formation may occur in the Åmål complex (Magnusson et al. 1963).

According to recent interpretations the granitic to tonalitic intrusives of the Åmål complex can be provisionally subdivided in the following way (Gorbatshev 1975). The oldest among the quantitatively important plutonics together constitute the Åmål I group, which predates the Kappebo and Ellenö supracrustals but postdates the Åmål formation. They form a differentiated suite from tonalite to granite and have undergone strong deformation. This suite is of calc-alkali type, in contrast with the Småland-Värmland intrusions (p. 20) with which it has earlier been correlated. Rb-Sr dating of the Åmål I group has yielded a reference line of 1 655 Ma (at Uddevalla; Welin and Gorbatshev 1976b) and 1 648 Ma (the Åmål granite; Welin and Gorbatshev in press). These are similar values as for granitoids in the SW-Swedish gneisses (see above), and the significance is also in these cases not quite clear.

A younger suite of plutonics is the Åmål II group, which has intruded in connection with the development of N-S and NNE-SSW trending foliation, and comprises in part megacryst-bearing granodiorites and granites. The relations with the Ellenö supracrustals are not clear. The Lane granite, which belongs to the Åmål II group (or forms a separate intrusion) has given an Rb-Sr age of 1 430 Ma (Welin and Gorbatshev 1978).

As mentioned above, the Ellenö granite has yielded an Rb-Sr age of 1 375 Ma.

Similar results (1 370 and c. 1 370 Ma, respectively) have been obtained by Skiöld (1976) for a granite at Ljungbergen and a granite at Härserud. The latter has been considered to be intrusive in the Dalsland group and thus much younger (Lundberg 1973; cf. below).

The so-called alkaline gneiss (a gneissose granite) of the Göteborg region can possibly be correlated with the Lane granite (Samuelsson 1978b).

The Hästefjorden and Ursand granites in southern Dalsland, with Rb-Sr ages of 1 215 and 1 225 Ma, respectively, (Gorbatshev and Welin 1975; Welin and Gorbatshev 1976c) are among the youngest, relatively little deformed granites of the Åmål complex. The megacryst-bearing, foliated Askim granite of the Göteborg region possibly belongs to this intrusive phase (Samuelsson 1978b).

From the above it is clear that the earlier view of a correlation between the intrusions of the Åmål complex and those of Småland-Värmland is no longer tenable (Gorbatshev 1975; cf. below, pp. 20–21).

DALSLAND GROUP

The Dalsland group (Dal formation), which is a mainly sedimentary sequence of nearly 2 000 m thickness, occurs in the eastern parts of Dalsland, west of Lake Vänern. The beginning of sedimentation is marked by basal arkoses and conglomerates, the latter carrying pebbles of particularly the Åmål complex plutonics (Fig. 9). In minor areas the Dalsland group is underlain by the supracrustal rocks of the Kappebo formation (see above).

Stratigraphic details of the Dalsland group are given in the following scheme (see Törnebohm 1870, Larsson 1956, Overeem 1948 and Magnusson et al. 1963):

- ''Liane slate'' (slate and metagreywacke)
- Quartzite
- Slate (in part marly) and quartzite sandstone with intercalations of metaspilite (''chlorite stone'')
- Quartzite sandstone
- Basal arkose and conglomerate

Metamorphism in the Dalsland group is mainly in the greenschist facies. Folding and thrusting has occurred in the Dalslandian orogeny. According to Rb-Sr dating the sedimentation of the Dalsland group took place c. 1 030–1 080 Ma ago (Skiöld 1976). A maximum figure is, furthermore, given by the Rb-Sr age of the Hästefjorden granite (1 215 Ma; see above), as this granite forms the basement of the Dalsland group. The latter has been considered to represent marine sedimentation approximately contemporaneous with the continental deposition of the Jotnian sandstones in the Svecokarelian fold belt (Sundius 1944). It is, however, according to available radiometric determinations, somewhat younger than the Jotnian sandstones of Dalarna and Nordingrå, the latter having minimum ages of 1 220 and 1 215 Ma, respectively (Patchett 1978; Welin and Lundqvist 1975).

BOHUS GRANITE

The youngest Precambrian granite of Sweden is the Bohus granite, which forms a large, probably flat-lying, sheet-like intrusion (Asklund 1947; Lind 1966) in the northern and western parts of Bohuslän and adjoining areas in Norway. It is accompanied by pegmatites. Some minor granite massifs in south-western Värmland, at first hand the Blomskog granite (Lindh 1977), have been correlated with the Bohus granite. Pegmatites associated with these granites are intrusive in the Dalsland group (Larsson 1947 and 1956). Pegmatites, which are chronologically equivalent to this granite occur even far from the Bohus granite in south-western Sweden. U-Pb dating of such pegmatites has given 910 Ma (Welin and Blomqvist 1964), and Rb-Sr dating of the Bohus granite has yielded 890 Ma (Skiöld 1976).

The Bohus granite has been extensively quarried as a building, ornamental and paving-stone (Asklund 1947). Nowadays the activity has been considerably reduced (Lundegårdh 1971).

YOUNGER DOLERITES

According to palaeomagnetic measurements (Abrahamsen 1974) WNW-oriented dolerites near Göteborg were formed c. 800–900 Ma ago. One example is the Tuve dike. Plagioclase, clinopyroxene, titaniferous magnetite and biotite, in some cases also olivine, are the most important constituents of these dolerites (Lundegårdh 1958).

CHRONOLOGY OF SOUTH-WESTERN SWEDEN

The chronology of south-western Sweden is summarized in Table 1, p. 18.

REGION OF SMÅLAND-VÄRMLAND INTRUSIONS

GENERAL FEATURES

The Småland-Värmland intrusions predominate the Precambrian bedrock over a vast region, extending from northern Blekinge in the south to northern Värmland and Norway in the north (Fig. 2). Particularly in Småland there are extensive supracrustal complexes closely related to the plutonics. Especially important are acid volcanic rocks, in part of ignimbrite type (Småland porphyries). Older, Svecokarelian complexes, including both metasediments, metavolcanics and gneissose granites and granodiorites also occur. The Småland plutonics have been intruded by two minor rapakivi massifs, and are overlain by the Almesåkra and Visingsö groups.

The Småland-Värmland intrusions cut the serrogenic migmatite structures of the Svecokarelian fold belt. As mentioned above (p. 5) they were earlier included in the Gothian cycle, together with Småland porphyries etc. As, however, geological indica-

TABLE 1. Chronological scheme of the Precambrian of south-western Sweden. Radiometric ages are mainly from the Laboratory for Isotope Geology, Swedish Museum of Natural History. For references see text. Note that the position of several units is of a tentative character.

Time scale (Ma)	Rock unit and event (age in Ma)
800	Dolerite dikes, Göteborg (800–900) Bohus granite and pegmatite (890–910)
1 000	Sveconorwegian regeneration (c. 1 000) Dalsland group (1 030–1 080) Vaggeryd syenite (1 127)
1 200	Syenites, Skåne (1 184) Hästefjorden–Ursand granites (1 215–1 225) Askim granite (?)
1 400	Ellenö granite (1 375), Ljungbergen granite (1 370) Åmål II (Lane) granite (1 430), alkaline gneiss, Göteborg (?)
1 600	Kappebo (incl. Ellenö) formation (?) Gräsmark formation (?) Hyperite, Värmland (1 516?) Hyperite dolerite (c. 1 570) Kongsvinger group Åmål I intrusions (1 655–1 684?) Granitoids in SW-Swedish gneisses (1 700?)
1 800	Åmål formation (?) Stora Le–Marstrand formation Supracrustals in SW-Swedish gneisses Hammarö formation
2 000	Quartzite etc., Hålsjöberget–Ruskåsen (?) Granite xenoliths in Åmål I intrusives Granite pebbles in Åmål formation

tions for distinguishing this cycle are very weak, and as radiometric age determinations place the Småland-Värmland intrusions and the Småland porphyries closely after the end of the Svecokarelian orogeny, the existence of a Gothian cycle or orogeny has been doubted (Welin et al. 1966; Lundqvist 1968). Instead, the intrusions and porphyries have been regarded as representing a subsequent magmatism of the Svecokarelian orogeny. The acidic intrusives and extrusives were thereby considered to have been formed by anatectic magmas generated during this orogeny (Lundqvist 1968).

The chronology of the geological units within the region of Småland-Värmland intrusions is summarized in Table 2, p. 48.

SMÅLAND PORPHYRIES

Porphyritic acid (meta)volcanics (Småland porphyries) occur as mega-inclusions in the Småland-Värmland plutonics. They are generally structurally and texturally well preserved, carrying phenocrysts of quartz and feldspar in an aphanitic or fine-grained

matrix. Spherulitic and perlitic textures occur (Fig. 10; Nordenskjöld 1894; Persson 1974). Ignimbrite structures and textures are common (cf. Hjelmqvist 1969 and Persson 1974). The Småland porphyries are accompanied by subordinately occurring intermediate to basic (meta)volcanics of dacitic to andesitic composition. Deformation is, as a rule, relatively weak. Structures such as lineation have, however, been observed, and may be related to the intrusion of the Småland granites (Persson 1974).

Conglomerates at Malmbäck and Virserum (see below, p. 20) may be regarded as sedimentary deposits associated with the Småland porphyries.

Porphyritic dikes (*Smålands gångporfyr*) cut the Småland porphyries and plutonics. In their central parts the dikes are usually granitic, whereas the marginal parts generally display a more basic composition (composite dikes; see Nordenskjöld 1894 and Persson 1974).

Rb-Sr dating of Småland porphyries has yielded 1 645 Ma (Åberg 1978). This is a somewhat lower value than for the Småland granites (1 690 Ma; Åberg op.cit.), although the latter are normally intrusive in the porphyries. However, it is possible that several generations of granite and porphyry exist, with only minor age differences. Småland granites and porphyries are considered to be genetically linked to each other (Persson 1974), although their initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios differ. The granites show a value of 0.704, whereas the porphyries give 0.708, in better harmony with ideas on an anatectic origin (Åberg 1978).

Rb-Sr dating of dike porphyries has involved difficulties, but by reasonable assumptions a probable age of 1 620 Ma has been obtained (Åberg 1978).

SVECOKARELIAN COMPLEXES

Rocks which are probably comparable in age with early Svecokarelian supracrustals and intrusions occur in the Västervik, Vetlanda-Oskarshamn and Rämsberg regions.

The Västervik formation, situated on the border between the Småland granites and the Svecokarelian orogenic belt in the east, is mainly composed of white, grey and reddish, more or less feldspathic quartzites. Subordinately occur metamorphosed greywackes, argillites and basalts. The quartzites display unusually well preserved primary sediment structures, such as discordant bedding and mud-cracks (Figs. 11, 12; S. Gavelin and Russell 1967). Interesting flecky gneiss structures formed by metamorphic differentiation occur in mica-bearing meta-arenites of the Västervik formation (Loberg 1963).

The stratigraphic position of the Västervik formation has been much debated. A. Gavelin (1904) was of the opinion that the formation rests on a weathered basement of the older, Svecokarelian (or Svecofennian) Loftahammar granite. The quartzites etc. at Västervik were therefore regarded as early Gothian supracrustals (cf. p. 5). New field investigations (S. Gavelin, Stockholm, lecture 1970; Elbers 1971) have, however, shown that they must be included among the early Svecokarelian supracrustal formations. In addition, detrital zircons in the Västervik quartzite have given a U-Pb age of

2 220–2 465 Ma, whereas zircons from the Loftahammar granite give 1 845–1 870 Ma. Thus, this granite does not appear to have formed the basement of the quartzite (Åberg 1978).

The Vetlanda supergroup (term according to Röshoff 1975) is composed of quartzites, phyllites, mica schists, basic metavolcanics and more sparsely occurring acid metavolcanics and crystalline limestone. In the Nömmen area the supracrustal sequence has been subdivided by Röshoff (op.cit.) into the Nömmen group (essentially basic and intermediate metavolcanics) and the Björkö group (acid metavolcanics, phyllites and mica schists). Organic remains have been found in metatuffites and metasediments from this area (Vidal and Röshoff 1971). A conglomerate with granite pebbles (the Malmbäck conglomerate) occurs in the Vetlanda region (cf. below).

An east-west belt of gneissose granitoids runs from Vetlanda to Oskarshamn. These rocks predate the Småland granites, but are intrusive into the Vetlanda supracrustals. Their Rb-Sr age (1 800 Ma; see Röshoff 1975) is thus a minimum age for the Vetlanda supergroup. In a road-cutting near Virserum a gneissose granite is overlain by arkose, ignimbrite, porphyry, and conglomerate (Hjelmqvist 1969). The U-Pb age of zircon in the gneissose granite is 1 925 Ma (Åberg 1978). It has been maintained that the arkose and conglomerate belong to the Vetlanda supracrustals, earlier regarded as Gothian, and that the underlying granite is Pregothian (Hjelmqvist op.cit.). However, with regard to radiometric data on gneissose granitoids in the Nömmen area and on the gneissose granite and ignimbrite at Virserum, it appears more likely that the volcanic and sedimentary rocks are of (post-orogenic Svecokarelian) Småland porphyry age (Röshoff 1975; Åberg 1978). As the Vetlanda-Oskarshamn granitoids are considered to occur as pebbles in the Malmbäck conglomerate, the latter might have a similar stratigraphic position.

Quartzites dominate in the Råmsberg formation of eastern Värmland. Conglomerates have also been observed. The quartzites have been intruded by Värmland granite, and therefore have a minimum age of c. 1 660 Ma (see below).

SMÅLAND-VÄRMLAND INTRUSIONS AND YOUNGER RAPAKIVI MASSIFS

The Småland-Värmland intrusions form a suite of usually massive plutonic rocks intruded into the Svecokarelian folded and metamorphosed complex and the Småland porphyries. Contacts with the SW-Swedish gneisses in the west are often diffuse or masked by shearing, but Lundegårdh (1977) considered the gneisses (termed gneiss-granites by him) to be older than the Värmland granites, and in part regenerated by the latter.

Granites are important among the Småland-Värmland intrusions. Furthermore there occur monzonites and monzodiorites. Granodiorite, diorite and gabbro are subordinate. A common textural feature is microcline megacrysts (phenocrysts), which may be mantled by plagioclase, as for example in the Filipstad granite. The differentiation

trend in the Småland-Värmland intrusions is different from the calc-alkali type displayed by, for example, the Svecokarelian primorogenic intrusions (see below). A geochemical comparison between these two igneous suites in the Linköping region (east of Lake Vättern) has been carried out by Gorbatshev (1971b).

Some Småland-Värmland intrusions occur as isolated massifs within the Svecokarelian fold belt. An example is the Graversfors granite north of Norrköping (Wikström 1976).

The Småland-Värmland intrusions are post-orogenic in relation to Svecokarelian folding and regional metamorphism. In some areas hornfels alterations such as spotted schists have been noted in the surrounding rocks (Magnusson 1925; Wikström 1976).

Radiometric Rb-Sr dating has given 1 690 Ma for Småland granites (Åberg 1978) and 1 655–1 665 Ma for Värmland granites (Welin et al. 1977b). In addition, K-Ar radiometric ages of Småland granites mainly fall between 1 400 and 1 500 Ma, which has been interpreted as the result of heating in connection with intrusive activity (e.g. the Karlshamn granite; see below) at this time (Åberg 1978).

Within the Småland granites there are two examples of younger intrusions of rapakivi granite. They occur on the islet of Jungfrun in Kalmarsund and at Göttemaren, between Oskarshamn and Västervik (Kresten and Chyssler 1976). Rb-Sr dating of the Göttemar granite has yielded 1 350 Ma (Åberg 1978).

SHEAR ZONES AT THE WESTERN BORDER OF THE SMÅLAND-VÄRMLAND INTRUSIONS

Along the western border of the Värmland granites there are zones of shearing and mylonitization, the frequency of which broadly increases towards the great Mylonite zone in the west (Lundegårdh 1977). Similar N-S trending zones are found along the western shore of Lake Vättern, and continue southward into the SW-Swedish gneisses. They can be followed as far as Romeleåsen in southern Skåne. Several intrusions seem to be intimately connected with the shear zones south of Vättern: hyperite and magnetite-olivinite at Smålands Taberg, Vaggeryd syenite, hyperite dolerites and syenites (p. 13).

It is likely that the shear zones have been repeatedly active. Thus, movements probably took place in connection with the hyperite dolerite intrusions at c. 1 570 Ma (p. 13). K-Ar data have been interpreted to indicate shearing between 1 300 and 1 000 Ma (Magnusson 1960a), which is also supported by Rb-Sr dating of syenites in Skåne and at Vaggeryd (p. 13). According to Welin and Blomqvist (1966) the distribution of K-Ar ages in southern Sweden indicates important faulting during or after the Sveconorwegian regeneration at c. 1 000 Ma, whereby the western block of SW-Swedish gneisses should have been uplifted along the shear zones in relation to the eastern block (of Småland-Värmland granites etc.).

ALMESÅKRA GROUP

The sedimentary Almesåkra group (Fig. 2) was deposited on the Småland granites. It has been included in the Jotnian complexes of Fennoscandia (cf. p. 32). Weathered granitic material (arkose) forms the base of the Almesåkra group, and is overlain by sandstones, shales and conglomerates (S. Gavelin 1931). Dolerites constitute a prominent component of Jotnian complexes, and such dikes are also abundant at Almesåkra, displaying both high and low dips. Observations of rounded pebbles of quartzite etc. within the dolerites ('dolerite conglomerates') have been interpreted to indicate a close connection in time between conglomerate sedimentation and dolerite intrusion (Eichstädt 1885; Berg-Lembke 1970).

The Almesåkra group has been gently folded. Locally, however, more intense deformation has resulted in thrusting (S. Gavelin 1931). The folding may be related to the Dalslandian orogeny in south-western Sweden.

A minimum age for the Almesåkra group is 960–980 Ma, the Rb-Sr age of cross-cutting dolerites (Patchett 1978). According to the above, the sedimentary rocks should not be much older than the dolerites. The Almesåkra group therefore appears to have a lower age than for example the Dala and Nordingrå sandstones, which have also been included in the Jotnian (cf. p. 34).

VISINGSÖ GROUP

Sedimentary rocks belonging to the Visingsö group occur mainly on the island of Visingsö and in several places around Lake Vättern. This group is composed of sandstones, arkoses, shales with limestone intercalations, and conglomerates. The total thickness has been estimated to be more than 1 000 m (Collini 1951). Algal stromatolites as well as microfossils have been found in the shales (Timofeev 1960; Vidal 1972, 1974, 1976).

The Visingsö group was largely deposited on a surface of Småland granite. It is cut by numerous faults, the main directions of which are N–NNE. Such faulting has given rise to Lake Vättern. Gravimetric measurements in the region have been interpreted to indicate that this lake is a graben (Lind 1972). The absence of observed faults along the western shore, however, contradicts this (Collini 1951).

According to its content of microfossils the Visingsö group is considered to have been deposited in late Precambrian time (Timofeev 1960), c. 700–850 Ma ago (Vidal 1974). A pre-Ordovician age is indicated by the presence of Visingsö sedimentary rocks as pebbles in an Ordovician conglomerate in Östergötland (Rosén 1925). K-Ar dating of mica in Visingsö rocks has given 985 Ma (Magnusson 1960a), but the significance of this is not clear.

BLEKINGE REGION

GENERAL FEATURES

Three rock units form the quantitatively most important elements in the Precambrian of the Blekinge region (cf. Fig. 2). These are the older granitoids, the so-called coastal gneiss with the Västana formation, and the Karlshamn-Spinkamåla granites. NNE trending dolerite dikes are also of importance.

As stated earlier the Precambrian of Blekinge can neither be readily correlated with south-western Sweden nor with the Svecokarelian fold belt. At least in the western parts there are metamorphic features similar to those of both south-western Sweden and the Svecokarelian, as kyanite and (manganiferous) andalusite occur together in the Västana formation (Bäckström 1897; Andersson 1975).

The chronology of the Precambrian units of the Blekinge region is summarized in Table 2, p. 48.

OLDER GRANITOIDS

The older granitoids (Wiklander 1974) were earlier embraced by the term Tving granite. They are composed of granodiorites, often carrying microcline megacrysts, and tonalites. In contrast to the Småland granites they are usually more or less gneissose, and at places exhibit pegmatite veining. Therefore, these granitoids are now considered to predate the Småland granites (Wiklander op.cit.). According to an earlier opinion they should represent foliated off-shoots of the latter granites (Norin 1959). Rb-Sr dating of the older granitoids has given a reference line of 1 500 Ma, which is probably due to heating of the older granitoids at the intrusion of the Karlshamn granite (Larsen and Springer 1976). According to Wiklander (1974) it is at present an open question whether the older granitoids of Blekinge can be correlated with other lithologically similar plutonics in the Swedish Precambrian. From the chronological scheme of Wiklander it can, however, be concluded that these granitoids must be older than 1 690 Ma, which is the Rb-Sr age of the Småland granites (p. 21).

VÄSTANÅ FORMATION AND COASTAL GNEISS

The so-called coastal gneiss of Blekinge (*Blekinge kustgnejs*) is a grey, fine- to medium-grained, granitic gneiss with an extensively developed lineation. At least in part it is of supracrustal origin, as it has been observed to pass over into acid, hälleflinta-like metavolcanics stratigraphically situated below the Västana formation (Bäckström 1897; Norin 1936). The latter includes quartzites (in part kyanite-bearing),

conglomerate, mica schists, basic, intermediate and acid metavolcanics and layers of hematite ore (Bäckström 1897; Andersson 1975). Amphibolites of dike character also occur.

Norin (1936) showed that the coastal gneiss predates the older granitoids. K-Ar dating of coastal gneiss and mica quartzite in the Västana formation has given 1 240–1 560 Ma (Magnusson 1960a). These figures evidently represent a secondary (metamorphic) age. The Västana formation has tentatively been correlated with the oldest Svecokarelian supracrustals (Lundegårdh et al. 1978).

KARLSHAMN-SPINKAMÅLA AND VÅNGA GRANITES

Several granite massifs have intruded the older granitoids and the coastal gneiss. The Karlshamn granite is medium- to coarse-grained, and contains phenocrysts of potash feldspar. Fine- and even-grained varieties are called Spinkamåla and Halen granites. Abundant pegmatite and aplite accompany the Karlshamn granite and have migmatized the surrounding older rocks.

Rb-Sr dating of the Karlshamn-Spinkamåla granites has yielded 1 430 Ma (Larsen and Springer 1976) and 1 360 Ma (Patchett 1978). U-Pb determinations of pegmatite associated with the Karlshamn granite and aplite connected with a Karlshamn-type granite on Romeleåsen, Skåne, have given 1 395 Ma (Welin and Blomqvist 1966).

In north-eastern Skåne, north to west of Ivösjön, occurs the Vånga granite, which is red, acid and rich in microcline-perthite (Fig. 13). It is normally foliated and in part migmatitic (Lundegårdh 1978). On the map of Magnusson et al. (1960) it has been given the same colour as the (Gothian) Småland granites. Lundegårdh (1978) considered it more likely that the (foliated part of the) Vånga granite should be correlated with either the Karlshamn granite (Norin 1959) or with the older granitoids (gneiss-granites) of Blekinge. Recent mapping in the area has supported the former alternative (K.-A. Kornfält, personal communication). Rb-Sr dating of migmatitic Vånga granite has yielded a scatter of points around a reference line of 1 455 Ma. The isotope system has evidently been opened, but the result is not possible to interpret further (E. Welin, personal communication in Lundegårdh 1978).

DOLERITE DIKES

Dolerite dikes striking NNE form the youngest Precambrian rocks in Blekinge. At least twelve major dikes have been observed between the Skåne-Blekinge border and the region east of Karlshamn. These dolerites can not always be unequivocally distinguished from the hyperite dolerites further west (p.13). They belong to the same dike generation as the Almesåkra dolerites (p.22), their Rb-Sr age being 870–975 Ma (Patchett 1978).

THE SVECOKARELIAN OROGENIC BELT WITH POST- AND ANOROGENIC COMPLEXES

GENERAL FEATURES

A broad outline of the Svecokarelian orogeny and the subsequent evolutionary phases has been given above (p. 6). The Svecokarelian orogenic belt embraces those Precambrian regions in which a significant part of the bedrock was affected by Svecokarelian folding and regional metamorphism, or was formed in close connection with these orogenic events. This belt therefore contains an essential element of rocks older than c. 1 750–1 800 Ma, equivalent in age or predating the serorogenic (late-kinematic) granites and pegmatites. It thus embraces the oldest supracrustal rocks (of Svecofennian and Karelian facies, p. 6) and the primorogenic and serorogenic intrusions as well as minor areas of pre-Svecokarelian basement. However, complexes formed after serorogenic time are also extensively represented. These are termed post- or anorogenic with regard to the Svecokarelian orogeny (cf. p. 6). As already mentioned the Småland-Värmland intrusions and associated volcanics belong to the post-orogenic complexes.

The pre-Svecokarelian basement in Sweden, on which early Svecokarelian supracrustal rocks were deposited, has been positively identified only in the northernmost parts of the country. It is there connected with the main pre-Svecokarelian basement occurring in eastern Finland and adjoining parts of the Soviet Union (cf. Simonen 1960a and Eskola 1963), and overlain by the Karelian supracrustal sequence of epicontinental facies. Basal Svecokarelian conglomerates occur, and are followed by quartzites, meta-argillites and basic metavolcanics (cf. p. 44).

Reliable stratigraphic schemes within the Svecokarelian orogenic complexes can only be established in areas where supracrustal sequences are well preserved. This is especially the case for the minor occurrences of greenschist facies rocks (cf. Lundqvist 1978). However, amphibolite facies is the entirely dominating metamorphic grade, and migmatites are extensively developed. Metamorphism is always of low-pressure type (Lundqvist *op.cit.*), and minerals such as cordierite and andalusite occur abundantly in rocks of suitable composition. The usually high metamorphic grade and the voluminous intrusions of granitic rocks make stratigraphic and tectonic analyses difficult. More than fifty percent of the exposed Svecokarelian orogenic belt is granite, granodiorite and tonalite belonging to different intrusive epochs.

Foliation is usually approximately conformable with primary bedding, and high to moderate dips prevail. This is in contrast with the tectonic structures of south-western Sweden (p. 8). In several parts of the Svecokarelian orogenic belt two major fold phases have been demonstrated (see further below).

For descriptive purposes the Svecokarelian orogenic belt is subdivided into four main regions (Fig. 1). For each of these, orogenic and post- to anorogenic complexes are treated separately. Important lithological and tectonic units etc. are given in Fig. 3.



Fig. 3. Index map showing important lithologic and tectonic units, geographic names etc. in the Svecokarelian orogenic belt. Cf. Fig. 1. The extension of the pre-Svecokarelian basement areas in the north is according to Lindroos and Henkel (1978) and M. Ambros (personal communication).

GÖTALAND AND SVEALAND

OROGENIC COMPLEX

The major part of the supracrustal rocks of Bergslagen (Fig. 3) and adjoining regions belongs to the Leptite formation. It has been demonstrated that acid metavolcanics (lavas and tuffs), in part reworked, are of great importance in this formation. The best preserved, aphanitic volcanics have traditionally been termed hälleflintas. In these, primary porphyritic and glass-shard textures can often be extremely well preserved (e.g. Sundius 1923). By increased metamorphism the hälleflintas were first transformed into leptites and then to leptite gneisses, which are in part migmatitic. Three main types can be distinguished with regard to chemical composition: sodic leptites with great predominance of albite or oligoclase over microcline, potassic leptites in which microcline predominates over sodic plagioclase, and alkali-intermediate leptites with approximately equal microcline and sodic plagioclase contents. Sodic leptites and hälleflintas generally underlie potassic varieties (p. 29).

Intercalations of crystalline limestone (marble) and dolomite occur in the Leptite formation. Near Sala stromatolitic structures have been found in dolomite (B. Collini, oral communication; see also Lundegårdh 1971), showing that organic processes contributed to the deposition of carbonate.

Occurrences of iron ore are economically important in the Leptite formation, mainly in the mining district of Bergslagen. The major part of these ores has been deposited on the earth's surface as intercalations in acid volcanics and carbonate rocks. Four main ore types have been distinguished: apatite iron ores, quartz iron ores, skarn iron ores and lime iron ores (Geijer and Magnusson 1944; Magnusson 1960b and 1970b).

The apatite iron ores are, due to their apatite content, characterized by more than 0.3 % P. Magnetite is the main ore mineral, but hematite also occurs. In some cases the ores have intruded the surrounding rocks. They are, however, regarded to be closely genetically connected with the leptite-hälleflinta volcanicity (Magnusson 1953). Geochemical investigations point to an origin by exogenic processes (Landergrén 1948). The iron ores of Grängesberg, Blötberget and Idkerberget belong to this type.

The quartz iron ore type is abundantly represented. Examples are the occurrences of Striberg, Stripa, Stråssa, Håksberg, Bispberg and Utö. The ore mineral is usually hematite, intercalated with quartz-rich layers (Figs. 14, 15). At low metamorphic grades these layers consist of bright-red jasper. Metamorphism has at places resulted in reduction, whereby magnetite has replaced hematite. The quartz iron ores also appear to be genetically linked with the volcanic activity through which the leptites etc. originated. In all probability they were formed by chemical sedimentation (Geijer and Magnusson 1944).

In the skarn iron ores the main ore mineral is magnetite, accompanied by skarn silicates in various proportions. Important silicates include garnets, epidote, amphiboles, pyroxenes, olivine, humite minerals, and mica. The skarn iron ores are

linked, through transitional types, with the fourth ore type, the lime iron ores. In the latter, the ore mineral is accompanied by carbonate. Presence of the latter seems to have been a necessary prerequisite for the formation of the skarn iron ores. Transitional types between the latter and the quartz iron ores also occur.

Skarn and lime iron ores are subdivided into Mn-poor and Mn-rich types, the former having a manganese content lower than 1 %, the latter, 1–12 %. Mn-poor ores are mainly restricted to the lower, sodic leptites and hällflintas, whereas Mn-rich types occur in potassic leptites etc. Examples of Mn-rich skarn and lime ores are Ställberg and Dannemora. A special type is formed by the iron-manganese ores of Långban, known for their abundance in minerals of, i.a., Mn, Pb, As, Sb, Ba, and Cu. Braunite and hausmannite are the main ore minerals. (See Moore 1971.)

Manganese-poor skarn and lime ores occur, for example, at Persberg and Herräng.

The genesis of the skarn iron ores has been much debated (see Geijer and Magnusson 1944, 1952, and Magnusson 1953, 1970b). According to one opinion, the skarn is a so-called reaction skarn, formed by metamorphism of lime-bearing volcanic-sedimentary layers. To this type belong the manganese-rich skarn iron ores, as well as the majority of manganese-poor ores. Indications of such an origin are transitions towards lime- and quartz-banded ores. It has also been shown in several cases that the skarn was formed after the ore. According to another view the skarn should be primary, formed by contact metasomatism (pyrometasomatism) caused by the primorogenic granites. The supposedly primary skarn is in part magnesium-rich, composed of the same minerals as those formed by magnesia metasomatism in connection with sulfide ore mineralization (see below). However, the "primary" skarn type could also have originated through magnesia metasomatism of a more or less lime-bearing iron ore (Magnusson 1953). A contact-metasomatic origin has been considered more likely for iron ores accompanied by a skarn including boron- and fluorine-bearing minerals such as ludwigite and the humite minerals (Geijer 1939, 1959).

In the mining district of Bergslagen there occur, in addition to iron ores, numerous sulfide deposits of chalcopyrite, pyrite, sphalerite, galena, etc. (e.g. Magnusson 1960b). The major part of these are embraced by the term sulfide ores of Falun type and have been considered to be genetically related to the primorogenic intrusions (pyrometasomatic; see Magnusson 1953 and 1960b). However, it has later been maintained that the ores are exhalative, syngedimentary with the Leptite formation (Koark 1962). They were later metamorphosed and mobilized during the Svecokarelian orogeny.

The horizons of crystalline limestone in the Leptite formation seem to have been particularly favourable for localizing the sulfide ores. The carbonates thereby reacted to give various skarn minerals (pyroxenes, amphiboles, garnet, olivine, humite minerals, fluorite, etc.). Dolomitization of limestone also seems to have occurred. The leptites have been metasomatically changed in connection with the sulfide mineralization. Due to high Mg contents in the alteration products the changes have been called

"magnesia metasomatism". The latter involved, i.e., a breakdown of feldspar, whereby quartzites (ore quartzites) and mica schists formed, in which minerals such as anthophyllite-gedrite, cordierite, andalusite, and almandite occur.

Examples of ores of Falun type are Falun, Garpenberg, Saxberget and Kaveltorp. At Sala silver-rich galena in dolomite has been mined.

The Ämmeberg zinc ores are examples of another sulfide ore type. Sphalerite and galena are the main ore minerals. They occur as horizons in leptite, crystalline limestone and skarn near the front of veined gneiss alteration (Johansson 1910; Magnusson 1948 and 1953). For this reason they have been considered to be genetically related to migmatization. Later investigations, however, have shown that it is more probable that ore deposition occurred in connection with the leptite volcanicity through submarine hydrothermal activity (Henriques 1964).

Isotope investigations on lead from various sulfide deposits of Falun and Ämmeberg types have yielded model ages in the range 1 640–1 930 Ma (Wickman et al. 1962; cf. also Rickard 1978).

Metasediments, mainly of argillite and greywacke type, are abundantly represented in the southern part of the Svecokarelian orogenic belt. Thus, the almandite-cordierite-sillimanite-rich veined gneisses of the so-called Mälars formation in Sörmland, south of Stockholm, are largely of argillitic origin (Fig. 16; Stålhös 1962). Near Stockholm a transition towards greywacke compositions in a northward direction has been demonstrated (Stålhös 1969).

The sedimentary Larsbo formation in Bergslagen, between Norberg and Smedjebacken, includes quartzites, mica schists, metagreywackes and conglomerates (Hjelmqvist 1938). Intercalations of basic metavolcanics occur. These metasediments overlie the ore-bearing Leptite formation.

Intermediate to basic metavolcanics of dacitic, andesitic or basaltic composition are mainly associated with sedimentary rocks, but are less common in the leptites.

The stratigraphic relations between the Leptite formation and metasediments are especially clear in the vicinity of Grythyttan, Bergslagen. According to Sundius (1923) the supracrustal rocks here form a syncline displaying the following stratigraphy:

- Conglomerate
- Grey slate
- Black slate with intercalations of scoriaceous metabasalt (metaspilite)
- Metagreywacke, in part conglomeratic
- Potassic hällflinta with intercalations of crystalline limestone and Mn-rich iron ore
- Sodic hällflinta with intercalations of crystalline limestone and Mn-poor iron ore.

The stratigraphy of this key area has been verified in several other regions in Bergslagen. It has therefore been assumed that also in areas with more obscure stratigraphic relations leptites and hällflintas generally underlie metasediments and

basic metavolcanics. However, from investigations in Finland it is clear that this is not always the case (Simonen 1960b). Exceptions from the above rule have also been noted on Utö and in the Ljusterö-Rödlöga region in the archipelago of Stockholm (Lundqvist 1962; S. Gavelin et al. 1976), in the Örebro region (Gorbatshev 1969; cf., however, Wikman 1972 and 1973) and south of Stockholm (Stålhös 1975). Fragments of quartzite in metavolcanics of the Leptite formation near Uppsala also indicate the existence of pre-leptitic metasediments (Lundegårdh 1957a). Leptites furthermore overlie mica schists and basic metavolcanics in the Åtvidaberg region (Sundius 1921a). It is thus clear that metasedimentary formations occur both above and below the Leptite formation, and that intercalations exist.

In the early, primorogenic phases of the Svecokarelian orogeny the supracrustal rocks were intruded by an igneous suite starting with gabbro, in part ultrabasic, followed by diorite, tonalite, granodiorite (in part microcline-megacryst-bearing) and granite. Granodioritic to tonalitic rocks in the region north of Stockholm are called Uppsala granite, and granitic varieties in the same area, Vänge granite and Vätö granite. Quartz-bearing primorogenic intrusions, which greatly predominate in the suite, have also, more popularly, been called gneiss-granites or '*urgraniter*' (oldest granites). Chilled, granophyric or porphyritic margins towards the supracrustal rocks are not uncommon. Monzonites occur very subordinately in the suite, for example near Åkersberga north-east of Stockholm (Stålhös 1969, 1972). The primorogenic granites are, in contrast with the serorogenic, poor in pegmatite.

Due to their early-orogenic intrusion the primorogenic plutonics have been more or less strongly deformed (foliated or lineated) and metamorphosed during later, serorogenic Svecokarelian phases. They have, however, as a rule, been more resistant to migmatization than the supracrustals. However, in some regions, as for example near Nyköping, even the most extreme migmatite stages have been attained (Lundström 1974).

The contacts of the primorogenic intrusions usually run parallel to foliation and primary bedding (Fig. 17). Sheet-like xenoliths of supracrustal rocks are common in the intrusions. Concordant dikes of primorogenic granites to tonalites are abundant in metasediments and metavolcanics.

Rb-Sr dating of primorogenic granites to tonalites in the Norrköping region has yielded 1 925 Ma, whereas U-Pb dating of zircon gave 1 875–1 890 Ma (Åberg 1978). The U-Pb age of zircons in the primorogenic Loftahammar and Örö-Hamnö granites of north-eastern Småland is 1 845–1 910 Ma (Åberg op.cit.). See also p. 19.

Observations in the Garpenberg area, Bergslagen, may indicate that primorogenic granitic rocks were here exposed to erosion relatively early, leading to deposition of arkoses (Du Rietz 1968). However, this interpretation needs verification. For supracrustal rocks falling in the interval between prim- and serorogenic intrusions the term Bothnian has been proposed (Sederholm 1893).

Following the primorogenic intrusions there was a so-called intraorogenic phase, characterized by formation of mostly doleritic dikes in older rocks (Fig. 18). Particu-

larly in north-eastern Uppland such dikes are numerous, for example in the Herräng field (Magnusson 1940). They have therefore also been called Herräng dikes. In serorogenic phases the dolerites have been transformed to amphibolites and, particularly in migmatite regions, strongly deformed.

Stålhös (1972) has also discussed the possibility that some amphibolite dikes of Herräng type do not belong to an intraorogenic stage but could have been intruded closely after the maximum of serorogenic metamorphism (migmatization).

The serorogenic stage involved a culmination of metamorphism and deformation and was characterized by more or less intense migmatization and gneissification of older supracrustal and intrusive rocks. Great volumes of granitic material were mobilized, which in part remained as veins etc. in the gneisses. Stålhös (1969, 1975) has pointed out that a prerequisite for the formation of veins in the argillitic gneiss of Sörmland was the instability of muscovite. This gave rise to the formation of alumina-rich minerals and melts of granitic composition. Part of the granitic material (formed by anatexis or palingenesis) is considered to have risen towards the roof of the migmatite zone, there forming massifs of undifferentiated granite accompanied by abundant pegmatite.

The most important serorogenic granites are the Stockholm, Malingsbo, Enkullen and Fellingsbro granites. The Stockholm granite is fine-grained and usually grey, but sometimes reddish. At Ytterby near Vaxholm, north-east of Stockholm, a pegmatite occurs which is probably related to the Stockholm granite. It is rich in rare earth elements, occurring in gadolinite, yttrantalite, fergusonite, xenotime, orthite, anderbergite etc. (Sundius 1948). The elements yttrium, ytterbium, erbium and terbium are named after Ytterby. The Fellingsbro granite c. 130 km west of Stockholm is microcline-porphyrritic, reddish or grey (e.g. Gorbatshev 1972a).

U-Pb dating of the Ytterby and related pegmatites has given 1 795 Ma (Welin and Blomqvist 1964), which is thus a minimum age of the serorogenic phase.

Some ore concentrations are related to the serorogenic granites and their pegmatites. Examples are the tungsten deposit of Yxsjöberg, west of Grängesberg (ore mineral: scheelite), and the molybdenum deposits of Hörkengruvorna and Uddgruvan, south of Grängesberg, and Bispbergs klack (ore mineral: molybdenite). In 1976 the Wigström ore was discovered south of Grängesberg (Frietsch 1980). The ore mineral is scheelite. The wolframite occurrence at Baggetorp, Östergötland, is not obviously related to serorogenic granite, see Hübner (1971) and Magnusson (1953).

Tectonic structures of those parts of the Svecokarelian fold belt that are embraced by the present chapter are in many cases characterized by complicated patterns. This has been shown to be due to two or more phases of deformation. The following examples may serve as illustrations.

In the ore-bearing region of Bergslagen steep planar and linear structures prevail (Geijer and Magnusson 1944) and give rise to a '*Schlingenbau*'. The latter has probably been caused by two main fold phases, the first of which was characterized by isoclinal folding along gently dipping fold axes and with steep axial planes (e.g. Koark

1973; Lundegårdh 1974). In the second phase a cross-folding along steep axes occurred. Iron and sulfide ores are frequently elongated parallel to these steep axes, which has been considered to be due to differences in competency between the ore and its wall-rock during folding and metamorphism (Koark *op.cit.*).

The tectonic structures of the Södertörn region south of Stockholm have been analyzed by Stålhös (1969 and 1976). Two main fold phases can be distinguished here. The first of these, considered to be primorogenic, was caused by E–W compression and involved folding, in part isoclinal, along N–S axes, axial planes dipping eastward. In the late-orogenic phase, a N–S compression occurred, whereby older structures were refolded and in part changed to E–W directions. As a consequence of the earlier overturning the resulting lineations and fold axes dip easterly. The fold structures are beautifully displayed by the morphology of the region. Stålhös later (1979) has given evidence that both major fold phases in Södertörn should in fact be serorogenic, and that the primorogenic magmas intruded into an essentially undisturbed supracrustal sequence.

In the region north-west of Örebro two fold phases have been similarly demonstrated by Wikman (1972, 1973).

Wikström (1975) has demonstrated five different phases of deformation in the Norrköping region, the second and third phase being equivalent with those of Stålhös (above). In outcrop scale dome-and-basin structures occur, which have been interpreted in harmony with the large-scale deformation (Wikström and Horndahl 1975).

POST- AND ANOROGENIC COMPLEXES

In northern Dalarna and the adjoining parts of south-western Norrland (Härjedalen) rock complexes occur which postdate the serorogenic migmatization and granites, and are therefore unaffected by regional folding and metamorphism. Large areas are occupied by the Dala sandstone, which, together with basalts and dolerites, has been ascribed to the Jotnian complexes of Fennoscandia (cf. Sederholm 1895). Below the base of the sandstone different volcanic, sedimentary, and intrusive rocks occur, which constitute the sub-Jotnian complex (cf. Högbom 1909a). The latter has been subdivided into an Upper Dala formation, occurring next to the Dala sandstone, and a Lower Dala formation, further away from the sandstone area (Hjelmqvist 1966).

The Lower Dala formation is composed of acid and basic (meta)volcanics (quartz porphyries and porphyrites), quartzites, schists and conglomerates. Among the latter especially the Leksand conglomerate should be mentioned. The pebbles are here composed of leptites and different granites, which have been interpreted as Svecokarelian (Hjelmqvist *op.cit.*).

It has been shown that some supracrustal rocks of the Lower Dala formation in fact belong to the early Svecokarelian sequences. Thus, metarhyolites, quartzite sandstones and phyllites at Noppikoski in north-eastern Dalarna predate the primorogenic intrusions (Lundqvist 1968). It is possible that also other parts of the Lower Dala

formation are of early Svecokarelian age. The stratigraphic position of this formation is at present not quite clear.

In the Upper Dala formation are included the Dala porphyries (Älvdalen porphyries) and associated, more basic Dala porphyrites. The former rocks are usually feldspar-porphyrific rhyolites to trachytes, largely of ignimbritic origin (Figs. 19, 20; Hjelmqvist 1956 and 1966; Lundqvist 1968). The latter are mainly latite-andesitic to latite-basaltic lavas and pyroclastics. In both Dala porphyries and porphyrites occur intercalations of so-called Digerberg rocks, i.e. stratified tuff(ite)s and various sedimentary rocks, for instance conglomerates (Hjelmqvist 1966). Rb-Sr dating of Dala porphyries has yielded 1 635 Ma (Welin and Lundqvist 1970).

The Dala granites are closely related to the Dala porphyries. Especially the rapakivi-like, porphyritic Garberg granite displays intimate chemical-petrographical relations with the latter (Hjelmqvist 1966; Lundqvist 1968). The granites occur in several generations. Also the Järna and Siljan granites have been included among the Dala granites, although their connection with the Dala porphyries is less obvious.

The Jotnian Dala sandstone overlies the sub-Jotnian complex. Stratification is usually almost horizontal, but in the south-western parts steep dips have been observed (Hjelmqvist 1966), probably due to Dalslandian movements (cf. Fig. 21). The sandstone is reddish, usually quartz-rich to arkosic, and is intercalated with shales and conglomerates. It attains a maximum thickness of c. 800 m. Conglomerates and sedimentary breccias form the basal layers (Fig. 22). The detrital material of the sandstones and conglomerates is largely of the same quartzite and porphyry types as in the surrounding areas. Primary sedimentary structures like discordant bedding, ripple marks, mud-cracks and raindrop imprints are exceptionally well preserved (Fig. 23). A major intercalation is formed by the Öje basalt, which is often amygdaloidal. The amygdules are composed of chalcedony, agate, quartz, chlorite, calcite, etc. Tuffaceous beds also occur (Hjelmqvist *op.cit.*).

In northern Dalarna and southern Härjedalen both the Dala sandstone and its basement are cut by dolerites (Åsby and Särna dolerites), mostly showing a low or moderate dip (Hjelmqvist *op.cit.*). Plagioclase, augite, and olivine form the major constituents (Fig. 24). In addition, monzonitic rocks occur. These dolerites are also included in the Jotnian complex. Their average Rb-Sr age is 1 220 Ma (Patchett 1978).

Dolerite dikes older than the Åsby and Särna types, but postdating the serogogenic granites, occur in southern Dalarna. They usually have a NE-SW strike, and have been called Tuna dolerites (Hjelmqvist 1966). In some cases the dolerites are associated with dike porphyries of granitic composition (Gustafs porphyries). Their Rb-Sr age is 1 371 Ma (Patchett 1978).

Steeply dipping NNW-SSE trending dolerite dikes occur in the Bergslagen-northern Dalarna region (Hjelmqvist 1966). Their Rb-Sr ages usually fall in the range 900-970 Ma (Patchett 1978).

In Lake Mälaren there is an occurrence of sandstone of Jotnian type on Ekerön and some adjacent islets (Gorbatshev 1962; Stålhös 1969). Further west, on Granholmen

near Kvicksund, a partially amygdaloidal dolerite is found. Studies of moraine boulders indicate that sandstone and conglomerate of Jotnian type occur in the neighbourhood (Lundegårdh 1954; Gorbatshev 1962).

South of Lake Mälaren, in Sörmland, the Svecokarelian migmatites etc. are cut by two broad, E-W striking dolerite dikes: the Hällefors and Breven dikes. The former is essentially composed of plagioclase, clinopyroxene and more or less altered olivine (Krokström 1936). In the Breven dolerite there is also orthopyroxene (Krokström 1932). In both dikes minor granophyre occurs. Narrow dolerite dikes, both of E-W and other directions, are found in many places in the Mälaren region (e.g. Gorbatshev 1961; Lundegårdh 1974; Stålhös 1975). The Hällefors-Breven and associated E-W dikes of Sörmland have given Rb-Sr ages of 1 510–1 560 Ma, whereas a NW trending dike gave 995 Ma (Patchett 1978).

Most of the dolerites treated above have been included in the Jotnian. It is clear from the radiometric ages that several generations of "Jotnian" dolerite occur (cf. also p. 22). The term Jotnian (as well as sub-Jotnian) therefore does not refer to a specific stratigraphic level, but merely implies a certain lithological type or association.

NORRLAND SOUTH OF VÄSTERBOTTEN COUNTY

OROGENIC COMPLEX

In southernmost Norrland the Svecokarelian supracrustal rocks are continuous with the ore-bearing Leptite formation of Bergslagen. Thus, in Gästrikland leptites predominate over sedimentary gneisses. Important iron ores include those of the Hofors-Torsåker district (Geijer and Magnusson 1944; Lundegårdh 1967). Skarn and lime ores predominate here, magnetite being the most important ore mineral. Both Mn-rich and Mn-poor types are represented.

Towards the north the leptites gradually give way to metasedimentary rocks, including reworked leptite material, and basic metavolcanics. The latter, which are in part spilitic or tuffitic, predominate in the Hamrånge formation, c. 30 km north of Gävle (Fig. 25). Minor quartzite also occurs. These supracrustal rocks form an anticline, cross-folded and overturned towards the west (Lundegårdh 1967).

The following stratigraphy has been established for a syncline in the central parts of the Los formation in north-western Gävleborg County (Lundqvist 1968). A grey slate, passing over into phyllite, mica schist, and migmatitic gneiss, forms the lowest parts. It is overlain by, in turn, quartzite sandstone, metarhyolite, and amphibolitic metabasalts. Above the latter dolomite, skarn iron ore, and skarn-bearing metasediments occur. The grey slate has intercalations of metaspilite, graphite-bearing black slate, a minor grunerite-magnetite ore, etc. The well known cobalt ore, in which A.F. Cronstedt discovered the element nickel in 1751, forms a vein in amphibolitic metabasalts.

North of the river Ljusnan, along which important faulting has occurred (Lundegårdh 1967; cf. also Strömberg 1976), acid metavolcanics (leptites) are com-

paratively rare. Sedimentary gneisses, largely of argillitic composition, are the predominating supracrustal rocks of northern Hälsingland. They are usually veined by pegmatite and rich in almandite, cordierite and sillimanite.

In Västernorrland County metagreywackes of varying metamorphic grade (the Härnö formation) occupy vast areas. Intercalations of amphibolitic metabasalts occur. The greywacke belt extends south-eastward to the Tampere region in Finland, where similar rocks are found (cf. Simonen 1960a). In Västernorrland the best preserved metagreywackes display graded bedding and other primary structures. In their most strongly migmatized parts they form rafts of greywacke gneiss in a granodioritic mobilizate (Fig. 26).

Around the Medelpad-Hälsingland border, at the southern limit of the Härnö formation, more or less feldspathic quartzites belonging to the Naggen formation occur (Fig. 27). According to Lundegårdh (1960) these meta-arenites were formed from a granitic basement by frost weathering and rapid transport. It has, however, not been possible to identify pre-Svecokarelian basement rocks in this region. The Naggen formation has been interpreted to represent the miogeosynclinal facies corresponding to the eugeosynclinal Härnö formation (Lundegårdh *op.cit.*).

As in more southerly areas the supracrustal rocks have been intruded by a suite of primorogenic plutonics, ranging in composition from quantitatively subordinate gabbros and diorites to tonalites, granodiorites and granites. In northern Hälsingland and southern Medelpad the latter two are generally rich in almandite (Lundegårdh 1967). The large massif of Ljusdal "granite" of Hälsingland is dominated by a granodiorite carrying microcline megacrysts (Fig. 28; Lundegårdh 1967). A primorogenic gabbro at Kramsta is economically interesting since it contains concentrations of titaniferous magnetite, in part rather rich in vanadium, and ilmenite (Lundegårdh 1957b). A large gabbro massif belonging to the primorogenic suite occurs at Hoting in north-western Ångermanland (Åhman 1967b).

Serorogenic granites are above all found in the metagreywacke terrains of Ångermanland, where they have been called Härnö granite. They form a large number of massifs associated with abundant pegmatite. Both muscovite and biotite may constitute the dominating mica. Like other serorogenic granites the Härnö granite is in part foliated.

The Revsund granite forms very large massifs in central Norrland. It is characterized by numerous rectangular or rounded megacrysts of microcline, which may attain a diameter of 10 cm (Fig. 29). The Revsund granite is, in contrast with the Härnö granite, poor in pegmatite. It is also younger than the latter granite, and in part of a post-orogenic character (Lundqvist 1968). In some areas hornfels aureoles occur around the Revsund granite. Geochemical and petrographical investigations indicate a differentiation from quartz-bearing monzodiorite to granite, the former being quantitatively subordinate. The trend is similar to that of the Finnish rapakivis (Persson 1978).

The Sörvik granite, on the border between the Provinces of Jämtland and Ångermanland, is typically quartz-porphyritic and pyroxene-bearing. Fayalite has also

been noted. Field observations and geochemical features indicate that the Sörvik granite probably forms an early forerunner to the Revsund granite (Persson 1978), although it has also been compared with the Ragunda rapakivi granite (Gorbatshev 1972b; cf. below).

In southern Norrland the main tectonic features of the Svecokarelian appear to be similar to those of more southerly regions. An older phase involved folding and overturning along gently plunging, NNW trending axes. A younger deformation caused a cross-folding along axes plunging gently towards ESE. The characteristic fold-arc pattern of the coast regions of Hälsingland and Gästrikland is the result of these two fold phases (Lundegårdh 1967).

POST- AND ANOROGENIC COMPLEXES

The Rätan granite forms a large, rather uniform massif with its centre north of Sveg in Härjedalen. It is clearly post-orogenic, and in several respects resembles the Småland-Värmland granites as well as the Järna and Revsund granites (Sundius 1921b). The major type is rich in rectangular to rounded phenocrysts of microcline, usually of 2–3 cm diameter, and has a fairly low quartz content (10–20%). Pegmatite and aplite dikes are rare. The Rätan granite has developed a hornfels aureole in the Los-Hamra slates and metabasalts (Lundqvist 1968). It has an Rb-Sr age of 1 650 Ma (Welin and Lundqvist 1977).

According to Lundegårdh (1967) the Hedesunda granite of Gästrikland is in tectonic respects similar to the Rätan granite.

In several regions occur igneous rocks which have been included in the sub-Jotnian. The Strömsbro and Rödö granites as well as the Nordingrå and Ragunda massifs should be mentioned here. Jotnian dolerites and sandstones are also found in southern Norrland.

The Strömsbro rapakivi granite forms a minor massif at Gävle, near an occurrence of Jotnian sandstone. It is red, medium-grained, usually porphyritic, and is accompanied by granophyre and granite porphyry (Lundegårdh 1967). The sandstone occurs between Gävle and Storvik, and is probably 800–1 000 m thick in the central parts (Gorbatshev 1967). It has been intruded by dolerite of Jotnian type.

In the Sundsvall archipelago occurs the red, porphyritic Rödö rapakivi granite as a small massif. Perthite phenocrysts display plagioclase mantling. The granite is accompanied by dikes of granite porphyry and more basic porphyrites (dolerites), in part appearing together as composite dikes (Holmquist 1899). According to von Eckermann (1938) one of the porphyrite dikes is anorthositic, indicating the presence of a magma of similar composition. Later investigations have, however, failed to verify this (Lundqvist 1975).

Red biotite and hornblende granites of rapakivi type, associated with quartz syenites and syenites, occur between Sollefteå and Östersund, in the Ragunda massif. As in most rapakivis the potash feldspar is strongly perthitic and structurally intermediate between orthoclase and microcline (Kornfält 1969). A dolerite-like gabbro with minor

anorthosite predates the granite (Fig. 30; Kornfält 1976). The Ragunda massif was earlier considered to be a laccolith (Högbom 1909b). Later investigations have, however, contradicted this opinion (Kornfält 1976). A genetic model, based on petrological-geochemical studies of the various rocks of the Ragunda massif, has been proposed by Kornfält (op.cit.). Rb-Sr dating of granite and syenite has given a preliminary age of c. 1 290 Ma (E. Welin, personal communication in Kornfält op.cit.).

The Mårdsjö massif, 40 km north-west of Ragunda, is similar to the Ragunda massif.

60 km NNW of Ragunda, near Nordsjö, is a minor massif of monzonite in Revsund granite. Dikes of various compositions (granitic, syenitic, monzonitic, doleritic) occur both in the massif and its surroundings. The monzonite massif and the dikes may be related to the igneous rocks at Ragunda (Persson 1978).

In the Nordingrå region, on the coast between Härnösand and Örnsköldsvik, the sub-Jotnian intrusions started with anorthosite and gabbro (Sobral 1913). The latter is essentially composed of plagioclase (labradorite to andesine), clino- and orthopyroxene, often in lamellar intergrowths, olivine (c. 50–85% Fa), and biotite, potash feldspar, Fe-Ti oxides etc. (Gunilla Lundqvist 1976). The anorthosite (or mainly rather gabbro-anorthosite) shows a similar mineralogy, but of course has a higher plagioclase content (70–95%). It was considered by von Eckermann (1938) to have formed by upward gravitative accumulation of early-formed plagioclase crystals in a gabbro-anorthosite magma. Later investigations have demonstrated that the gabbro is a layered intrusion, in places displaying rhythmical layering (Gunilla Lundqvist op.cit.).

The gabbro and anorthosite have been intruded by the reddish, rapakivi-like Nordingrå granite, the groundmass of which is largely granophyric. Rb-Sr dating has yielded a preliminary age of c. 1 415 Ma for the granite, whereas the gabbro and anorthosite have given c. 1 550 Ma (E. Welin, personal communication in Kornfält 1976).

The sub-Jotnian igneous rocks of Nordingrå (anorthosite, gabbro and granite) are overlain by a flat-lying sandstone formation attaining a maximum thickness of 60 m (the Nordingrå sandstone). Intercalations of shale and conglomerate occur. The underlying igneous rocks are strongly weathered below the sandstone (Sobral op.cit.). Above the sandstone occurs the Ulvö dolerite sill, which has an approximate thickness of 300 m (Fig. 31). It is similar to the Åsby dolerite (p. 33) and forms the youngest rock of the region. The Ulvö dolerite is a layered intrusion, especially the rhythmical layering being well developed (Fig. 32; Lundqvist and Samuelsson 1973; Larson 1973). Essential constituents are plagioclase (labradorite), augite, olivine, biotite and Fe-Ti oxides. The latter have accumulated in thin layers of vanadium-bearing titanium-bearing iron ore, in which the mineral ulvöspinel (ulvite) was discovered by Mogensen (1946). The Ulvö dolerite continues towards the north as a gently inclined sheet in the older, Svecokarelian gneisses etc. Monzonites and granites occur at the uppermost levels of the intrusion (Sobral op.cit.). Microcline in the wall-rock has been altered to orthoclase (Lundqvist 1973).

The sandstone and dolerite of Nordingrå are included in the Jotnian complex. K-Ar dating has given an isochron age of 1 215 Ma for the dolerite (Welin and Lundqvist 1975).

Numerous occurrences of usually flat-lying dolerite sheets are found in Ångermanland, Medelpad and Jämtland. In the former province, the most important dolerite body is a semicircular lopolith with a diameter of 100 km (Lundqvist and Samuelsson 1973). In Ångermanland and Medelpad the sheet-like dolerites are accompanied by abundant narrow, steeply dipping dolerite dikes, mostly of E-W strike.

Sandstones, dolerites, acid volcanics and associated rapakivi-like granites in the south-western parts of Härjedalen have been included in a previous chapter (p. 32).

Investigations in the Bothnian Sea and studies of boulders along adjacent shores have shown that there are extensive areas of porphyry, rapakivi granite, Jotnian sandstone and dolerite in this sea (Eskola 1928, 1934; Veltheim 1962; Winterhalter 1972; Thorslund and Axberg 1979).

VÄSTERBOTTEN COUNTY AND SOUTHERNMOST NORRBOTTEN COUNTY OROGENIC COMPLEX

In the southern parts of Västerbotten County the Precambrian is similar to that of Ångermanland, described above. Thus, metagreywackes, largely migmatized and similar to those of the Härnö formation (p. 35), and Revsund granite occupy vast areas (S. Gavelin 1955a). In the northern parts of the county (the Skellefte field; see Fig. 3), the bedrock is much more complicated, and the metamorphic grade lower than further south. Phyllites, meta-arenites, conglomerates and minor crystalline limestone occur here, in addition to metagreywackes. Large areas are occupied by various volcanic rocks, ranging in composition from basalts to rhyolites with subordinate keratophyres. Especially important are acid and intermediate metavolcanics. They are in part texturally well preserved (S. Gavelin *op.cit.*).

North of the Skellefte field vast areas are occupied by the Arvidsjaur porphyries, a c. 1 500 m thick volcanic sequence ranging from basaltic andesite to rhyolite. Keratophyres also occur. Textural features like lithophysae (Fig. 33) and spherulites are in many cases well preserved (Grip 1935). The acid volcanic rocks are largely ignimbrites. In these, glass shards and pumice fragments appear very distinctly under the microscope (Lilljequist and Svenson 1974). Stratigraphically the more basic volcanics in general underlie the acid. However, andesites occur at high levels in the sequence (Grip *op.cit.*).

The primorogenic intrusions of Västerbotten County belong to the Jörn suite, varying in composition from gabbro to granite. Most important are grey granodiorites (Jörn "granite"). Quartz-porphyritic or granophyric margins towards the supracrustal rocks are common (S. Gavelin 1955a).

Supracrustal sequences clearly overlying the primorogenic intrusions occur along the river Skellefteälven at Vargforsen and Ledfat in the northernmost parts of Väs-

terbotten County (cf. map of S. Gavelin 1955a). Especially important are here conglomerates, but sandstones, andesites, tuffites etc. also occur. Pebbles and boulders of Jörn "granite" are found in the conglomerates. An important question, which has been much debated, is the stratigraphic position of the conglomerates in relation to the Revsund granite (see below).

The coarsely porphyritic Revsund granite is serorogenic to post-orogenic and forms a continuation of more southerly massifs. Observations in Västerbotten County have been interpreted to indicate that this granite was formed by metamorphism and mobilization of greywackes and schists (S. Gavelin 1955a; Svensson 1970). The Revsund granite has also been considered to be closely related to migmatization, folding and sulfide ore formation (S. Gavelin *op.cit.*). The fine- and even-grained Skellefte granite corresponds to the Härnö granite further south (p. 35).

Rb-Sr dating of the Revsund granite has given 1 745 Ma (Welin et al. 1971). According to Welin et al. (1977a) similar figures (1 740 and 1 735 Ma) have been obtained for the Arvidsjaur granite of southern Norrbotten County and for the Adak granite in the north-western part of the Skellefte field, respectively (cf. Ödman 1957 and S. Gavelin 1955a). As the Revsund granite marks the transition from serorogenic to post-orogenic conditions, this transition seems to have taken place at c. 1 750 Ma in the Skellefte field.

A pegmatite which is related to the Revsund and Skellefte granites occurs at Varuträsk near Skellefteå. It is characterized by high contents of Li, Cs and Rb and by several rare minerals (see Quensel 1952).

Uranium mineralizations in the south-western parts of Norrbotten County are roughly synchronous with the Revsund granite, according to U-Pb dating (1 736–1 772 Ma; Adamek and Wilson 1977). Of special interest is the Pleutajokk deposit at Arjeplog. Vein fillings of pitchblende here occur in acid metavolcanics.

In the supracrustal rocks of the Skellefte field a great number of sulfide deposits have been found. According to one interpretation they are related to the (serorogenic) migmatization and granitization which has affected the bedrock of more southerly regions (S. Gavelin 1955a,b). Ore deposition frequently occurred in fold structures or schistosity zones, and was accompanied by intense wall-rock alteration to sericite and chlorite quartzites and schists (S. Gavelin *op.cit.*). The sulfides are often localized to the border zone between acid metavolcanics and phyllites. The best known deposit is Boliden, where, however, mining has ceased. Pyrite and arsenopyrite formed the major ore constituents (Ödman 1941). Particularly the latter contained native gold. Copper and silver were also mined. Other important sulfide deposits are Kristineberg (pyrite, chalcopyrite, sphalerite; Du Rietz 1953), Rakkejaur (pyrite, sphalerite, chalcopyrite and arsenopyrite) and Renström (pyrite, sphalerite, galena and chalcopyrite with fairly high silver and gold contents). For details see Grip and Frietsch 1973.

Rickard and Zweifel (1975), contrary to the above genetical interpretation, considered the sulfide ores of the Skellefte field to be stratabound and formed by hydrothermal solutions associated with the volcanic activity of the region. Folding and regional

metamorphism subsequently altered the ores. See also discussions of S. Gavelin (1976) as well as Rickard and Zweifel (1976).

Copper mineralization in the Adak area has been claimed to be related to the Adak granite (S. Gavelin 1948, 1955a). However, a synvolcanic origin, as suggested by Rickard and Zweifel (1975) for the sulfide ores of the Skellefte field, can probably not be excluded. The ores occur in a dome-like structure in metavolcanics and metatuffites near the Adak granite, and are accompanied by (magnesia-)metasomatic wall-rock alteration (S. Gavelin 1948; Ljung 1974). A connection between ores and doming is apparent. According to Ljung (op.cit.) doming seems to have started during the intrusion of the Jörn "granite".

The Skellefte field has been extensively investigated in connection with sulfide ore prospecting. Different stratigraphic interpretations have been given for the complicated geology of this area:

S. Gavelin (1955a) distinguished two major complexes. The older (Svecofennian) complex is composed of the acid to basic metavolcanics of the Skellefte formation, which are overlain by the metasediments of the Skellefte formation (phyllites, meta-arenites and metagreywackes, conglomerates and basic metavolcanics). The (meta)volcanics of the Arvidsjaur formation (Arvidsjaur porphyries) were deposited on the Skellefte formation. All these supracrustals were intruded by the primorogenic Jörn "granite" suite, and by the serogenic to post-orogenic Revsund granite.

The younger (Karelian) complex of S. Gavelin (op.cit.) includes the sedimentary and volcanic rocks of the Vargfors formation (conglomerates, greywackes, arkoses, sandstones, phyllites, acid tuffs, andesitic lavas and tuffs). These supracrustals have been intruded by the Sorsele (below, p. 42) and Adak granite suites, to which also gabbros belong.

Kautsky (1957) referred to oldest supracrustal rocks of the Skellefte field to the Maurliden group. The latter roughly corresponds to S. Gavelin's Skellefte formation, but displays an interbedding of volcanic and sedimentary rocks. The Arvidsjaur porphyries were correlated with the upper parts of the Maurliden group. During the intrusion of the early-orogenic Jörn "granite" weak folding occurred. After a period of deep weathering the Elvaberg group was deposited unconformably on the older supracrustals and intrusives. The marine Elvaberg facies starts with lime-cemented conglomerates and breccias (Mensträsk conglomerates), with rare clasts of Jörn "granite". Above these follow the Elvaberg schists (original sandstones and greywackes). The terrestrial or fluvial Elvaberg facies is dominated by conglomerates (Vargfors conglomerates) and sandstones with intercalations of andesitic lava. Numerous pebbles of Jörn "granite" occur in the lower Abborrtjärn conglomerate, whereas such pebbles are rare in the upper Dömanberg conglomerate. After the Elvaberg sedimentation followed a period of folding, migmatization and ore deposition, succeeded first by the intrusion of the Revsund granite and later by the Sorsele granite. The Adak granite was correlated with the Revsund granite. According to the interpretation of Kautsky (1957) the Elvaberg group should be Bothnian (cf. p. 30).

The contrasting interpretations of S. Gavelin and Kautsky initiated a discussion, in which their views on the stratigraphy of the Skellefte field were further elaborated (S. Gavelin 1958; Kautsky 1959b).

Helfrich (1971) on the whole adhered to the interpretation of Kautsky, but modified the stratigraphic scheme mainly by means of geochemical grouping of the igneous rocks. The basal parts of the Elvaberg group (the Abborrtjärn conglomerate) and the uppermost parts of the Maurlidén group were thus ascribed to a separate Vargfors group, which is in turn overlain by the Elvaberg group of Helfrich. The latter comprises the upper parts of Kautsky's Elvaberg group. Both the Vargfors and Elvaberg group postdate the Jörn "granite", except for the basal parts of the former, which were considered to be approximately synchronous with the Jörn suite. The Revsund granite is younger than all the other rocks.

According to Helfrich (op.cit.) the Vargfors and Mensträsk conglomerates form the basal parts of the geosynclinal Härnö formation (p. 35). However, as the latter predates the intrusion of the primorogenic suite (Jörn "granite" etc.), this interpretation must be rejected. For similar reasons the Elvaberg schists of Kautsky (1957) cannot be correlated with the Härnö formation.

Vessby (1968) suggested that the Arvidsjaur porphyries as well as the Vargfors and Mensträsk conglomerates may have been formed in the time interval including the Jörn suite and the Revsund granite.

Kautsky (1959a) as well as Adamek and Wilson (1977) interpreted the Arvidsjaur porphyries as a terrestrial facies, deposited on "the Arvidsjaur land", and corresponding to the more southerly marine volcanic and sedimentary deposition of the Skellefte field (Maurlidén group). Kautsky (op.cit.) also drew palaeogeographical maps for both the Maurlidén and the younger Elvaberg group.

Offerberg (1959) has made a detailed study of the Ledefat supracrustal group, 35 km east of Sorsele. These supracrustals are included in the Vargfors formation of S. Gavelin (1955a) and are similar to the fluvatile facies of the Elvaberg group of Kautsky (1957). They rest on a basement of Arvidsjaur porphyries. Andesites, conglomerates, sandstones and tuffites constitute the lower parts of the Ledefat group. They are overlain by conglomerates with pebbles and boulders of, i.a., porphyry, arkose, and, in the uppermost beds, also granite (Fig. 34). The latter pebbles are in part of typical Jörn "granite", but in part also bear resemblance to the Revsund granite (cf. Kautsky 1959b). Intrusions of Sorsele granite and of a granite earlier interpreted as Adak granite occur in the Ledefat group. Recent Rb-Sr dating has, however, yielded a lower age of 1 645 Ma for the latter cross-cutting granite as compared with 1 735 Ma for the Adak granite (Welin et al. 1977a). In conclusion, the Ledefat group is either Bothnian or post-orogenic.

Welin (1970) suggested that the Ledefat conglomerates postdate the Revsund granite and belong to what he calls the period of intrusion and deposition. This involves a post-orogenic position in relation to the Svecokarelian orogeny.

Opinions differ on the tectonic history of the Skellefte field. However, at the Jörn

"granite" intrusion the oldest supracrustal rocks of the Skellefte field were folded in WNW-ESE oriented anticlines and synclines. Later tectonic phases involved a more intense folding in a similar stress field, whereby the Jörn "granite" massifs acted as resistant blocks (Grip 1941; S. Gavelin 1955a). Dominantly steep fold axes were formed and migmatization occurred, especially in metasediments. The Revsund granite intruded when folding had ceased. According to the interpretation of S. Gavelin (1955a) the most intense folding and migmatization occurred before the deposition of the Vargfors conglomerates etc. Therefore, the latter only show weak alteration and folding, but more pronounced faulting. In Kautsky's (1957) opinion, the main folding and migmatization postdated the Vargfors conglomerates and Elvaberg schists.

POST- AND ANOROGENIC COMPLEXES

It has already been stated (p. 39) that the Revsund, Arvidsjaur and Adak granites intruded at the transitional stage between serogenic and post-orogenic conditions. From the above it is also clear that certain supracrustal formations ascribed to the Bothnian may in fact be post-orogenic, as they may postdate the Revsund granite. This is possible for instance for parts of the Arvidsjaur porphyries (cf. Vessby 1968). As the conglomerates etc. at Ledfat and Vargforsen postdate the primorogenic intrusions and have minimum ages below 1 750 Ma they may also be post-orogenic, as suggested by Welin (1970) in harmony with the stratigraphy of S. Gavelin (1955a). It is to be observed that contact relations between the Revsund granite massif and these conglomerates cannot be directly observed, as the granite does not extend as far north as the conglomerate areas (cf. map of S. Gavelin 1955a).

In the Dobblon (Duobblon) area near Sorsele clearly post-orogenic supracrustal rocks occur (Einarsson 1979). Folded Svecokarelian metagreywackes have here been intruded by the Dobblon granite, which should probably be correlated with the Revsund granite (Welin et al. 1977a; Einarsson op.cit.). Unconformably on these rocks rests a basal conglomerate with pebbles of Dobblon granite. This is in turn overlain by lithophysae-bearing volcanics, tuffites, a polymict conglomerate and acid volcanics. The supracrustal sequence above the Dobblon granite (the Dobblon Group of Einarsson 1979) has been intruded by the Sorsele granite. Rb-Sr dating of the acid volcanics of the Dobblon Group and the Sorsele granite has yielded 1 690 and 1 590 Ma, respectively (Welin et al. 1971). Thus, the Sorsele granite is clearly post-orogenic, which is also supported by its undeformed structure. This granite forms massifs along the border between Västerbotten and Norrbotten Counties. It is somewhat alkalic, and is associated with syenitic and monzonitic intrusives (S. Gavelin 1955a). Dolerites and quartz-porphyritic dikes are also related to the Sorsele granite.

Rocks ascribed to the sub-Jotnian or Jotnian are sparse in Västerbotten County (S. Gavelin 1955a). Rapakivi granite similar to the Nordingrå granite (p. 37) occurs on the islet Bonden ESE of Nordmaling. A flat-lying olivine dolerite is found on the coast of Nordmaling, and all evidence suggests that it forms a continuation of the Ulvö dolerite

in the south (p. 37). Steep dolerite dikes of similar type occur in the southern parts of the county as far westward as the Caledonian margin at Vilhelmina. A flat-lying dolerite dike has also been observed in a tunnel at Storuman (Stålhös 1958).

NORRBOTTEN COUNTY

OROGENIC COMPLEX

Supracrustal rocks of the eastern parts of Norrbotten County mainly belong to the Karelian epicontinental facies (p. 6), dominated by basic metavolcanics, quartzites, meta-argillites etc. Primorogenic intrusions are represented by the Haparanda suite (gabbro to granite). In the west acid metavolcanics of Svecofennian facies type are quantitatively important (Ödman 1957). Vast areas are occupied by younger granites (Lina granite etc.; see map of Ödman 1957) which correspond to the serorogenic and post-orogenic granites of more southerly regions.

The Precambrian of Norrbotten County has formerly been subdivided into rocks of the older, Svecofennian (Svionian) and the younger, Karelian cycle, respectively (Ödman 1957). As already mentioned (p. 5) this subdivision is no longer relevant with regard to radiometric ages. Some of the supracrustal rocks ascribed to the Svecofennian have also been shown by recent mapping to be younger than "Karelian" metasediments and metavolcanics. According to Rb-Sr dating they appear to belong to the post-orogenic formations, their ages being lower than 1 750–1 800 Ma (cf., however, p. 47). It should also be mentioned that a revision of the stratigraphic interpretation of Ödman (op.cit.) has as yet only been carried out for limited areas in Norrbotten County.

For the Vittangi region the following stratigraphy has been established by Eriksson and Hallgren (1975). It is essentially in accordance with Geijer (1931a):

Migmatite granites, perthite syenites etc.

Quartzite, conglomerate, minor phyllite (Maattavaara Quartzite Group)

Acid metavolcanics with intercalated intermediate and basic metavolcanics, apatite iron ore, minor metasedimentary rocks. Conglomerates near base. (Porphyry Group)

Haparanda suite (gabbro to granite)

Quartzite, arkose, mica schist (Kilavaara Quartzite Group)

Basic metavolcanics (greenstones; Fig. 35), in part spilitic, graphite schists, crystalline limestone, skarn iron ores (Vittangi Greenstone Group)

Quartzite (Tjärro Formation in Vittangi Greenstone Group)

Major unconformity

Basement granite (not exposed in the area)

Recent investigations in northern Norrbotten (Offerberg 1967; Padget 1970, 1977; Witschard 1970, 1975) are in agreement with the above stratigraphic scheme.

The pre-Svecokarelian basement to the above supracrustal sequence occurs north and east of Kiruna in the northernmost parts of Sweden (Fig. 3). It belongs to the basement complex of mainly granitic gneisses exposed in eastern Finland and the Soviet Union (Simonen 1960a). North of Kiruna such basement rocks have been identified by U-Pb dating, which has yielded 2 750–2 800 Ma (Welin et al. 1971). Basement complexes have been interpreted to exist in the region between Karesuando and Huuiki by combined geophysical and geological methods. However, U-Pb dating of zircon has here failed to give basement ages, but essentially gives figures within the range of primorogenic Svecokarelian rocks (Lindroos and Henkel 1978).

The beginning of the Svecokarelian stratigraphy in some areas is marked by basal conglomerate or sedimentary breccia, in part calcareous (Offerberg 1967).

As in the Vittangi area basic metavolcanics with subordinate crystalline limestones, graphite-bearing schists and skarn iron ores occupy a relatively low stratigraphic position also in other parts of northern Norrbotten County. Thus, for instance the Kiruna greenstones of Geijer (1931a) and Offerberg (1967) should probably be correlated with the Vittangi Greenstone Group of Eriksson and Hallgren (1975). In the scheme of Ödman (1957) the basic metavolcanics etc. were largely included in the Karelian cycle. For such "early Karelian" supracrustals the term Lapponian was sometimes used. The basic metavolcanics and metasediments predating the Haparanda suite together form the supracrustal sequences of Karelian facies (p. 6). They occupy large areas at Pajala, Tärendö-Masugnsbyn and Kalix (Eriksson 1954; Padget 1970, 1977; Ödman 1957). In the Kalix archipelago stromatolitic structures have been observed in a dolomite (Geijer 1931a; Ödman 1957; Åhman 1967a; cf. p. 27). Iron ores, usually of phosphorus-poor magnetite skarn ore type, are broadly associated with the basic metavolcanics. Most of them are found in metasedimentary rocks belonging to the greenstone groups. Examples are the deposits of Masugnsbyn and Kaunisvaara (Geijer 1929; Lindroos 1974; Grip and Frietsch 1973; Frietsch 1963, 1977 and 1980). The skarn iron ores are regarded as sedimentary deposits (Frietsch 1977), but they have also been considered to be contact-metasomatic (Geijer and Magnusson 1952; cf. p. 28).

Acid volcanics (Kiruna porphyries) are situated high in the stratigraphic schemes of northern Norrbotten County. Chemically they are dominantly rhyolites and trachytes, intercalated with basaltic and andesitic effusives. Sedimentary rocks are usually subordinate. Radiometric dating of porphyries at Kiruna and Kaska-Tjäurek have yielded 1 570 and 1 600 Ma, respectively (Welin et al. 1971). It therefore seems possible that the Kurravaara conglomerate occurring below the porphyries of Kiruna (Geijer 1931a; Offerberg 1967) represents the beginning of post-orogenic sedimentation at c. 1 750 Ma, as suggested by Welin (1970). This conglomerate, the acid volcanics of the Porphyry Group (Kiruna porphyries etc.) and the overlying supracrustal rocks are therefore treated below (p. 46) in the chapter on the post- and anorogenic complexes. A discussion is also given on alternative stratigraphic interpretations.

In a region from Stora Sjöfallet in the north to Lake Hornavan in the south occurs the Snavva-Sjöfall formation of c. 10 000 m thickness (Ödman 1957). Quartzites and feldspar quartzites predominate, and in part display exceptionally well preserved primary structures. Minor mica schists, conglomerate, crystalline limestone and basic metavolcanics also occur. In the so-called Sjöfall quartzites partially potassium-rich tuffs with well preserved glass shard textures have been observed. Towards the south the metamorphic grade increases, so that sillimanite, cordierite and garnet have formed in Al-rich rocks. According to Ödman (1947) the Snavva-Sjöfall formation is overlain in a monoclinical structure on Ultevis by acid metatuffites, a basic metavolcanite, crystalline limestone and in part gneissose acid metavolcanics (porphyries and leptites). Recent investigations in the Ultevis area, however, contradict this stratigraphic interpretation (F. Witschard, oral communication 1979).

In the acid metavolcanics and metatuffites of Ultevis occur manganese mineralizations, in part as primary beds, in part epigenetically as a matrix in breccias or in replacement structures (Ödman 1947). The manganese minerals are braunite, bixbyite and hollandite. Piemontite, spessartite and hematite have also been observed. Geochemically interesting are the high contents of F, Ba, and Pb. The manganese ores are considered to be genetically related to thermal activity in connection with volcanicity. Later metamorphism caused mobilization and epigenetic ore formation (Ödman 1947, 1957).

Several copper mineralizations have been discovered in the Precambrian of Norrbotten (e.g. Ödman 1957; Grip and Frietsch 1973). At Laver, west of Älvsbyn, a copper ore has earlier been mined in volcanic rocks belonging to the Arvidsjaur porphyries (p. 38). The ore mineral is chalcopyrite, accompanied by pyrrhotite and sphalerite. In 1973 the so-called Viscaria ore west of Kiruna was taken for evaluation. This is a stratiform chalcopyrite mineralization in metasedimentary intercalations in the Kiruna greenstones. Pyrrhotite also occurs along with minor sphalerite, pyrite and galena (Godin 1976). At Aitik, 15 km east of Gällivare, a copper ore in gneissose metasediments is mined (Zweifel 1976). The metasediments are biotite, amphibole and sericite schists and quartzites, in part with skarn schlieren. Chalcopyrite is the ore mineral, accompanied by pyrite, magnetite, pyrrhotite and minor amounts of other sulfides. The ore has been interpreted as a sedimentary deposit, mobilized in connection with metamorphism (Zweifel *op.cit.*).

So-called leucodiabase or albite diabase occurs in several places in the Karelian-facies supracrustals, mainly in basic metavolcanics. Constituents of this rock type are albite and minor actinolite, carbonate and epidote. The leucodibases have been interpreted as sodic differentiates associated with hypabyssic intrusives in the metavolcanics (Ödman 1957; Meriläinen 1961), or as metasomatic formations near late-orogenic faults (Padget 1959 and Frietsch 1966).

The supracrustal rocks of Karelian facies (basic metavolcanics and metasediments) have been intruded by the primorogenic Haparanda suite, mainly varying in composition from gabbro to granodiorite. The latter, named Haparanda granite, predominates

(Ödman 1957). Rb-Sr dating of massifs in the coastal area has yielded 1 840 Ma (Welin et al. 1970).

Ödman (1957) distinguished two different migmatite generations: an early, Svecofennian (Svionian) associated with the Revsund granite, and a later, Karelian, genetically linked with various migmatite granites (Lina granite etc.). The present opinion on the relationship between the Svecofennian and Karelian orogenies (p. 5) raises the question whether there is still reason to maintain the view of two migmatite phases. Comparison with more southerly regions indicates that also in Norrbotten County extensive migmatization probably occurred closely before the intrusion of the Revsund granite. Radiometric dating has also clarified the presence of granites of serorogenic Svecofennian age. Examples are the Degerberg granite at Kalix, which has an Rb-Sr age of 1 770 Ma (Skiöld 1977), and the older Lina granite (1 780 Ma; Welin et al. 1971). A post-1 750 Ma migmatization should most probably be related to the younger of the two Lina granite generations indicated by Rb-Sr dating (1 530 Ma; Welin et al. 1971). In both early and recent publications the Lina granite is maintained to be associated with migmatization (Ödman 1957; Offerberg 1967; Padget 1970, 1977; Witschard 1970, 1975; Eriksson and Hallgren 1975). However, it is not clear whether both or only one generation of Lina granite according to Rb-Sr dating are related to migmatites (cf. also below, p. 50).

The tectonic features of the Precambrian of Norrbotten County are summarized below (p. 49).

POST- AND ANOROGENIC COMPLEXES

The distinction between Svecofennian orogenic and post- to anorogenic complexes is much more problematic in Norrbotten County than elsewhere in the Svecofennian. To the latter complexes have been referred rocks, which above all through radiometric dating appear to have formed after the final phase of the Svecofennian orogeny (after c. 1 750 Ma). Examples are the Kiruna and Kaska-Tjåurek porphyries (Rb-Sr isochron ages 1 570 and 1 600 Ma, respectively; Welin et al. 1971). A geological indication of a post-orogenic age may be the trachytic composition of the so-called syenite porphyries of the Kiruna and other areas, as such compositions are generally rare in the Svecofennian orogenic complex. It should, however, be noted that gradual transitions between the syenite porphyries and the younger perthite syenites exist (Ödman 1957). According to the interpretation of Ambros (1970 and 1978; see also Welin 1970) an unconformity exists in the Lannavaara area between acid metavolcanics of the Porphyry Group and underlying metabasalts of the Greenstone Group. This is an indication that folding and erosion of the greenstones in this area preceded the deposition of the porphyries. The rocks removed by erosion correspond to the Kilavaara Quartzite Group of Eriksson and Hallgren (1975). It should be noted that other stratigraphic schemes of northern Norrbotten County do not display a similar unconformity between porphyries and greenstones (Eriksson and Hallgren *op. cit.*; Offerberg 1967; Padget 1970, 1977; Witschard 1970, 1975).

Field observations of the age relationship between acid volcanics of the Porphyry Group and the Haparanda suite of plutonics are lacking. However, quartzites of the Maattavaara Quartzite Group, postdating the porphyries, have been observed to overlie a diorite ascribed to the Haparanda suite by an erosional contact (Eriksson and Hallgren 1975).

Rb-Sr dating of porphyries at Kiruna and Kaska-Tjåurek has yielded values well below the Rb-Sr age of the Haparanda suite (see above). However, Welin et al. (1971) pointed out that fine-grained rocks of porphyry type relatively easily suffer isotopic homogenization, and that therefore further geochronological investigations in the Kiruna area are necessary to establish the extrusion age of the porphyries. With regard to the Precambrian of southern and central Sweden it is difficult to accept a post-1 750 age of the porphyry volcanicity, as available descriptions demonstrate folding and metamorphism of the Porphyry Group, features that are foreign to more southerly post-orogenic complexes. This can in part be explained by the existence of two generations of porphyry (early orogenic and post-orogenic, respectively), as in Västerbotten County and Dalarna (cf. Welin 1970). However, the Malmberget porphyries for example, which are associated with apatite iron ores and thus can be correlated with the Kiruna porphyries, display metamorphic alterations. A consequence of a post-orogenic position of the Porphyry Group in relation to the Svecokarelian orogeny thus seems to be post-Svecokarelian folding and metamorphism. This could be related to the younger of the two radiometrically established Lina granites (1 530 Ma; cf. p. 50).

If future investigations should reveal a pre-1 900 extrusion age of the porphyries of Kiruna etc., correlation with southern and central Sweden would be facilitated. Efforts must then be made to date the regional migmatization of northernmost Sweden in order to ascertain whether this occurred at c. 1 800 Ma or whether it was, at least in part, later.

In spite of the problems discussed above, the Kurravaara and related conglomerates at the base of the porphyries together with the overlying supracrustal rocks (p. 43) have all been referred to the post-orogenic complex in this work, in agreement with the suggestions of Welin (1970).

The Kurravaara conglomerate rests conformably on the Kiruna greenstones, and is in part interbedded with the latter. Different porphyries (mostly sodic) form the majority of pebbles, whereas plutonic rocks are absent (Offerberg 1967). Above the conglomerate follow the Kiruna porphyries, including trachytic (syenite-porphyrific, in part sodic), and rhyolitic (quartz-porphyrific) volcanics. Among the former are types rich in magnetite (magnetite syenite porphyries). The apatite-bearing magnetite ore at Kiruna, which is one of the largest iron ores of the world, occurs as an inclined sheet, the foot wall of which is syenite porphyry and the hanging wall, quartz porphyry. The ore was considered by Geijer (1931b) to be the result of differentiation of the same magmas as gave rise to the Kiruna porphyries. Thus late-magmatic iron-rich differentiates were formed, which intruded the porphyries, brecciating the

TABLE 2. Chronology of major rock units in the Svecokarelian orogenic belt, the region of the Småland-Värmland-Swedish Museum of Natural History. For references see text.

	Region of Småland-Värmland intrusions	Blekinge region	Sveco- Götaland, Svealand
Post-orogenic and anorogenic complexes (in relation to Svecokarelian orogeny)	Visingsö group (c. 700-850) Dolerite, Almesåkra (960-980) Almesåkra group Götemar granite (1 350) Jungfrun granite Norra Kärr massif (1 545) Småland dike porphyry (1 620) Värmland granites (1 655-1 665) Småland granites (1 690) Småland porphyry (1 645)	Dolerites (870-975) Karlshamn granite (1 360-1 430) Vånga granite? Småland granites	NNW striking dolerites (900-970) Granholmen dolerite Åsby-Särna dolerite (1 220) Tuna dolerites (1 371) Öje basalt Dala sandstone Mälarsandstone Hällefors-Breven dolerites (1 510-1 560) Almunge massif (1 587-1 700) Dala granites Dala porphyries (1 635) Lower Dala formation?
1 750-1 800			Stockholm granite and pegmatite (1 795) Fellingsbro granite Malingsbo granite Enkullen granite
Serogenic intrusions			
Bothnian			("Intraorogenic" dikes)
Primorogenic intrusions	Vetlanda-Oskarshamn intrusions (1 800-1 925)	Older granitoids?	Gabbro - granite, e.g. at Norrköping (1 875-1 925), Loftahammar (1 845-1 870), Öro-Hamnö (1 845-1 910), Uppsala, Vänge, Vätö etc.
1 950			
Oldest supra-crustals	Vetlanda supergroup Västervik formation	Västana formation? Coastal geniss?	Grythyttan slates etc. Larsbo formation Leptite formation Mälarsandstone formation
2 200-2 500			
Pre-Svecokarelian	Basement of Västervik quartzite (2 220-2 465)		

land intrusions, and Blekinge. Age figures (in Ma) are mainly from the Laboratory for Isotope Geology,

karelian orogenic belt

Norrland south of Västerbotten County	Västerbotten County and southernmost Norrbotten County	Norrbotten County	
Ulvö dolerite (1 215) Gävle-Nordingrå sandstones Rödö granite Strömsbro granite Ragunda granite, syenite (c. 1 290) Nordingrå granite (c. 1 415) Ragunda gabbro Nordingrå gabbro (c. 1 550)	Dolerite (Ulvö type) Rapakivi granite, Bonden Sorsele granite (1 590) Ledfat granite (1 645) Dobblon volcanics (1 690)	Kalix alkaline ultra-basic dikes (1 152) Gabbro diabase, Nabrenjarka Perthite granites and syenites (1 505–1 530) Lina granite, in part (1 530) Upper Hauki complex, Quartzite Groups Paittasjärvi greenstones Kiruna porphyry (1 570?) Kaska-Tjäurek porphyry (1 600?) Kurraavaara conglomerate (?) Bälinge formation?	Post-orogenic and anorogenic complexes (in relation to Sveco-karelian orogeny)
Rätan granite (1 650) Hedesunda granite (?)	Arvidsjaur porphyries (in part)? Vargfors-Ledfat supracrustals? Adak granite (1 735) Arvidsjaur granite (1 740)		1 750–1 800
Revsund granite Sörvik granite	Revsund granite (1 745)	Degerberg granite (1 770) Lina granite, in part (1 780)	Seroro-genic intrusions
Härnö granite	Skellefte granite		
	Arvidsjaur porphyries (in part)? Vargfors-Ledfat supracrustals? Elvaberg schists?	Bälinge formation?	Bothnian
Gabbro-granite, e.g. Ljusdal "granite"	Gabbro-granite (Jörn suite)	Gabbro-granite (Haparanda suite; 1 840)	Primoro-genic intrusions
Härnö formation Naggen formation Los formation Hamrånge formation Leptite formation	Arvidsjaur porphyries (in part)? Metasediments and meta-volcanics in the Skellefte field	Ultevis metavolcanics(?) Snavva-Sjöfall formation(?) Quartzite Groups Greenstone Groups	1 950 Oldest supra-crustals
Basement of Naggen quartzite		Gneissose granites north of Kiruna (2 750–2 800)	Pre-Sveco-karelian

latter (Fig. 36). Geological observations in the field and geochemical data have later been interpreted by Parák (1975) to indicate an exhalative-sedimentary origin, in agreement with the conclusions of Landergren (1948) and Oelsner (1961). Frietsch (1978) criticized this interpretation, maintaining a magmatic-intrusive origin.

Iron ores of Kiruna type occur for example at Gällivare (Geijer 1930), Luossavaara, Tuolluvaara, Svappavaara (Frietsch 1966), Ekströmsberg and Mertainen. (See also Frietsch 1963 as well as Grip and Frietsch 1973.) The ores are all related to acid or intermediate volcanics (porphyries).

In the porphyries of Kiruna type occur intercalations of intermediate and basic (meta)volcanics, agglomerates, tuffs and tuffites, conglomerates and arenitic to pelitic metasediments (Offerberg 1967; Eriksson and Hallgren 1975).

Above the porphyries of Kiruna type follow quartzites, phyllites and conglomerates, included in the Maattavaara Quartzite Group of Eriksson and Hallgren (1975) and in the Upper Hauki Complex of Geijer (1931a) and Offerberg (1967). Between the latter complex and the Kiruna porphyries occur the Paittasjärvi greenstones of Offerberg (op.cit.). These in part show pillow structures, and are associated with tuffites and skarn iron ore.

Supracrustal formations which may be included in the post-orogenic complex occur in some limited areas near the coast of Norrbotten County. The Bälunge formation near Luleå is mainly composed of conglomerates (Fig. 37) with minor feldspar-quartzitic sandstones, porphyrites, and phyllites (Åhman and Ödman 1952; Ödman 1957). Plutonics of the Haparanda suite, veined gneiss, pegmatite, various volcanic rocks, and a granite correlated with the Revsund granite form the pebbles. The Bälunge formation should probably be regarded as post-orogenic in relation to the Svecokarelian orogeny. Its stratigraphic position is, however, not clear. This is also true of the Pite conglomerate (Grip 1939; Åhman 1957; Ödman 1957).

Considering the fact that the pre-Svecokarelian basement forms a lobe towards the northern end of the Gulf of Bothnia (Simonen 1960a), it seems possible that some conglomerates etc. observed on the Swedish side may in fact belong to the basal Svecokarelian formations. Possibly the older conglomerate observed by Åhman (1953) in the Vallen-Alhamn area and the Pite conglomerate may in fact have this stratigraphic position, and may therefore rather belong to the orogenic complex.

Large granite massifs occur in Norrbotten County. In many cases their position in the chronological scheme is uncertain. By radiometric dating it has, however, become clear that perthite granites and syenites and part of the Lina granite are post-orogenic in relation to the Svecokarelian orogeny. The perthitic intrusives occur in several massifs from Pajala in the east via Kiruna to the Caledonian border in the west. They are characterized by strongly perthitic alkali feldspars (Fig. 38; Ödman 1957). Monzonitic varieties also occur (Witschard 1975). Rb-Sr dating of perthite granites has yielded 1 505 Ma, and of perthite syenites etc. 1 530 Ma (Gulson 1972).

The Lina granite, or rather parts of what has been called Lina granite, belongs to the youngest granites of the region, having an Rb-Sr age of 1 530 Ma (Welin et al. 1971).

It is accompanied by pegmatites and migmatization (cf., however, p. 46). An extensive scapolitization in older rocks (Fig. 39) has been ascribed to the Lina granite (Ödman 1957).

The gabbro diabase at Nabrenjarka, Stora Lulevatten, postdates perthite granites and Lina granite (Witschard 1975). It forms a semicircular body with a diameter of c. 50 km, dipping gently westward. Essential constituents are plagioclase, augite, biotite, magnetite, and secondary hornblende. Hypersthene and pigeonite also occur.

The tectonic evolution of the Precambrian of Norrbotten County is complicated and not yet fully investigated. It seems especially important to clarify the age of different fold phases and their relation to metamorphism (migmatization).

Offerberg (1967) emphasized the importance of block movements and faulting for the N-S structures of the Kiruna porphyry region. Folding was less important. In the Vittangi region at least two phases of folding have occurred (Eriksson and Hallgren 1975). The first of these was probably connected with the Haparanda intrusives, and should therefore predate the porphyries of Kiruna type. The second phase, during which migmatization occurred, cannot be clearly distinguished from the first.

On account of the scanty exposures of the bedrock in these parts of Sweden tectonic interpretations are largely based on aeromagnetic mapping. In this way an interference of folding along N-S axes with weaker folding along E-W axes has been demonstrated in the Fjällåsen region (Witschard 1975). An interference of NW-SE and NE-SW folding has been established for the Tärendö and Lainio regions. Possibly this folding was connected with the Haparanda intrusives (Padget 1970, 1977).

CHRONOLOGY

The chronology of the Svecokarelian orogenic complex and post- to anorogenic complexes is summarized in Table 2. Included are also the region of the Småland-Värmland intrusions and the Blekinge region. It is to be noted that the position of several units is tentative. In some cases two alternative possibilities have been given. The order within the different "boxes" does not necessarily reflect stratigraphic relations.

ALKALINE COMPLEXES

In Sweden there are four alkaline complexes characterized by minerals like nepheline, cancrinite, alkali pyroxene, alkali amphibole, etc. The occurrences are found at Särna, Norra Kärr, Almunge, and Alnön (Fig. 4). In this connection the alkaline, ultrabasic dikes of Kalix archipelago should also be mentioned.

For the sake of uniformity all the above complexes are treated here, although some of them are of Phanerozoic age.

Near Särna occurs cancrinite-bearing nepheline syenite (särnaite) associated with aegirine-rich dike rocks (tinguaites). The latter cut i. a. the Dala sandstone (Hjelmqvist



Fig. 4. Occurrences of alkaline rocks in Sweden.

1966). Rb-Sr dating has yielded 281 Ma (Late Carboniferous), i.e. similar to the age of the igneous complex of the Oslo region in Norway (Bylund and Patchett 1977).

The Norra Kärr massif near Gränna is composed of various nepheline-syenitic rocks, carrying for example the zirconium-bearing minerals eudialite and catapleite (Adamson 1944; cf. also von Eckermann 1968 and Koark 1969). According to an Rb-Sr determination the age is 1 545 Ma (Blaxland 1977).

In the Almunge massif east of Uppsala syenitic, in part nepheline-cancrinite-bearing rocks predominate (Quensel 1914). The surrounding crystalline rocks have been fenitized, i.e. metasomatically altered towards more alkaline compositions. Alkali pyroxenes and amphiboles were thereby formed (Gorbatshev 1960). K-Ar dating of biotite from the Almunge massif has yielded 1 700 Ma (Gorbatshev 1970) and 1 587 Ma (Doig 1970).

Near Sundsvall occurs the Alnö alkaline complex. This complicated massif has above all been studied by von Eckermann, who has presented his results in a great number of publications (e.g. von Eckermann 1948, 1961, 1974). Intrusive carbona-

tites (sövites) form steeply dipping dikes. According to von Eckermann the sövite magma caused a fenitization of the surrounding migmatites, so that more or less homogeneous, ultra-fenitic nepheline syenites were formed. A less intense fenitization resulted in syenites and quartz syenites. Also basic fenites occur, some of which are rich in titaniferous magnetite. In the Alnö massif and the surrounding Precambrian rocks a great number of dikes occur. Especially noteworthy are carbonatites (alvikites dominated by calcite and beforsites by dolomite), alnöites and kimberlites. Phonolitic dikes are also found. With regard to their attitude in relation to the Alnö massif some of the dikes can be classified as cone sheets, others as radial dikes. There occur, however, numerous dikes which fit into neither of these patterns (Kresten and Lundqvist, unpublished investigations).

Recent magnetometric work in the Alnö region has indicated that the main alkaline complex is smaller than assumed by von Eckermann, and is accompanied by a satellite intrusion in the north (Kresten 1976). In addition, some of the alkaline rocks earlier regarded as fenites are probably intrusive and magmatic. Kresten (op. cit.) thus regards the ijolites as primary magmatic intrusions, which have caused the major fenitization. There are also observations suggesting the presence of another intrusion centre on the bottom of Åvikebukten north-east of Alnön (Söderström 1966; see also Kresten et al. 1977).

According to available K-Ar data the Alnö alkaline and carbonatitic intrusions occurred during the Cambrian period, c. 550–580 Ma ago (Doig 1970; Welin et al. 1972; Kononova et al. 1973; Kresten et al. 1977).

In the archipelago of Kalix a number of alkaline ultrabasic dikes have been found. They seem to be unrelated to a massif of alkaline rocks. Larsson (1943) subdivides the dikes into alnöitic, picrite-porphyritic, and carbonatitic kimberlites, while Kresten et al. (1977) classify them as alnöites, silicocarbonatites, and beforsites. A K-Ar age determination has yielded 1 152 Ma (Kresten et al. op.cit.).

PLATE-TECTONIC ASPECTS ON THE SWEDISH PRECAMBRIAN

The author would like to conclude this review by briefly giving his personal ideas on the application of plate-tectonic concepts to the Swedish Precambrian. This might perhaps seem premature as our present knowledge is imperfect in several respects. Nevertheless, the aspects given below might serve as a working hypothesis for future research.

It is possible that Phanerozoic plate-tectonic concepts cannot be directly applied to the Precambrian, because of a higher heat flow during early phases of the earth's history, for example. Despite this, tectonic, metamorphic and geochronological features accounted for in earlier chapters may be taken to indicate that the Svecokarelian orogenic belt and the older supracrustal and intrusive gneisses of south-western Sweden and southern Norway are genetically related and together form a pair of Precambrian metamorphic belts. The two belts should have been generated in connec-

tion with a subduction zone starting in a NNW trending trench in the present south-western Sweden and southern Norway and dipping rather gently eastward below the Svecokarelian orogenic belt of Sweden and Finland. This model is essentially based on concepts referred and summarized by Miyashiro (1973). It is in agreement with the conclusions of Hietanen (1975), based on a comparison of magmatic evolution in south-western Finland and the northern Sierra Nevada, North America. Hjelmqvist (1973) and Torske (1977) have also emphasized similarities in geological evolution between Cordilleran-type orogeny on one hand, and the Swedish and south-Norwegian Precambrian, respectively, on the other.

The following arguments may be put forward in favour of the proposed model:

1. Megastructures in the Swedish and Finnish Precambrian run in a N-S to NW-SE direction (cf. Magnusson et al. 1960 and Simonen 1960a). Examples are the western border of the pre-Svecokarelian basement, the belt of Småland-Värmland intrusions, the shear (fault) zones at the western border of the latter, and the Åmål complex.
2. There is a pronounced contrast in tectonic style between the Svecokarelian orogenic complex and the SW-Swedish gneisses. As already stated, the latter are characterized by more flat-lying structures and more intense deformation ('*Durchbewegung*'), than the Svecokareliides. The SW-Swedish gneisses in their tectonic style bear some resemblance to the Caledonides (e.g. Zwart 1967, Strömberg 1978).
3. In the Svecokarelian orogenic belt metamorphism is exclusively in the low pressure facies series (Lundqvist 1978; Simonen and Vormaa 1978). In the SW-Swedish gneisses there occur assemblages characteristic of both low and intermediate pressure facies series. It is not known whether one assemblage replaces the other or whether transitional conditions have prevailed (Lundqvist 1978). Neither is the age of the two types of metamorphism known. In the south-Norwegian Precambrian only low-pressure metamorphism seems to be represented (Torske 1977).
4. According to radiometric dates mainly emanating from the pioneer work of E. Welin and co-workers (see Tables 1 and 2) the magmatic evolution of the Svecokarelian orogenic belt, including post- and anorogenic complexes, embraces the time interval between roughly 2 000 Ma and c. 900 Ma (cf. also Kouvo and Tilton 1966, and the Annual Reports of the Geological Survey of Finland for the latest two decades). However, the oldest Svecokarelian volcanic rocks of Sweden have as yet not been dated by radiometric methods. The final phases are represented by dolerite intrusions (Patchett 1978). Folding and metamorphism on a regional scale were essentially completed at c. 1 750-1 800 Ma (cf., however, p. 47). In south-western Sweden the oldest magmatic (volcanic) rocks are probably of the order of 2 000 Ma, but radiometric data are lacking. Granitic magmatism started at c. 1 700-1 920 Ma, and ceased at c. 900 Ma (cf. Table 1 and p. 9). Later dolerites (800-900 Ma) are of minor importance. Folding and metamorphism in all

evidence occurred repeatedly up to c. 1 000 Ma. In the Precambrian of southern Norway radiometric ages, as summarized by Verstevee (1975) and Torske (1977), are similar to those of south-western Sweden. In the western part of southern Norway ages as low as 840 Ma have been determined for plutonic intrusives (Verstevee *op.cit.*).

It thus appears that radiometric ages of magmatic rocks in south-western Sweden and in the Svecokarelian orogenic belt broadly fall in the same time interval (c. 2 000–900 Ma). However, there is a definite tendency for higher ages in the Svecokarelian. An important difference is that essentially younger phases of deformation and regional metamorphism and more voluminous young granitic intrusions (c. 1 400–900 Ma) have occurred in south-western Sweden.

5. Shear zones, which run approximately along the western border of the Småland-Värmland intrusions, represent faulting of great magnitude. Thus, the distribution of K-Ar ages in southern Sweden indicates a major uplift of the western block during or after the Sveconorwegian regeneration at c. 1 000 Ma (Welin and Blomqvist 1966). Earlier movements along these tectonic zones have probably also occurred (p. 21).
6. Hietanen (1975) has compared compositional trends of igneous rocks in the Svecokarelian of Finland and Sweden with those of the Sierra Nevada region of North America. Hietanen, based on this observation, suggested a plate-tectonic model which essentially agrees with that proposed here. In addition, lateral variations in dolerite chemistry may be taken to indicate an eastward dipping subduction zone as outlined above. Jotnian dolerites of central Sweden are alkali olivine-basaltic (Lundqvist and Samuelsson 1973), whereas in the more westerly (trench-near) hyperite dolerites in northern Skåne high alumina-basaltic and tholeiitic compositions also occur (cf. Kornfält *et al.* 1978). Although the two dolerite generations are not synchronous and the subduction zone thus may have migrated between their intrusions (cf. below), this may be an expression of a tectonic situation similar to that prevailing in Quaternary time in Japan (e.g. Kuno 1960).

Additional evidence is given by data on the isotopic composition of ore lead from the Svecokarelian of Sweden and Finland (Rickard 1978). The north-eastward decreasing proportion of radiogenic lead is consistent with the plate-tectonic model suggested by Hietanen (1975).

From the above, the following evolution may be briefly outlined. At c. 2 000 Ma there existed a major NNW-ly trench in the oceanic crust in south-western Sweden and Norway. This trench was successively filled with mainly sedimentary and basaltic to andesitic material, now exposed as, for example, the Stora Le–Marstrand formation and supracrustal rocks among the SW–Swedish gneisses. In the east there occurred volcanic island arcs in the roof of an eastward dipping subduction zone. These arcs mainly existed in the Bergslagen region and in the Skellefte field (Hietanen 1975, Rickard and Zweifel 1975, Adamek and Wilson 1977, Löfgren 1979, and Loberg

personal communication). Between the arcs major basins were successively filled with greywackes, argillites, etc. (cf. Hietanen *op.cit.*). The pre-Svecokarelian (c. 2 700 Ma) continent was situated in the present region of eastern Finland and the Soviet Union. Basement rocks of similar (or somewhat lower) age were probably also exposed in the neighbourhood of the Västervik, Los-Hamra and Naggen regions, where they weathered to form thick quartzitic and arkosic sediments. This westerly basement was not necessarily continuous with that of eastern Finland etc., but may have formed disrupted fragments of the latter. Thus, it is possible that the early Svecokarelian (Svecofennian; cf. p. 6) supracrustal formations were in part deposited directly on an oceanic crust.

Large volumes of calc-alkali magmas were formed in connection with subduction, giving rise to the prim- and serrogenic intrusions in the Svecokarelian orogenic belt and later (?) to the mainly tonalitic to granitic plutonics in south-western Sweden. If 1 700 Ma represents the intrusive age of the latter, these plutonics were intruded when post-orogenic (in relation to the Svecokarelian orogeny) magmatism was active in the Småland-Värmland belt further east. In the region of south-western Sweden and southern Norway, which represented what Miyashiro (e.g. 1973) calls "the main theatre of metamorphism", intense penetrative movements under the conditions of the intermediate pressure facies series changed the early supracrustals and intrusives to gneisses.

During later phases of movement the subduction zone may have migrated towards the west (oceanward), as the centre of igneous activity was displaced in this direction. The magmas thus generated gave rise to the more alkalic post- and anorogenic igneous rocks in the essentially stabilized Svecokarelian orogenic belt (cf. Hjelmqvist 1973, Lundqvist and Samuelsson 1973, Gorbatshev 1979 and personal communication). Sedimentation was here mainly of continental type (sandstones of Jotnian type). Important faulting occurred, in part probably controlled by pre-existing major shear zones (Strömberg 1976). In south-western Sweden magmatic activity of dominantly granitic composition took place at c. 1 400, 1 200 and 900 Ma (Table 1, p. 18).

Younger (post-1 700 Ma) phases of regional metamorphism in south-western Sweden may, with regard to the possible westward migration of the subduction zone, have been of low pressure type. However, this is only a hypothesis, as direct evidence of a change from intermediate to low pressure conditions with time is lacking (cf. above). The low pressure metamorphic minerals of southern Norway (Torske 1977) may possibly have completely replaced earlier intermediate-pressure phases. In this context it should also be noted that high-grade, low-pressure metamorphism of Dalslandian age has been reported from the Precambrian of south-western Norway by Hermans et al. (1975).

It is possible that the Dalslandian orogeny at c. 1 000 Ma may be linked with earlier orogenic events in south-western Sweden and southern Norway through the above suggested westward migration of the subduction zone. As pointed out by Gorbatshev (1979) a prolonged continental margin situation of Andean type is in agreement with

available evidence from this region. However, at present there seem to be insufficient data for establishing a model for this evolution, and further investigations in south-western Sweden and southern Norway must be awaited. Important problems to be solved concern the age and extent of tectonic phases in the interval c. 1 600–1 100 Ma, the extent of the Dalslandian orogeny, and the metamorphic imprints left by the Sveconorwegian regeneration.

After the Dalslandian orogeny block movements and faulting along more or less steeply dipping zones became important, perhaps as a consequence of re-establishment of isostatic equilibrium. Such faulting probably also occurred earlier, and may have been related to periods of decreasing rate of subduction. In this way older gneisses, granites etc. were exposed to erosion. The most important faulting took place along the eastern border of the SW-Swedish gneisses and involved an uplift of the latter in relation to the Svecokarelian fold belt and the Småland-Värmland intrusions (Welin and Blomqvist 1966). Dolerite dikes of c. 900 Ma age (Patchett 1978) are probably connected with this faulting. They run parallel to and east of the fault zones, and occur in a c. 700 km belt from Blekinge to Dalarna. It is interesting to note in this connection that major faults generally occur between high and low pressure metamorphic belts in the Circum-Pacific region, as for example the Median Tectonic Line of Japan (Miyashiro 1973).

From the above discussion it seems possible to distinguish two main Precambrian tectonic units in Sweden: the Svecokarelian orogenic belt with post- and anorogenic complexes on one hand and the Precambrian of south-western Sweden on the other. The latter displays a more complex and prolonged tectonic and metamorphic evolution, which may have started with an intermediate-pressure metamorphic belt associated with the low-pressure Svecokarelian belt. In addition, there is the pre-Svecokarelian basement complex in minor areas in the northernmost parts of the country.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the invaluable help given by friends and colleagues in discussions which have facilitated the compilation of the present review. Special thanks are due to the following persons, who read the manuscript and made valuable suggestions: S. Ahlin, M. Ambros, R. Frietsch, R. Gorbatshev, K.-A. Kornfält, B. Lundberg, P.H. Lundegårdh, I. Lundström, L. Persson, D. Rickard, L. Samuelsson, A. Strömberg, G. Stålhös, E. Welin, U. Wiklander, H. Wikman, A. Wikström and F. Witschard. P. Kresten checked the chapter on the alkaline complexes.

E. Welin in addition kindly put recalculated radiometric age figures at the author's disposal, and D. Rickard checked the English of the first draft.

B. Bygghammar, E. Göransson, B-E. Holmgren, and A. Nielsen gave valuable technical aid.

REFERENCES

GFF=Geologiska Föreningens i Stockholm Förhandlingar

NGU=Norges Geologiske Undersøkelse

SGU=Sveriges geologiska undersökning

- ÅBERG, G., 1978: Precambrian Geochronology of south-eastern Sweden. – GFF 100, pp. 125–154.
- ABRAHAMSEN, N., 1974: The palaeomagnetic age of the WNW-striking dikes around Gothenburg, Sweden. – GFF 96, pp. 163–170.
- ADAMEK, P. M., and WILSON, M. R., 1977: Recognition of a new uranium province from the Precambrian of Sweden. In "Recognition and Evaluation of Uraniferous Areas". – Int. Atomic Energy Agency, Vienna.
- ADAMSON, O. J., 1944: The petrology of the Norra Kärr District. An occurrence of alkaline rocks in southern Sweden. – GFF 66, pp. 113–255.
- ÅHMAN, E., 1953: Vallen-Alhamnområdet i Nederluleå s:n. Summary: The Vallen-Alhamn area, parish of Nederluleå, North-Eastern Sweden. – SGU C 529.
- 1957: Degerberget, Baggen och Kluntarna. Några drag ur Piteåområdets berggrundsgeologi. – SGU C 555.
- 1967a: Västra Gräddmanhällan, Kalix skärgård, Norrbottens län. – GFF 89, pp. 50–61.
- 1967b: Hoting-Rörströmabbbron i Västernorrlands län. English abstract. – SGU C 607.
- ÅHMAN, E., and ÖDMAN, O., 1952: Konglomeratet på Bälingsberget i Nederluleå s:n. – SGU C 523.
- AMBROS, M., 1970: Diskordans mellan två bergartsgrupper i norra Norrbottens urberg. Abstract, IX Nordiske Geologiske Vintermöde, Lyngby, Jan. 1970.
- 1978: Berggrundskartan 30L Lannavaara SV. – SGU Af 27.
- ANDERSSON, W., 1975: Precambrian geology of the Västanaå area, southern Sweden. Dissert., Univ. Lund.
- ASKLUND, B., 1947: Svenska stenindustriområden I–II. Gatsten och kantsten. – SGU C 479.
- 1950: Kosteröarna, ett nyckelområde för västra Sveriges prekambriiska geologi. Summary: The Koster Isles, a key area for the pre-Cambrian geology of Western Sweden. – SGU C 517.
- BÄCKSTRÖM, H., 1897: Vestanaåfältet. En petrogenetisk studie. Summary: The Vestanaå region. – SGU C 168.
- BERG-LEMBKE, E., 1970: A microscopic study of the Almesåkra quartzite-dolerite conglomerate. – GFF 92, pp. 40–48.
- BERGSTRÖM, L., 1963: Petrology of the Tjörn area in western Sweden. – SGU C 593.
- BLAXLAND, A. B., 1977: Apatitic magmatism at Norra Kärr? Rb-Sr isotopic evidence. – Lithos 10, pp. 1–8.
- BYLUND, G., and PATCHETT, P. J., 1977: Palaeomagnetic and Rb-Sr isotopic evidence for the age of the Säma alkaline complex, western central Sweden. – Lithos 10, pp. 73–79.
- COLLINI, B., 1951: "Visingsöformationen" in "Beskrivning till kartbladet Gränna" by P. GEJER. B. COLLINI, H. MUNTHE och R. SANDEGREN. – SGU Aa 193.
- DOIG, R., 1970: An alkaline province linking Europe and North America. – Can. Earth Sci. 7, pp. 22–28.
- DU RIETZ, T., 1953: Geology and ores of the Kristineberg deposit, Vesterbotten, Sweden. – SGU C 524.
- 1968: Huvuddragen av Garpenbergstraktens bergbyggnad. English abstract. – SGU C 631.
- ECKERMANN, H. von, 1938: The Anorthosite and Kenningite of the Nordingrå-Rödö region. – GFF 60, pp. 243–284.
- 1948: The alkaline district of Alnö Island (Alnö alkalina område). – SGU Ca 36.
- 1961: The Petrogenesis of the Alnö Alkaline Rocks. – Bull. Geol. Inst. Univ. Uppsala XL, pp. 25–36.
- 1968: New contributions to the interpretation of the genesis of the Norra Kärr alkaline body in Southern Sweden. – Lithos 1, pp. 76–88.
- 1974: The chemistry and optical properties of some minerals of the Alnö alkaline rocks. – Ark. Mineral. Geol. 5 no. 8.
- EICHSTADT, FR., 1885: Om kvartsit-diabaskonglomeratet i Småland och Skåne. – SGU C 74.
- EINARSSON, Ö., 1979: Den prekambriiska berggrunden i Dobblonområdet, Västerbottens län. The Precambrian rocks of the Dobblon area, Västerbotten County. – SGU C 748.
- ELBERS, F. J., 1971: Evolution of the Svecofennian orogeny in the north-eastern part of the Västervik area, south-eastern Sweden, with special reference to deformation, metamorphism and magmatism. Dissert., Vrije Univ., Amsterdam.
- ERIKSSON, B., and HALLGREN, U., 1975: Beskrivning till berggrundskartbladen Vittangi NV, NO, SV, SO. Description of the geological maps Vittangi NV, NO, SV, SO. Appendix: Geofysiska undersökningar (geophysical aspects) by H. Henkel. – SGU Af 13–16.
- ERIKSSON, T., 1954: Pre-Cambrian geology of the Pajala district, northern Sweden. – SGU C 522.

- ESKOLA, P., 1928: On rapakivi rocks from the bottom of the Gulf of Bothnia. – *Fennia* 50 no. 27.
- 1934: Über die Bottenmeerporphyre. – *Bull. Comm. géol. Finl.* 104, pp. 111–127.
- 1963: The Precambrian of Finland. In "The Geologic Systems: The Precambrian", vol. I (ed. K. Rankama), pp. 145–263. – J. Wiley & Sons Inc., London.
- FRIETSCH, R., 1963: Järnmalmförekomster inom Norrbottens län. With an English abstract. – *SGU C 592*.
- 1966: Berggrund och malmer i Svappavaaraområdet, norra Sverige. – *SGU C 604*.
- 1977: The Iron Ore Deposits in Sweden. Explanations to the International Map of the iron ore deposits of Europe. – *Geol. Bundesanst., Hannover*.
- 1978: On the Magmatic Origin of Iron Ores of the Kiruna Type. – *Econ. Geol.* 73, pp. 478–485.
- 1980: The ore deposits of Sweden. Guide to excursions O 78 A+C. 26th Int. Geol. Congr. – *Bull. Geol. Surv. Finl.*
- GAVELIN, A., 1904: Beskrifning till kartbladet Loftahammar. – *SGU Aa 127*.
- GAVELIN, S., 1931: Några iakttagelser över stratigrafi och tektonik inom Almesåkraformationen. – *GFF* 53, pp. 137–149.
- 1948: Adakområdet. Översikt av berggrund och malmer. Summary: The Adak Area. A review of geology and ore deposits. – *SGU C 490*.
- 1955a: Beskrivning till berggrundskarta över Västerbottens län. 1. Urbergsområdet inom Västerbottens län. – *SGU Ca 37*.
- 1955b: Sulfide mineralization in the Skellefte District, northern Sweden, and its relation to regional granitization. – *Econ. Geol.* 50, pp. 814–831.
- 1958: Synpunkter på urbergsstratigrafin inom gränsområdena mellan Västerbottens och Norrbottens län. – *GFF* 80, pp. 198–208.
- 1976: Genesis of Precambrian Sulfide Ores, Skellefte District, Sweden. Discussion. – *Econ. Geol.* 71, pp. 672–674.
- GAVELIN, S., and RUSSELL, R., 1967: Primary sedimentary structures from the Precambrian of Southeastern Sweden. – *GFF* 89, pp. 74–104.
- GAVELIN, S., LUNDSTRÖM, I., and NORSTRÖM, S., 1976: Svecofennian stratigraphy on Utö, Stockholm archipelago. Correlations with Finland and Sweden. – *SGU C 719*.
- GEIJER, P., 1929: Masugnsbyfältens geologi. – *SGU C 351*.
- 1930: Gällivare malmfält. Geologisk beskrivning. Summary: Geology of the Gällivare iron ore field. – *SGU Ca 22*.
- 1931a: Berggrunden inom malmtrakten Kiruna-Gällivare-Pajala. English summary: Pre-Cambrian geology of the iron-bearing region Kiruna-Gällivare-Pajala. – *SGU C 366*.
- 1931b: The iron ores of the Kiruna type. – *SGU C 367*.
- 1939: The Paragenesis of Ludwigite in Swedish Iron Ores. – *GFF* 61, pp. 19–33.
- 1959: Några aspekter av skarnmalmsproblemen i Bergslagen. English abstract. – *GFF* 514–533.
- 1963a: The Precambrian of Sweden. In "The Geologic Systems: The Precambrian", vol. I (ed. K. Rankama), pp. 81–143. – J. Wiley & Sons Inc., London.
- 1963b: Genetic relationships of the paragenesis Al_2SiO_5 -luzulite-rutile. – *Ark. Mineral. Geol.* 3, pp. 423–464.
- GEIJER, P., and MAGNUSSON, N. H., 1944: De mellansvenska järnmalmernas geologi. – *SGU Ca 35*.
- 1952: The iron ores of Sweden. In "Symposium sur les gisements de fer du monde", XIX Int. Geol. Congr., Alger, pp. 477–499.
- GODIN, L., 1976: Viscaria – en ny kopparmineralisering i Kirunagrönsten. Abstract, XII Nordiska geologiska vintermötet, Göteborg, Jan. 1976.
- GORBATSHEV, R., 1960: On the Alkali Rocks of Almunge. A preliminary report on a new survey. – *Bull. Geol. Inst. Univ. Uppsala XXXIX*, pp. 1–69.
- 1961: Dolerites of the Eskilstuna region, eastern central Sweden. – *SGU C 580*.
- 1962: Dolerite intrusions and cementation of the Jotnian sandstone in the Mälaren area, central Sweden. – *GFF* 84, pp. 65–87.
- 1967: Petrology of Jotnian rocks in the Gävle area, east central Sweden. – *SGU C 621*.
- 1969: A study of Svecofennian supracrustal rocks in central Sweden: Lithological association, stratigraphy, and petrology in part of the Mälaren-Hjälmaren basin. – *GFF* 91, pp. 479–535.
- 1970: K-Ar age of biotite from the Almunge alkaline intrusion. – *GFF* 92, pp. 501–502.
- 1971a: Aspects and problems of Precambrian geology in western Sweden. – *SGU C 650*.
- 1971b: Age relations and rocks of the Svecofennian-Gothian boundary, Linköping, south central Sweden. – *SGU C 664*.
- 1972a: Beskrivning till berggrundskartbladet Örebro NO. Description of the petrological map Örebro NO. – *SGU Af 103*.
- 1972b: The X-ray obliquity of potassic feldspar in the granites of Jämtland, northern central Sweden. – *GFF* 94, pp. 213–229.
- 1975: Fundamental subdivisions of Precambrian granitoids in the Åmål mega-unit and the evolution of the south-western Baltic Shield, Sweden. – *GFF* 97, pp. 107–114.

- 1977: Correlation of Precambrian supracrustal complexes in south-western Sweden and the sequence of regional deformation events in the Åmål tectonic mega-unit. – GFF 99, pp. 336–346.
- 1979: The Precambrian of the western Baltic Shield. "Expanded abstract" of a paper in Russian to be published in "Principles and criteria of subdivision of the Precambrian in mobile belts". (Report of the symposium "Precambrian correlations in the north of Europe", Leningrad 1978.)
- GORBATSHEV, R., and WELIN, E., 1975: The Rb-Sr age of the Ursand granite on the boundary between the Åmål and "Pregothian" mega-units of south-western Sweden. – GFF 97, pp. 379–381.
- GRIP, E., 1935: Die Arvidsjaurporphyre. Eine archaische Effusivgesteinsreihe im nördlichen Schweden. – Bull. Geol. Inst. Univ. Upsala XXV, pp. 135–220.
- 1939: Pitekonglomeratet och dess åldersställning. English summary. – GFF 61, pp. 49–62.
- 1941: Die Tektonik und Stratigraphie der zentralen und östlichen Teile des Skelleftefeldes. – Bull. Geol. Inst. Univ. Upsala XXX, pp. 67–90.
- GRIP, E., and FRIETSCH, R., 1973: Malm i Sverige 2. Norra Sverige. – Almqvist & Wiksell Läromedel, Stockholm.
- GULSON, B. L., 1972: The Precambrian Geochronology of Granitic Rocks from Northern Sweden. – GFF 94, pp. 229–244.
- GVEIN, Ø., 1967: Kongsvingerfeltets geologi. – NGU 246 B.
- GVEIN, Ø., SKÅLVOLL, H., and SVERDRUP, T., 1974: Berggrundskart 1:250,000 Torsby. – NGU.
- HELFRICH, H. K., 1971: Stratigraphie, Tektonik, Petrochemie und montangeologische Zuege am Nordrand der zentralen "Norrländgeosynklinalen". – SGU C 654.
- HENRIQUES, Å., 1964: Geology and Ores of the Åmmeberg District (Zinkgruvan) Sweden. – Ark. Mineral. Geol. 4 no. 1.
- HERMANS, G. A. E. M., TOBI, A. C., POORTER, R. P. E., and MAIJER, C., 1975: The High-grade Metamorphic Precambrian of the Sirdal-Ørsdal Area, Rogaland/Vest-Agder, South-west Norway. – NGU 318, pp. 51–74.
- HEYBROOK, P., 1950: The geology of the Dalskog Dals-Rostock region, Dalsland, Sweden. – Leidse Geol. Meded. 16, pp. 55–195.
- HIETANEN, A., 1975: Generation of potassium-poor magmas in the northern Sierra Nevada and the Svecofennian of Finland. – J. Res. U.S. Geol. Surv. 3, no. 6, pp. 631–645.
- HJELMQVIST, S., 1934: Zur Geologie des südschwedischen Grundgebirges. Die kristallinen Gesteine des Romeleåses. – Medd. Lunds geol.-mineral. inst. 58, pp. 1–183.
- 1938: Über Sedimentgesteine in der Leptitformation Mittelschwedens, die sogenannte "Larsboserie". – SGU C 413.
- 1950: The titaniferous iron-ore deposit of Taberg in the south of Sweden. – SGU C 512.
- 1956: On the Occurrence of Ignimbrite in the Pre-Cambrian. – SGU C 542.
- 1966: Beskrivning till berggrundskarta över Kopparbergs län. Summary: Description to map of the Pre-Quaternary rocks of the Kopparberg County, Central Sweden. With map in two sheets, to the scale of 1:200,000. – SGU Ca 40.
- 1969: En pålagringskontakt mot äldre Smålandsgranit. – GFF 91, pp. 149–158.
- 1973: An old evolution and a young "model". – SGU C 686.
- HÖGBOM, A. G., 1909a: Precambrian geology of Sweden. – Bull. Geol. Inst. Univ. Upsala X, pp. 1–80.
- 1909b: The igneous rocks of Ragunda, Alnö, Rödö and Nordingrå. – GFF 31, pp. 347–375.
- HOLMQUIST, P. J., 1899: Om Rödö rapakivi och gångbergarter. Mit einem Resumé in deutscher Sprache. – SGU C 181.
- HUBBARD, F. H., 1975: The Precambrian crystalline complex of south-western Sweden. The geology and petrogenetic development of the Varberg region. – GFF 97, pp. 223–236.
- HÜBNER, H., 1971: Molybdenum and tungsten occurrences in Sweden. – SGU Ca 46.
- JOHANSSON, H. E., 1910: The Åmmeberg Zinc ore field. – GFF 32, pp. 1 051–1 078.
- KAUTSKY, G., 1957: Ein Beitrag zur Stratigraphie und dem Bau des Skelleftefeldes, Nordschweden. English Summary: The stratigraphy and geological history of the Skellefte district, Archean, Northern Sweden. – SGU C 543.
- 1959a: Studien zur Paläogeographie des Archaikums im nördlichen Schweden. – GFF 81, pp. 559–571.
- 1959b: Gesichtspunkte zur Stratigraphie des Archaikums im Grenzgebiet zwischen Västerbotten und Norrbotten, Nordschweden. (Mit einem Beitrag von Sven Gavelin.) – GFF 81, pp. 733–750.
- KLINGSPOR, INGER, 1976: Radiometric age-determinations of basalts, dolerites and related syenite in Skåne, southern Sweden. – GFF 98, pp. 195–216.
- KOARK, H. J., 1962: Zur Altersstellung und Entstehen der Sulphiderze vom Typus Falun. – Geol. Rundschau 52, pp. 123–145.
- 1969: Zu Hülle, Inhalt, Gefüge und Alter des Alkaligesteinsvorkommen von Norra Kärr im südlichen Mittelschweden. – GFF 91, pp. 159–184.
- 1973: Zur Entstehung des tektonischen Stengelbaus an präkambrischen Eisen- und Sulfiderzkörpern der zentralschwedischen Leptiserie. – Mineral. Deposita (Berl.) 8, pp. 19–34.

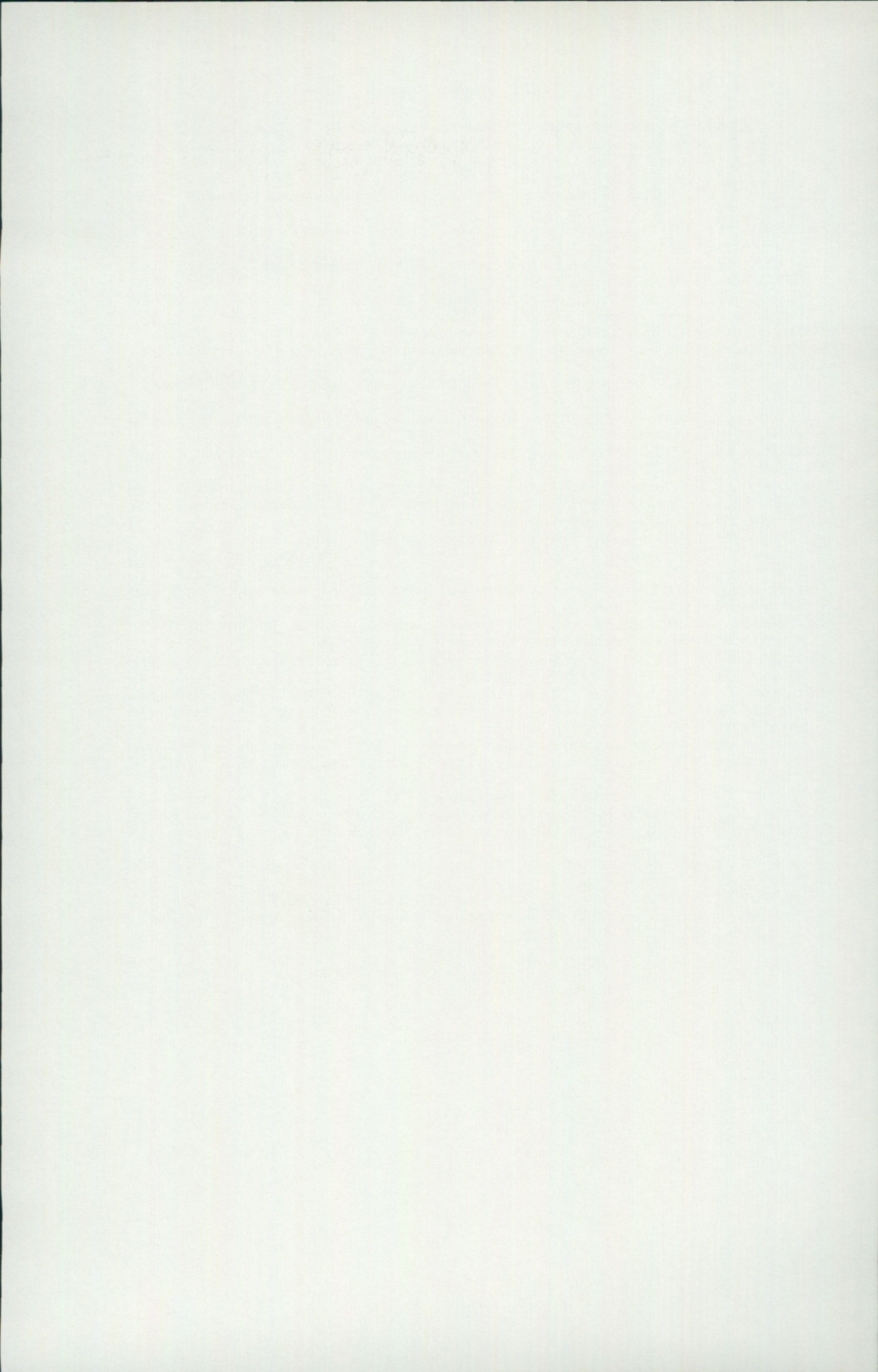
- KONONOVA, V. A., ŠALIN, L. L., and ARAKELJANC, M. M., 1973: Alkaline massifs and carbonatites – their time of formation. (Title translated from the Russian.) – *Izv. AN SSSR, ser. geol.* no. 5, pp. 25–36.
- KORNFÄLT, K.-A., 1969: X-ray and optical observations on the K-feldspars from the Ragunda area, central Sweden. – *SGU C 636*.
- 1976: Petrology of the Ragunda rapakivi massif, central Sweden. – *SGU C 725*.
- KORNFÄLT, K.-A., BERGSTRÖM, J., CARSERUD, L., HENKEL, H., and SUNDQVIST, B., 1978: Beskrivning till berggrundskartan och flygmagnetiska kartan Kristianstad SO. Description to the map of solid rocks and the aeromagnetic map Kristianstad SO. – *SGU Af 121*.
- KOUVO, O., and TILTON, G. R., 1966: Mineral ages from the Finnish Precambrian. – *J. Geol.* 74, pp. 421–442.
- KRESTEN, P., 1976: A magnetometric survey of the Alnö Complex. – *GFF 98*, pp. 361–362.
- KRESTEN, P., and CHYSSLER, J., 1976: The Götömar massif in southeastern Sweden. A reconnaissance survey. – *GFF 98*, pp. 155–161.
- KRESTEN, P., PRINTZLAU, I., REX, D., VARTIAINEN, H., and WOOLLEY, A., 1977: New ages of carbonatitic and alkaline ultramafic rocks from Sweden and Finland. – *GFF 99*, pp. 62–65.
- KROKSTRÖM, T., 1932: The Breven dolerite dike. A petrogenetic study. – *Bull. Geol. Inst. Univ. Upsala XXIII*, pp. 243–330.
- 1936: The Hällefors dolerite dike and some problems of basaltic rocks. – *Bull. Geol. Inst. Univ. Upsala XXVI*, pp. 113–263.
- KUNO, H., 1960: High-alumina Basalt. – *J. Petrol.* 1, pp. 121–145.
- LANDERGREN, S., 1948: On the geochemistry of Swedish iron ores and associated rocks. A study on ore-formation. – *SGU C 496*.
- LARSEN, O., and SPRINGER, N., 1976: Radiometrisk datering af granitoider i Blekinge og på Bornholm. Stencil. communic., XII Nordiska geologiska vintermötet, Göteborg, Jan. 1976.
- LARSON, S. Å., 1973: Igneous layering in the Ulvö dolerite, Ångermanland, Central Sweden. – *GFF 95*, pp. 407–409.
- LARSSON, W., 1943: Zur Kenntnis der alkalinen ultrabasischen Ganggesteine des Kalixgebiets, Nordschweden. – *SGU C 456*.
- 1947: Några resultat av berggrundsgeologiska studier inom Dalformationens norra gränsområde. English abstract. – *GFF 69*, pp. 321–336.
- 1956: "Berggrunden" in "Beskrivning till kartbladet Värvik" by W. LARSSON and R. SANDEGREN. – *SGU Aa 187*.
- 1966: "Berggrunden" in "Beskrivning till kartbladet Halmstad" by C. CALDENIUS, W. LARSSON, E. MOHRÉN, G. LINNMAN and H. TULLSTRÖM. – *SGU Aa 198*.
- 1968: "Berggrunden" in "Beskrivning till kartbladet Laholm" by E. MOHRÉN and W. LARSSON. – *SGU Aa 197*.
- LILLJEQUIST, R., and SVENSON, S.-Å., 1974: Exceptionally well preserved Precambrian ignimbrites and basic lavas in N. Sweden. – *GFF 96*, pp. 221–229.
- LIND, G., 1966: Gravity measurements over the Bohus granite in Sweden. – *GFF 88*, pp. 542–548.
- 1972: The Gravity and Geology of the Vättern Area, Southern Sweden. – *GFF 94*, pp. 245–258.
- LINDH, A., 1974: The mylonite zone in southwestern Sweden (Värmland). – *GFF 82*, pp. 183–197.
- 1977: The Blomskog granite – a possible diapiric structure. – *Precambrian Research 5*, pp. 261–282.
- LINDROOS, H., 1974: The stratigraphy of the Kaunisvaara iron ore district, northern Sweden. – *SGU C 695*.
- LINDROOS, H., and HENKEL, H., 1978: Regional geological and geophysical interpretation of Precambrian structures in northeastern Sweden. – *SGU C 751*.
- LJUNG, S., 1974: Adak-Lindsköld- och Brännmyrangruvorna inom Adakfältet. Petrografi och malmer. Summary: The Adak-Lindsköld- and Brännmyran mines in the Adak area, N. Sweden. Petrography and ores. – *SGU C 701*.
- LOBERG, B., 1963: The formation of a flecky gneiss and similar phenomena in relation to the migmatite and vein gneiss problem. – *GFF 85*, pp. 3–109.
- LÖFGREN, C., 1979: Do leptites represent Precambrian island arc rocks? – *Lithos 12*, pp. 159–165.
- LUNDBERG, B., 1973: Granite intrusions in the Dal Group, Central Sweden. – *GFF 95*, pp. 113–119.
- LUNDEGÄRDH, P. H., 1953: Petrology of the Mölndal-Styrsö-Vallda region in the vicinity of Gothenburg. – *SGU C 531*.
- 1954: "Berggrunden" in "Beskrivning till kartbladet Västerås" by P. H. LUNDEGÄRDH and G. LUNDQVIST. – *SGU Aa 196*.
- 1957a: Petrology of the Uppsala region. – *SGU C 544*.
- 1957b: The titaniferous ore-bearing gabbro of Helsingland, Central Sweden. – *SGU C 549*.
- 1958: Göteborgstraktens berggrund. Summary: Petrology of the Göteborg (Gothenburg)-Kungälv region, Western Sweden. – *SGU C 553*.
- 1960: The miogeosynclinal rocks of eastern central Sweden. – *SGU C 570*.

- 1967: Berggrunden i Gävleborgs län. Petrology of the Gävleborg County in Central Sweden. With maps to the scale of 1:200,000 and 1:75,000. – SGU Ba 22.
- 1971: Nyttosten i Sverige. – Almquist & Wiksell, Stockholm.
- 1974: Beskrivning till berggrundskartan Eskilstuna NV. Description to the map of solid rocks Eskilstuna NV. – SGU Af 111.
- 1977: The Gråsmark formation in western central Sweden. – SGU C 732.
- 1978: The Vånga granite in southernmost Sweden. – SGU C 749.
- LUNDEGÅRDH, P. H., LUNDQVIST, J., and LINDSTRÖM, M., 1974: Berg och jord i Sverige. 4th ed. – Almquist & Wiksell, Uppsala.
- 1978: Berg och jord i Sverige. 5th ed. – Ibid.
- LUNDQVIST, GUNILLA, 1976: Nordingråområdets gabbro och anortosit. Thesis, Univ. Göteborg.
- LUNDQVIST, TH., 1962: Det svekofenniska suprakrustalstråket mellan Ljusterö och Rödlöga i Stockholms norra skärgård. Summary: The Svecofennian supracrustal rocks in the region between Ljusterö and Rödlöga in the northern archipelago of Stockholm. – SGU C 585.
- 1968: Precambrian geology of the Los-Hamra region, central Sweden. – SGU Ba 23.
- 1973: Potash feldspar megacrysts of a granite at Skagsudde, Central Sweden. – SGU C 687.
- 1975: The "Kenningite" found near Sundsvall, central Sweden. – GFF 97, pp. 189–192.
- 1978: The Precambrian of Sweden. In "Explanatory text to Metamorphic map of Europe 1:2,500,000" (H. J. Zwart ed.), Leiden 1978, pp. 28–32. – Subcomm. for the Cartography of the Metamorphic Belts of the World, Leiden – Unesco Paris.
- LUNDQVIST, TH., and SAMUELSSON, L., 1973: The differentiation of a dolerite at Nordingrå, central Sweden. – SGU C 692.
- LUNDSTRÖM, I., 1974: Beskrivning till berggrundskartan Nyköping SV. Description to the map of solid rocks Nyköping SV. – SGU Af 109.
- MAGNUSSON, N. H., 1925: Persbergs malmtrakt och berggrunden i de centrala delarna av Filipstads bergslag. Dissert.
- 1929: Gillbergaskålens byggnad. – SGU C 360.
- 1940: Herrängsfältet och dess järnmalm. Summary: The Herräng field and its iron ores. – SGU C 431.
- 1948: Zinc and lead deposits of Central Sweden. XVIII Int. Geol. Congr. Great Britain. Rep. Pt. VII.
- 1953: Malmgeologi. – Jernkontoret, Stockholm.
- 1960a: Age determinations of Swedish Precambrian rocks. – GFF 82, pp. 407–432.
- 1960b: Iron and sulphide ores of Central Sweden. XXI Int. Geol. Congr. Norden. Guide to Excursions Nos. A26 and C21. – SGU.
- 1965: Pre-Cambrian history of Sweden. – Q. J. Geol. Soc. Lond. 121, pp. 1–30.
- 1970a: Stratigrafi och tektonik. Atlas över Sverige 5–6. – AB Kartografiska Institutet, Esselte AB, Stockholm.
- 1970b: The origin of the iron ores in central Sweden and the history of their alterations. Part I and II. – SGU C 643.
- MAGNUSSON, N. H., LUNDQVIST, G., and GRANLUND, E., 1957: Sveriges geologi. 3rd ed. – Svenska Bokförlaget/Norstedts, Stockholm.
- MAGNUSSON, N. H., THORSLUND, P., BRÖTZEN, F., ASKLUND, B., and KULLING, O., 1960: Description to accompany the map of the pre-Quaternary rocks of Sweden. With one map to the scale of 1:1,000,000 (1958). – SGU Ba 16.
- MAGNUSSON, N. H., LUNDQVIST, G., and REGNÉLL, G., 1963: Sveriges geologi. 4th ed. – Svenska Bokförlaget/Norstedts, Stockholm.
- MERILÄINEN, K., 1961: Albite diabases and albitites in Enontekiö and Kittilä, Finland. – Bull. Comm. géol. Finl. no. 195.
- MIYASHIRO, A., 1973: Metamorphism and Metamorphic Belts. – G. Allen & Unwin, London.
- MOGENSEN, F., 1946: A ferro-ortho-titanate ore from Södra Ulvön. – GFF 68, pp. 578–588.
- MOORE, P. B., 1971: Mineralogy & Chemistry of Långban-type Deposits in Bergslagen, Sweden. – Mineral. Record, Jan. 1971, pp. 154–172.
- MULDER, E. G., 1971: Paleomagnetic research in some parts of central and southern Sweden. – SGU C 653.
- NORDENSKIÖLD, O., 1894: Ueber archaische Ergussgesteine aus Småland. – SGU C 135. Also published in Bull. Geol. Inst. Upsala vol. 1 no. 2 (1893).
- NORIN, R., 1936: Contributions to the geology of western Blekinge. – GFF 58, pp. 481–561.
- 1959: Några genetiska relationer inom Södra Sveriges urberg. – GFF 81, pp. 427–466.
- ÖDMAN, O., 1941: Geology and ores of the Boliden deposit, Sweden. – SGU C 438.
- 1947: Manganese mineralization in the Ultevis district, Jokkmokk, north Sweden. – SGU C 487.
- 1957: Beskrivning till berggrundskarta över urberget i Norrbottens län. English summary: Description to Map of the Pre-Cambrian Rocks of the Norrbotten County, N. Sweden (excl. the Caledonian Mountain Range). – SGU Ca 41.
- OELSNER, O., 1961: Zur Genese der nord- und mittelschwedischen Eisenerzlagertstätten. – Geologi 10, pp. 601–622.

- OFFERBERG, J., 1959: Rocks and stratigraphy of the Ledfat area, Västerbotten County, northern Sweden. – SGU C 564.
- 1967: Beskrivning till berggrundskartbladen Kiruna, NV, NO, SV, SO. Description of the geological maps Kiruna NV, NO, SV, SO. With an appendix on the areomagnetic maps by S. Werner. – SGU Af 1–4.
- OVEREEM, A. J. A. van, 1948: A section through the Dal-formation. Dissert., Leiden.
- PADGET, P., 1959: Leucodiabase and Associated Rocks in the Karelic Zone of Fennoscandia. – GFF 81, pp. 316–332.
- 1970: Beskrivning till berggrundskartbladen Tändö NV, NO, SV, SO. Description of the geological map Tändö NV, NO, SV, SO. With an appendix on geophysical aspects by J. D. Cornwell. – SGU Af 5–8.
- 1977: Beskrivning till berggrundskartbladen Pajala NV, NO, SV, SO. Description of the geological maps Pajala NV, NO, SV, SO. Appendix: Geofysiska undersökningar (geophysical investigations) av H. Henkel. – SGU Af 21–24.
- PARAK, T., 1975: The origin of the Kiruna iron ores. – SGU C 709.
- PATCHETT, P. J., 1978: Rb/Sr ages of Precambrian dolerites and syenites in southern and central Sweden. – SGU C 747.
- PERSSON, L., 1974: Precambrian rocks and tectonic structures of an area in north-eastern Småland, southern Sweden. – SGU C 703.
- 1978: The Revsund-Sörvik granites in the western parts of the province of Ångermanland, central Sweden. – SGU C 741.
- PRIEM, H. N. A., MULDER, F. G., BOELRIJK, N. A. I. M., HEBEDA, E. H., VERSCHURE, R. H., and VERDURMEN, E. A. TH., 1968: Geochronological and Palaeomagnetic Reconnaissance Survey in parts of Central and Southern Sweden. – Phys. Earth Planet. Inter. 1, pp. 373–380.
- QUENSEL, P., 1914: The alkaline rocks of Almunge. – Bull. Geol. Inst. Univ. Upsala XII, pp. 129–200.
- 1951: The Charnockite series of the Varberg district on the south-western coast of Sweden. – Ark. Mineral. Geol. 1 no. 10.
- 1952: The Paragenesis of the Varuträsk Pegmatite. – Geol. Mag. LXXXIX, pp. 49–60.
- 1960: Vaggerydssyeniten. Summary: The Vaggeryd Syenite in Southern Sweden. – SGU C 576.
- RANKAMA, K., and WELIN, E., 1972: Joint meeting of the Precambrian stratigraphy groups of Denmark, Finland, Norway, and Sweden in Turku, Finland, March 1972. – Geol. Newsl. 1972 no. 4, pp. 265–267.
- RICKARD, D. T., 1978: The Svecofennian anomalous ore lead line. – GFF 100, pp. 19–30.
- RICKARD, D. T., and ZWEIFEL, H., 1975: Genesis of Precambrian Sulfide Ores, Skellefte District, Sweden. – Econ. Geol. 70, pp. 255–274.
- 1976: Genesis of Precambrian Sulfide Ores, Skellefte District, Sweden. Discussion. – Econ. Geol. 71, pp. 674–678.
- ROSEN, S., 1925: Konglomeratens vittnesbörd om Visingsöformationens geologiska ålder. Föredragsreferat. – GFF 47, pp. 365–366.
- RÖSHOFF, K., 1975: Some aspects of the Precambrian in south-eastern Sweden in the light of a detailed geological study of the Lake Nömmen area. – GFF 97, pp. 368–378.
- SAMUELSSON, L., 1978a: Beskrivning till berggrundskartan Göteborg SO. Description to the map of solid rocks Göteborg SO. – SGU Af 117.
- 1978b: The pre-Quaternary geology of the Göteborg region, south-western Sweden. Dissert., Univ. Lund.
- SAMUELSSON, L., and AHLIN, S., 1976: The Precambrian crystalline complex of south-western Sweden: The geology and petrogenetic development of the Varberg region. A comment. – GFF 98, pp. 168–170.
- 1978: Zircon morphology in the polymetamorphic rocks of south-western Sweden. – SGU C 737.
- SANDELL, A., 1941: Tektonik och morfologi inom dalformationen med omgivande urbergsterräng. Dissert., Univ. Lund.
- SEDERHOLM, J. J., 1893: Om berggrunden i södra Finland. – Fennia 8.
- 1895: Några ord om södra Finlands prekvartära geologi. – Fennia 12 no. 3.
- SIMONEN, A., 1960a: Pre-Quaternary rocks in Finland. – Bull. Comm. géol. Finl. 191.
- 1960b: Pre-Cambrian Stratigraphy of Finland. Int. Geol. Congr., Part IX. Report of the Twenty-First Session. Norden.
- SIMONEN, A., and VORMA, A., 1978: The Precambrian of Finland. In "Explanatory text to Metamorphic map of Europe" 1:2,500,000 (H. J. Zwart ed.), Leiden 1978, pp. 20–27. – Subcomm. for the Cartography of the Metamorphic Belts of the World, Leiden – Unesco Paris.
- SKIÖLD, T., 1976: The interpretation of the Rb-Sr and K-Ar ages of late Precambrian rocks in south-western Sweden. – GFF 98, pp. 3–29.
- 1977: Granite ages in the Kalix area, northern Sweden. – GFF 99, pp. 76–79.
- SOBRAL, J. M., 1913: Contributions to the geology of the Nordingrå region. Dissert. Univ. Upsala.
- SÖDERSTRÖM (TALLBACKA), L., 1966: The kimberlites of Åvike Bay, on the Bothnian coast of Sweden. – GFF 88, pp. 352–360.

- STÅLHÖS, G., 1958: En bäddformig jotnisk diabas i norra Västerbotten. With an English abstract. – GFF 80, pp. 55–58.
- 1962: Nya synpunkter på Sörmlandsgnejsernas geologi med särskild hänsyn till Stockholmstrakten. Summary: Aspects of the Sörmland Gneisses in Eastern Sweden. – SGU C 587.
- 1969: Beskrivning till Stockholmstraktens berggrund. With map to the scale of 1:100,000 (1968). English summary. – SGU Ba 24.
- 1972: Beskrivning till berggrundskartbladen Uppsala SV och SO. Solid rocks of the Uppsala region (map-sheets Uppsala SW and SE). – SGU Af 105–106.
- 1975: Beskrivning till berggrundskartan Nyköping NO. Description to the map of solid rocks Nyköping NO. – SGU Af 115.
- 1976: Aspects of the regional tectonics of eastern central Sweden. – GFF 98, pp. 146–154.
- 1979: Beskrivning till berggrundskartan Nynäshamn NV/SV. Description to the map of solid rocks Nynäshamn NV/SV. – SGU Af 125.
- STEIGER, R. H., and JÄGER, E., 1977: Subcommission on Geochronology: Convention on the use of decay constants in Geo- and Cosmochronology. – Earth Planet. Sci. Lett. 36, pp. 359–362.
- STRÖMBERG, A. G. B., 1976: A pattern of tectonic zones in the western part of the East European Platform. – GFF 98, pp. 227–243.
- 1978: The Caledonides of Sweden. In "Explanatory text to Metamorphic map of Europe" 1:2,500,000 (H. J. Zwart ed.), Leiden 1978, pp. 70–73. – Subcomm. for the Cartography of the Metamorphic Belts of the World, Leiden – Unesco Paris.
- SUNDIUS, N., 1921a: Ätvidabergstraktens geologi och malmfyndigheter. Resumé in deutscher Sprache. – SGU C 306.
- 1921b: Några frågor rörande våra arkeiska intrusivformationer i mellersta och södra Sverige. – GFF 43, pp. 548–595.
- 1923: Grythyttfältets geologi. – SGU C 312.
- 1944: Orogene Erscheinungen im südwestlichen Schweden. – GFF 66, pp. 288–294.
- 1948: Beskrivning till berggrundskarta över Stockholmstrakten. – SGU Ba 13.
- SVENSSON, U., 1970: Geochemical investigation of the principal Pre-Cambrian rocks of Västerbotten County, Sweden. – SGU C 652.
- TALLBACKA, see SÖDERSTRÖM.
- THORSLUND, P., and AXBERG, S., 1979: Geology of the southern Bothnian Sea. Part I. – Bull. Geol. Inst. Univ. Uppsala, N. S. 8, pp. 35–62.
- TIMOFEEV, B. V., 1960: Sur la caractéristique micropaléontologique de la formation de Visingsö. – GFF 82, pp. 28–42.
- TÖRNEBOHM, A. E., 1870: Några ord till upplysning om bladet "Upperud". – SGU Aa 37.
- TORSKE, T., 1977: The south Norway Precambrian region – a Proterozoic Cordilleran-type orogenic segment. – Nor. Geol. Tidsskr. 57, pp. 97–120.
- WAHL, W., 1936: Om granitgrupperna och bergskedjeveckningarna i Sverige och Finland. – GFF 58, pp. 90–101.
- WELIN, E., 1970: Den svekofenniska orogena zonen i norra Sverige – en preliminär diskussion. – GFF 92, pp. 433–451.
- WELIN, E., and BLOMQVIST, G., 1964: Age measurements on radioactive minerals from Sweden. – GFF 86, pp. 33–50.
- 1966: Further age measurements on radioactive minerals from Sweden. – GFF 88, pp. 3–18.
- WELIN, E., and GORBATSCHEV, R., 1976a: Rb-Sr age of granitoid gneisses in the "Pregothian" area of south-western Sweden. – GFF 98, pp. 378–381.
- 1976b: A Rb-Sr geochronological study of the older granitoids in the Åmål tectonic mega-unit, south-western Sweden. – GFF 98, pp. 374–377.
- 1976c: The Rb-Sr age of the Hästefjorden granite and its bearing on the Precambrian evolution of south-western Sweden. – Precambrian Research 3, pp. 187–195.
- 1978: Rb-Sr age of the Lane granites in south-western Sweden. – GFF 100, pp. 101–102.
- in press: A Rb-Sr age of the Åmål granite at Åmål, Sweden. – GFF.
- WELIN, E., and LUNDQVIST, TH., 1970: New Rb-Sr age data for the sub-Jotnian volcanics (Dala porphyries) in the Los-Hamra region, central Sweden. – GFF 92, pp. 35–39.
- 1975: K-Ar ages of Jotnian dolerites in Västernorrland County, central Sweden. – GFF 97, pp. 83–88.
- 1977: Rb-Sr dating of the Råtan granite, central Sweden. – GFF 99, pp. 417–420.
- WELIN, E., BLOMQVIST, G., and PARWEL, A., 1966: Rb/Sr whole rock age data on some Swedish Precambrian rocks. – GFF 88, pp. 19–28.
- WELIN, E., CHRISTIANSSON, K., and NILSSON, Ö., 1970: Rb-Sr age dating of intrusive rocks of the Haparanda suite. – GFF 92, pp. 336–346.
- 1971: Rb-Sr radiometric ages of extrusive and intrusive rocks in northern Sweden. I. – SGU C 666.
- WELIN, E., LUNDSTRÖM, I., and ÅBERG, G., 1972: Fission Track Studies on Hornblende, Biotite and Phlogopite from Sweden. – Bull. Geol. Soc. Finl. 44, pp. 35–46.

- WELIN, E., EINARSSON, Ö., GUSTAFSSON, B., LINDBERG, R., CHRISTIANSSON, K., JOHANSSON, G., and NILSSON, Ö., 1977a: Radiometric Ages of intrusive Rocks in Northern Sweden. II. – SGU C 731.
- WELIN, E., GORBATSCHEV, R., and LUNDEGÄRDH, P. H., 1977b: Rb-Sr dating of rocks in the Värmland granite group in Sweden. – GFF 99, pp. 363–367.
- VELTHEIM, V., 1962: On the pre-Quaternary geology of the bottom of the Bothnian Sea. – Bull. Comm. géol. Finl. 200.
- VERSTEEVE, A. J., 1975: Isotope Geochronology in the High-grade Metamorphic Precambrian of South-western Norway. – NGU 318, pp. 1–50.
- VESBY, E., 1968: On the acid volcanics and the ore formation in the Skellefte district, northern Sweden. – GFF 90, pp. 272–301.
- WICKMAN, F. E., BLOMQUIST, N. G., GEJER, P., PARWEL, A., UBISCH, H. von, and WELIN, E., 1962: Isotopic constitution of ore lead in Sweden. – Ark. Mineral. Geol. 3 no. 11, pp. 193–257.
- VIDAL, G., 1972: Algal stromatolites from the Late Precambrian of Sweden. – Lethaia 5, pp. 353–368.
- 1974: Late Precambrian microfossils from the basal sandstone unit of the Visingsö beds, south Sweden. – Geol. Palaeontol. 8, pp. 1–14.
- 1976: Late Precambrian microfossils from the Visingsö Beds in southern Sweden. – Fossils and Strata 9, pp. 1–57.
- VIDAL, G. and RÖSHOFF, K., 1971: Organic Remains in Metasedimentary and Metatuffitic Rocks of the Vetlanda Series, South Sweden. A Preliminary Report. – GFF 93, pp. 775–778.
- WIKLANDER, U., 1974: Precambrian geology, geochemistry and age relations of northeastern Blekinge, southern Sweden. – SGU C 704.
- WIKMAN, H., 1972: "Rinkaby-Väringensområdet" In "Beskrivning till berggrundsgeologiska kartbladet Örebro NV. Description of the petrological map Örebro NW" by P. H. LUNDEGÄRDH, H. HÜBNER, H. WIKMAN, L. KARIS, and E. MAGNUSSON. – SGU Af 102.
- 1973: Ett svekofenniskt suprakrustalkomplex i Örebroområdet. Dissert., Univ. Lund.
- WIKSTRÖM, A., 1975: Beskrivning till berggrundskartan Norrköping NO. Description of the map of solid rocks Norrköping NO. – SGU Af 112.
- 1976: Beskrivning till berggrundskartan Katrineholm SV. Description of the map of solid rocks Katrineholm SV. – SGU Af 116.
- WIKSTRÖM, A., and HORNDAL, A. -K., 1975: Orientation of biotite in a dome- and -basin interference structure near Norrköping, south-eastern Sweden. – GFF 97, pp. 243–249.
- WINTERHALTER, B., 1972: On the geology of the Bothnian Sea. An epeiric sea that has undergone Pleistocene glaciation. – Geol. Surv. Finl. Bull. 258.
- WITSCHARD, F., 1970: Description of the geological maps Lainio NV, NO, SV, SO. Beskrivning till berggrundskartbladen Lainio NV, NO, SV, SO. With an appendix by P. Niskanen: The aeromagnetic maps Lainio NV, NO, SV, SO. – SGU Af 9–12.
- 1975: Description of the geological maps Fjällåsen NV, NO, SV, SO. Beskrivning till berggrundskartbladen Fjällåsen NV, NO, SV, SO. With an appendix on geophysical aspects by H. Henkel. – SGU Af 17–20.
- ZACHRISSON, E., (compil.), ERIKSSON, B., LUNDEGÄRDH, P. H., GORBATSCHEV, R., LUNDQVIST, TH., COLLINI, B., and SKOGLUND, R., in press: The Precambrian of Sweden, its platform cover and platform magmatism. Explanatory note to the International Tectonic Map of Europe. Chapter III. 2: The Baltic Shield.
- ZECK, H. P., and MALLING, S., 1976: A major global suture in the Precambrian basement of SW Sweden? – Tectonophysics 31, pp. T 35–T 40.
- ZWART, H. J., 1967: The duality of orogenic belts. – Geol. Mijnbouw 46, pp. 283–309.
- ZWEIFEL, H., 1976: Aitik-geological documentation of a disseminated copper deposit. A preliminary investigation. – SGU C 720.



Figs. 5-39



Fig. 5. Foliated and folded granodiorite with several generations of veins. Kåsjön, east of Göteborg.
Photo L. Samuelsson.



Fig. 6. Supracrustal gneiss. Stenkullen, east of Göteborg. Photo L. Samuelsson.



Fig. 7. Koster dolerites in gneissose granite. Nordkoster. Photo Th. Lundqvist.



Fig. 8. Folded metasediments of greywacke-subgreywacke type belonging to the Stora Le-Marstrand formation. Intercalations of amphibolitic metabasalt. Orust, c. 50 km north of Göteborg. Photo L. Samuelsson.

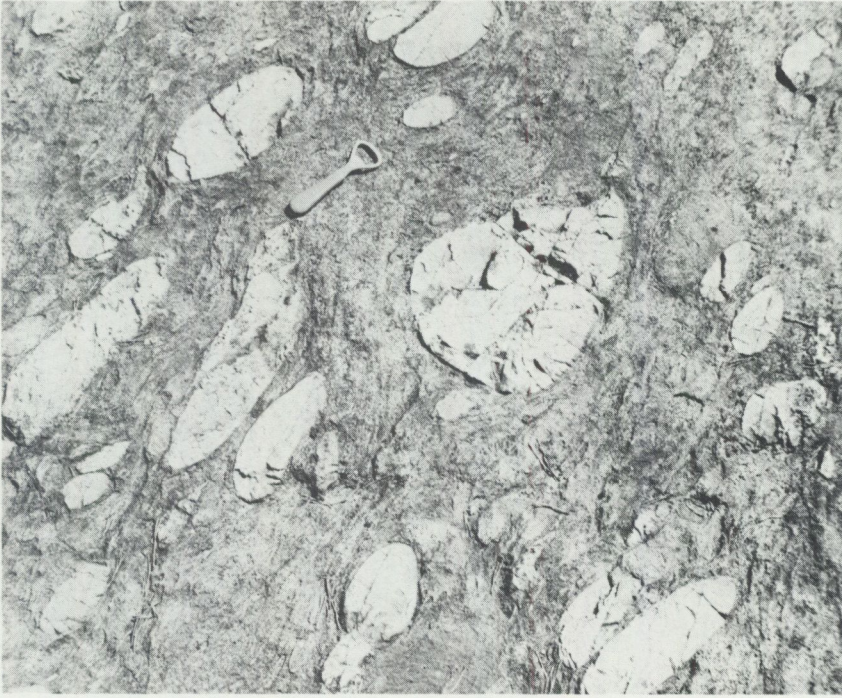


Fig. 9. Conglomerate belonging to the basal parts of the Dalsland group. Sandfallet, Sundals Ryr. Photo P. H. Lundegårdh 1973.

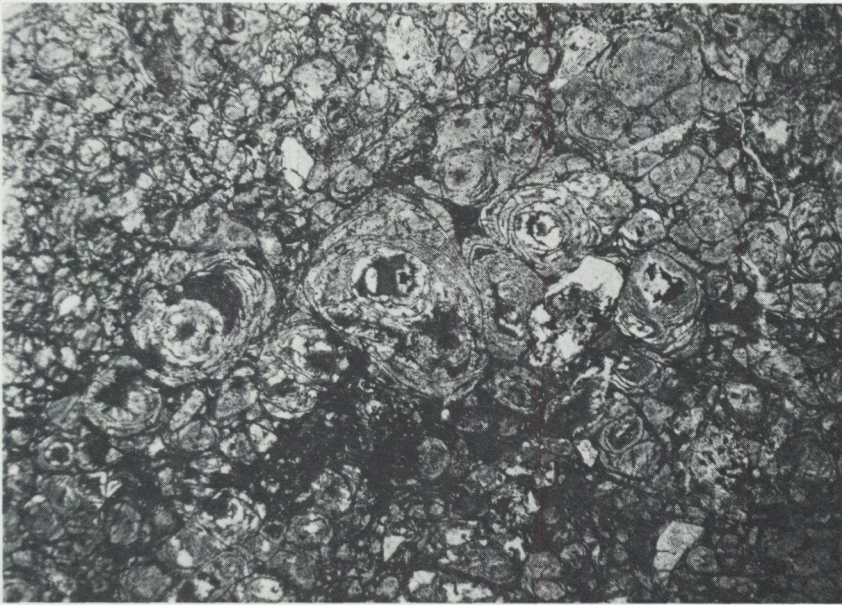


Fig. 10. Perlitic texture in Småland porphyry. South of Vimmerby. 1 nic., 40x. Photo L. Persson.

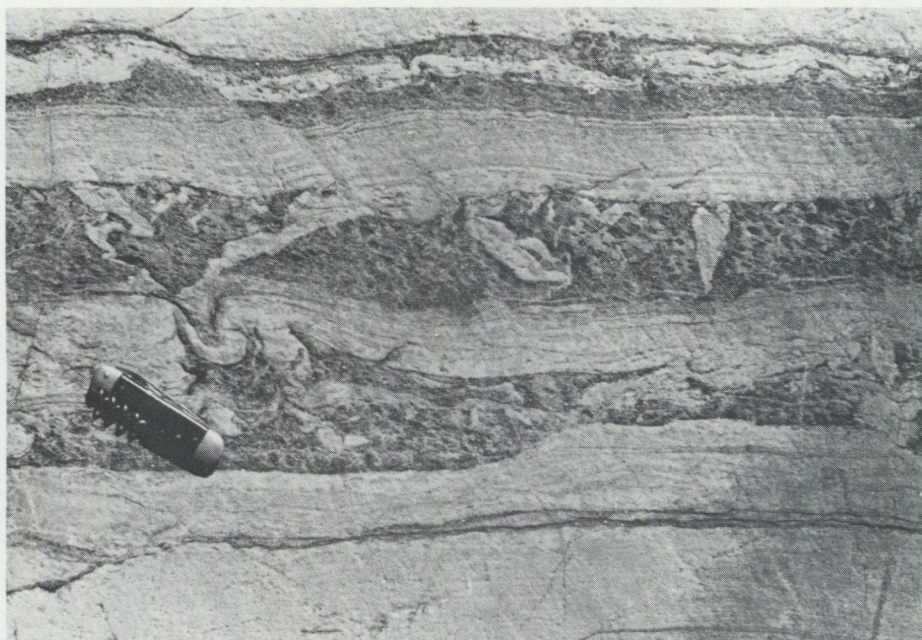


Fig. 11. Relict mud-cracks in meta-argillitic layers interbedded with meta-arenite. L. Äppleholmen, archipelago of Västervik. Photo Th. Lundqvist.



Fig. 12. Discordant bedding in meta-arenite of the Västervik formation. Archipelago of Västervik. Photo P. H. Lundegårdh 1960.



Fig. 13. Vånga granite showing well developed horizontal jointing. The granite is extensively quarried as ornamental building stone. Quarry south-west of Vånga church. Photo K-A. Kornfält.

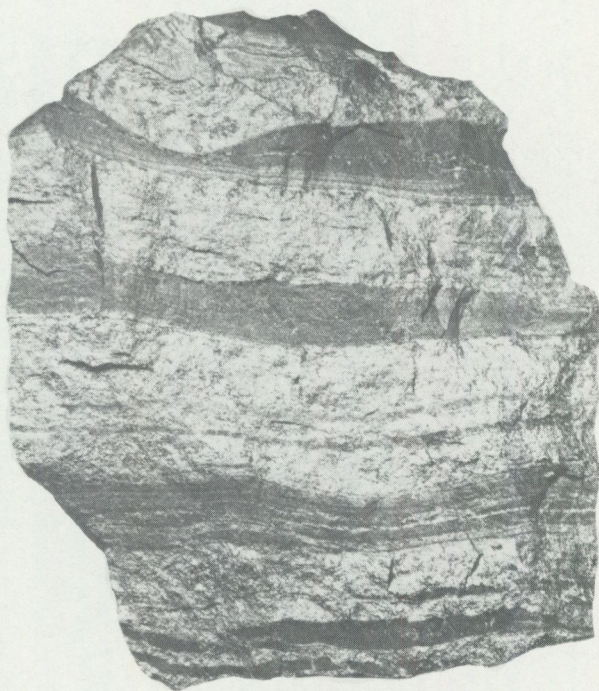


Fig. 14. Quartz-banded hematite ore. Stripa, Västmanland. Scale 1:4. (After P. Geijer.)

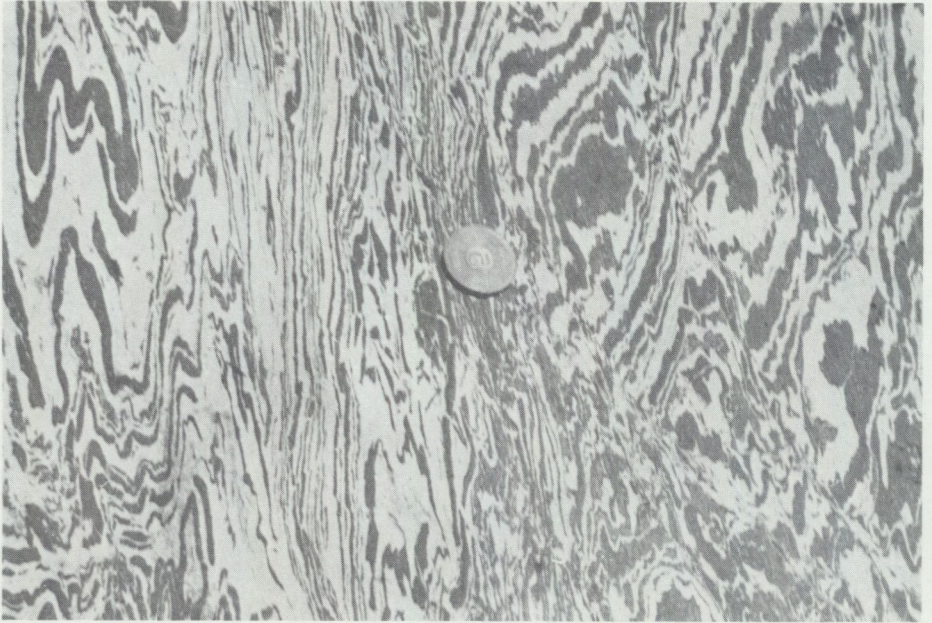


Fig. 15. Folded quartz-banded hematite ore. Kärrgruvan, Norberg, Västmanland.
Photo P. H. Lundegårdh 1967.

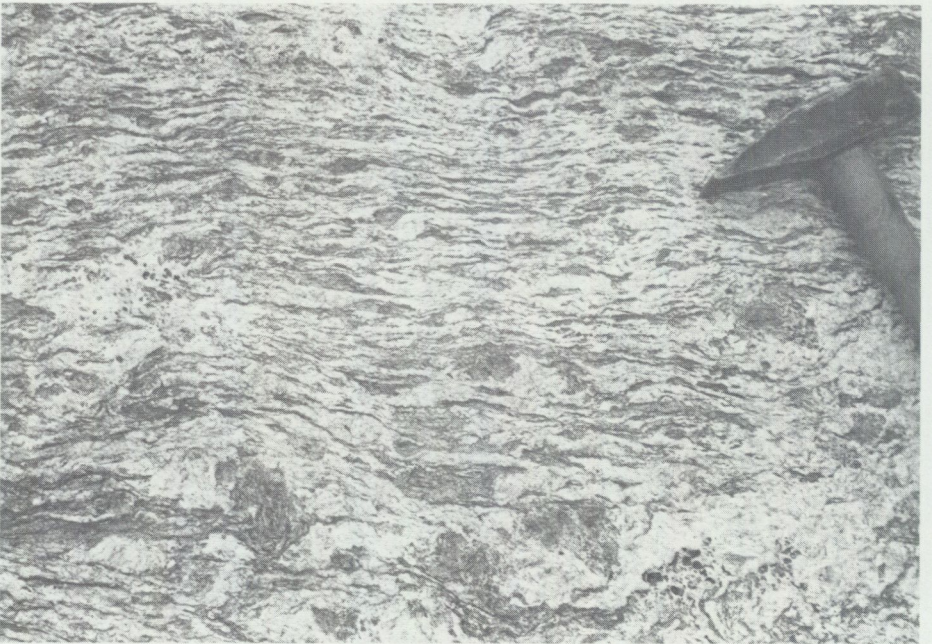


Fig. 16. Veined garnet-cordierite gneiss of argillitic composition. Hölö, 40 km south-west of Stockholm.
Photo G. Stålhös.

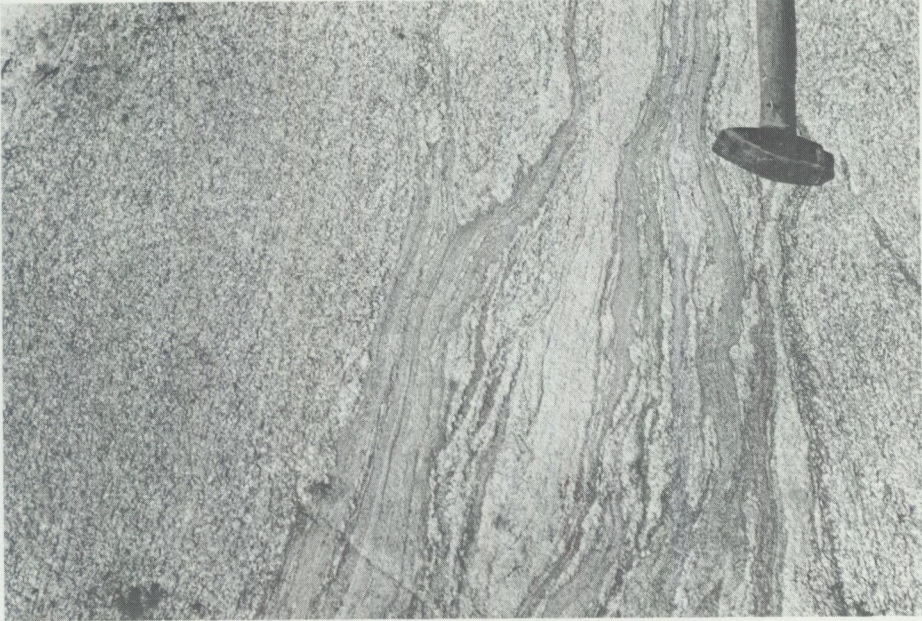


Fig. 17. Primorogenic tonalite conformably penetrating metasediments. Yttergran, Uppland.
Photo G. Stålhös.



Fig. 18. Intraorogenic amphibolite dikes cutting metasediments. Ornö, southern archipelago of Stockholm. Photo G. Stålhös.

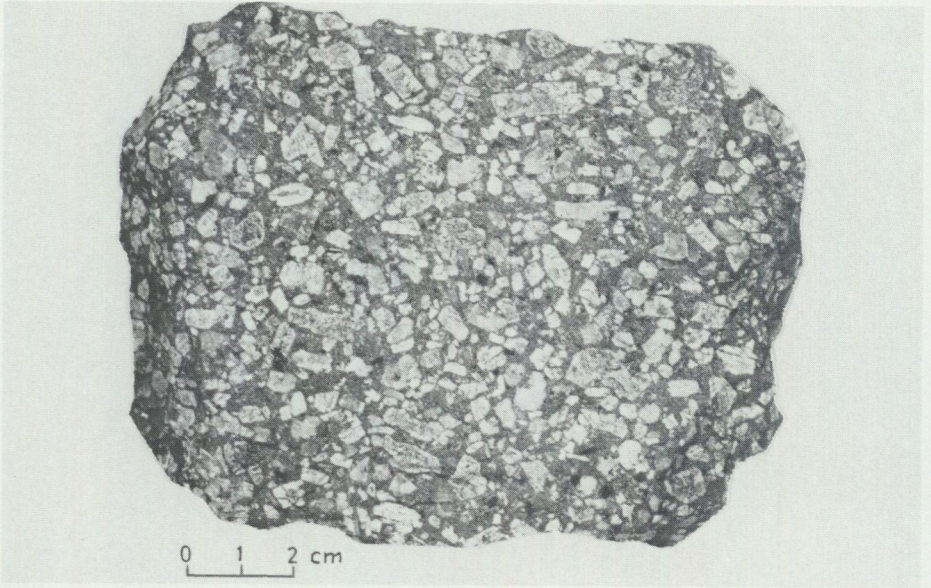


Fig. 19. Dala porphyry rich in phenocrysts (quartz-trachytic). Sundsjön, northern Dalarna. Photo Th. Lundqvist.

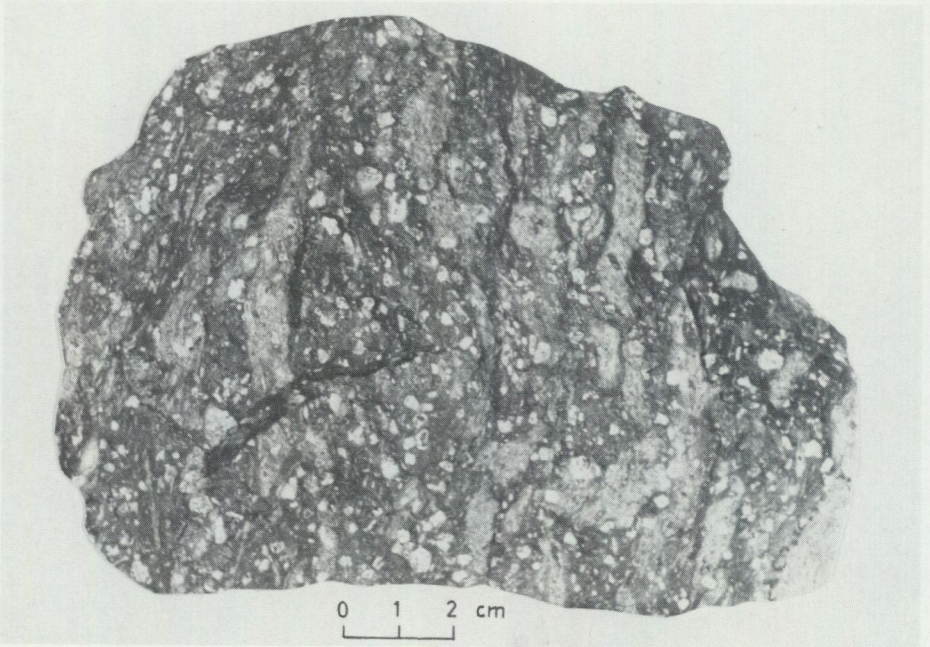


Fig. 20. Dala porphyry poor in phenocrysts (rhyolitic), with ignimbrite "flames". Älvho, northern Dalarna. Photo Th. Lundqvist.



Fig. 21. Folded Dala sandstone. Årån, Dalarna. Photo P. H. Lundegårdh 1958.



Fig. 22. Basal breccia of the Dala sandstone. Fragments are mostly of different Dala porphyries. Tvååberg, Dalarna. Photo Th. Lundqvist.

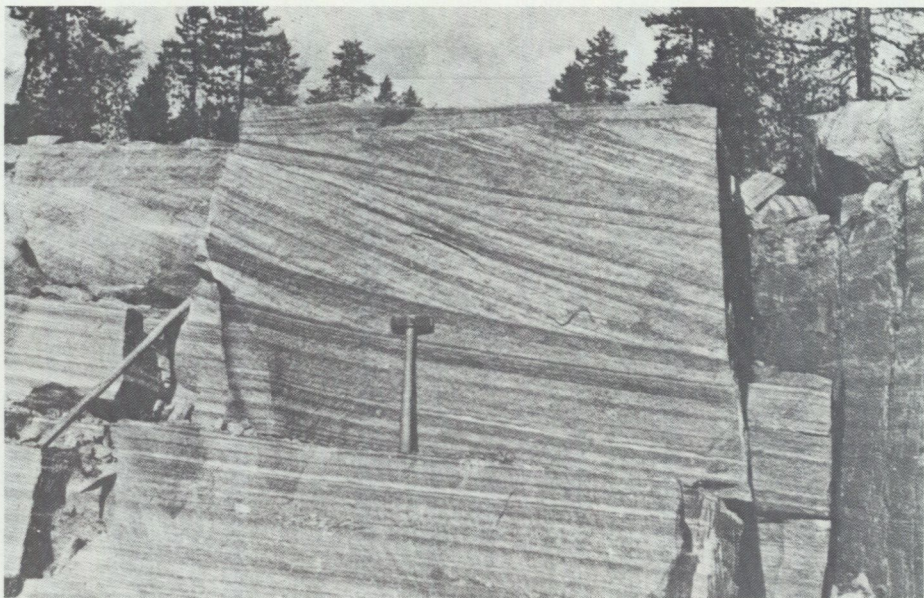


Fig. 23. Discordant bedding in Dala sandstone. Mångsbodarna, Dalarna. Photo S. Hjelmqvist.

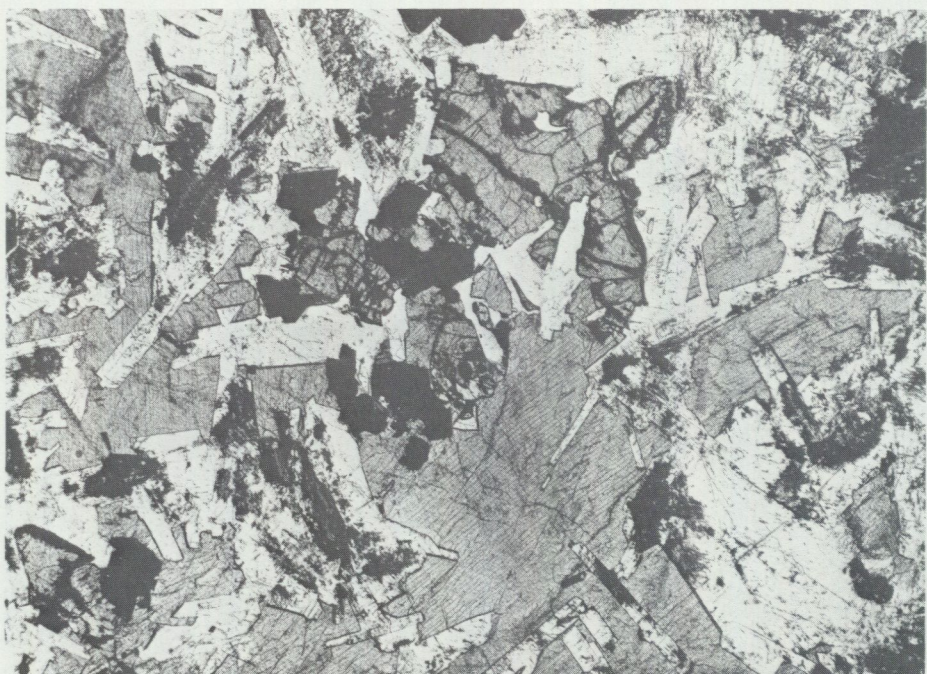


Fig. 24. Ophitic dolerite of Åsby type. Lath-shaped plagioclase crystals are surrounded by augite (grey crystals showing cleavage). Titanomagnetite-ilmenite (black) and olivine (above centre) also occur. Naapo, northern Dalarna. 1 nic., 17x. Photo I. Signorelli.



Fig. 25. Volcanic breccia in metabasalt of the Hamrånge formation. Norrsundet, Gästrikland.
Photo P. H. Lundegårdh 1955.



Fig. 26. Strongly migmatized greywacke gneiss (raft migmatite). Grundsunda, coast of Ångermanland.
Photo Th. Lundqvist.



Fig. 27. Feldspar-rich Naggen quartzite displaying bedding and well preserved clastic texture. Lillnaggen, Medelpad. Photo P. H. Lundegårdh 1958.

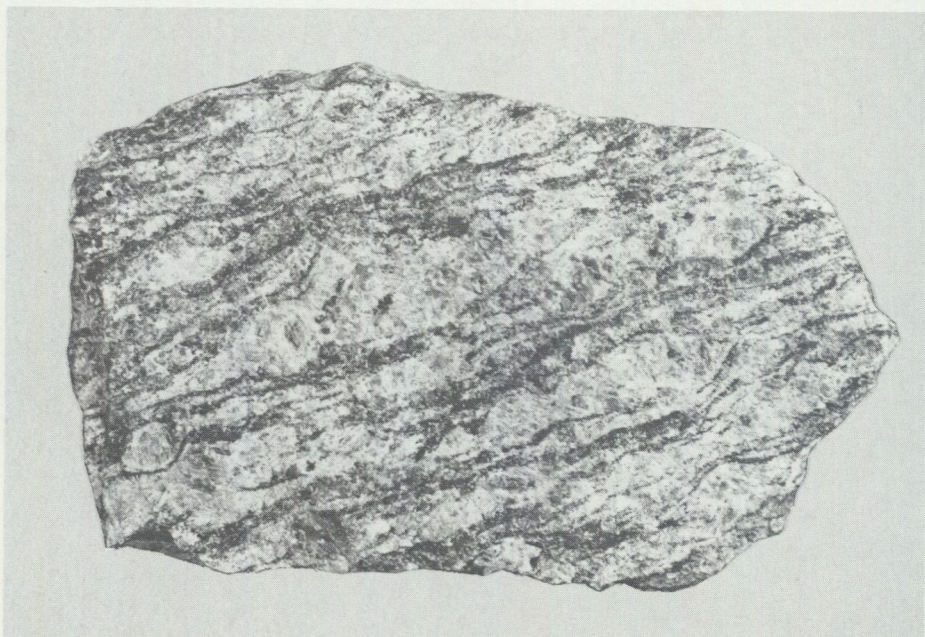


Fig. 28. Strongly foliated primorogenic granodiorite rich in deformed microcline megacrysts (Ljusdal "granite"). South-west of Järvsö, Hälsingland. Scale 3:5. Photo P. H. Lundegårdh 1965.

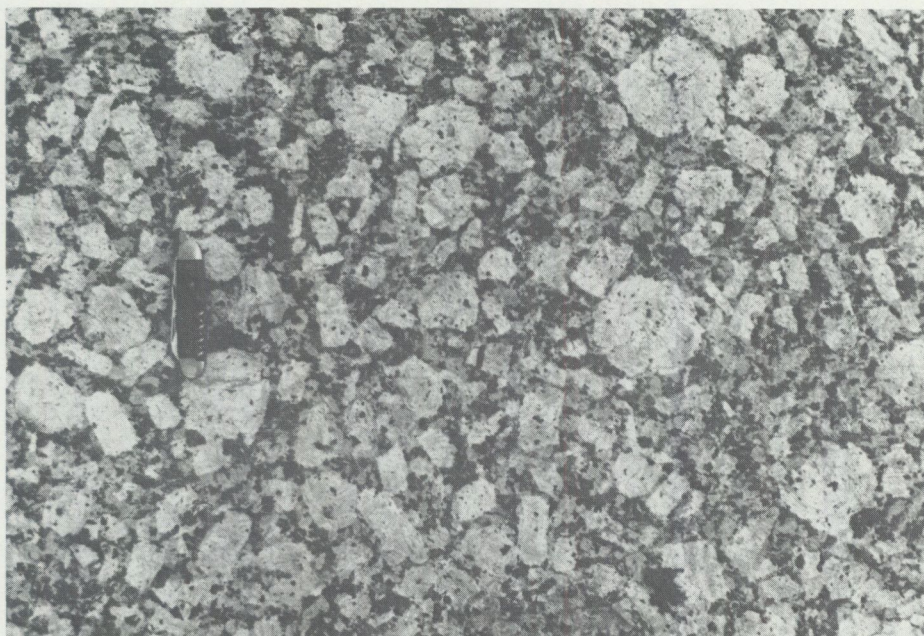


Fig. 29. Revsund granite rich in large microcline megacrysts. Bodumssjön, c. 25 km north of Örensköldsvik.
Photo Th. Lundqvist.



Fig. 30. Gabbro brecciated by Ragunda granite. Hammarforsen Falls, Hammarstrand, Jämtland.
Photo K.-A. Kornfält.

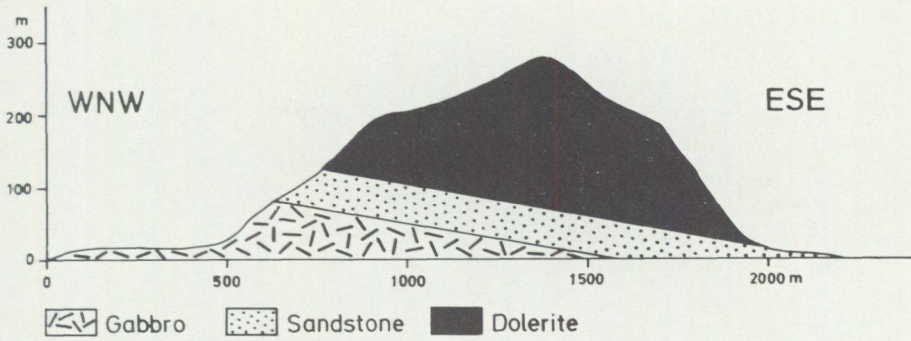


Fig. 31. Vertical section through the Ringkallen hill, Nordingrå, coast of Ångermanland. Sub-Jotnian gabbro is overlain by Jotnian sandstone and dolerite (Ulvö dolerite). After Lundqvist and Samuelsson.



Fig. 32. Rhythmical layering in the Jotnian Ulvö dolerite. Långroudden, north-eastern Ångermanland. Photo Th. Lundqvist.

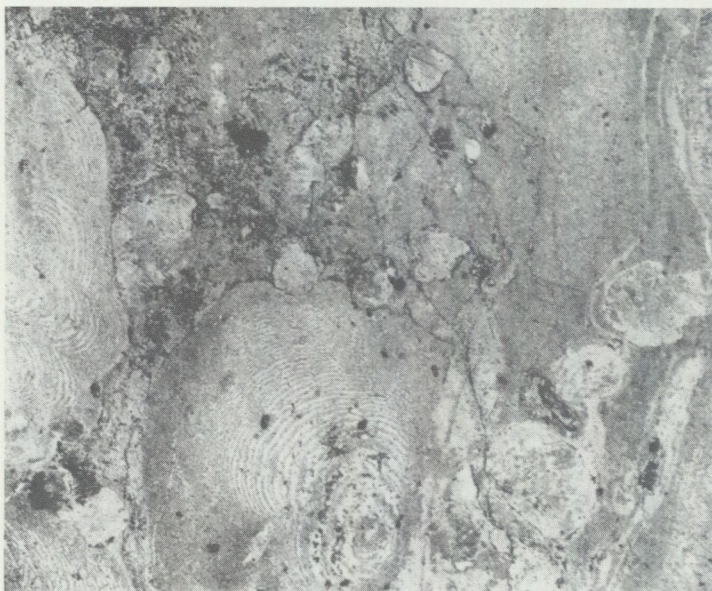


Fig. 33. Lithophysae in rhyolitic Arvidsjaur porphyry. Palja, southern Norrbotten County. 1 nic., 5x. After Grip.



Fig. 34. Conglomerate and arkose. Ledefat area, Västerbotten County. Photo P. H. Lundegårdh 1961.

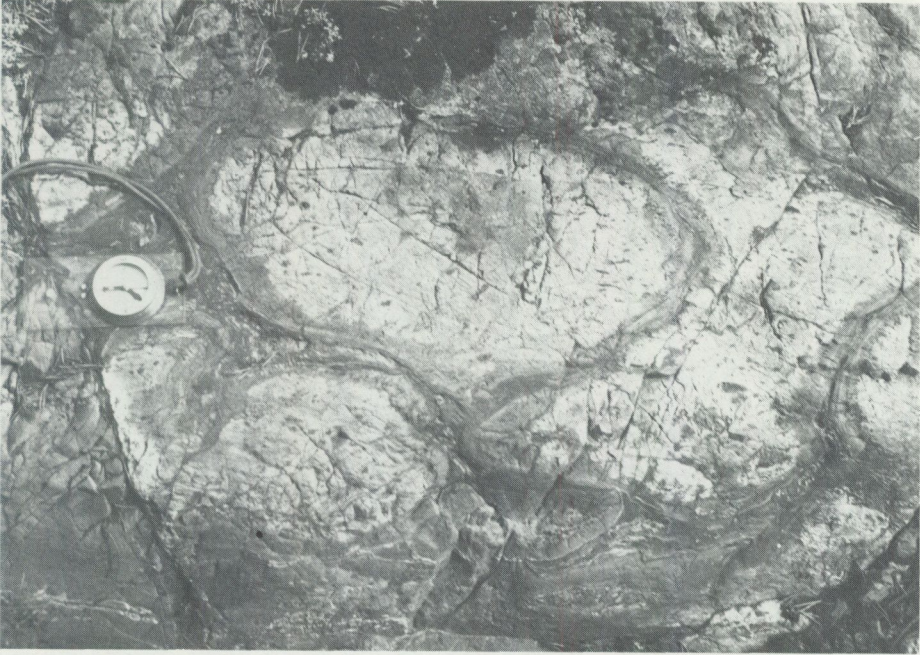


Fig. 35. Pillow lava structure in metabasalt of the Vittangi Greenstone Group. Paanikielinen, Vittangi region. Photo G. Nilsson.

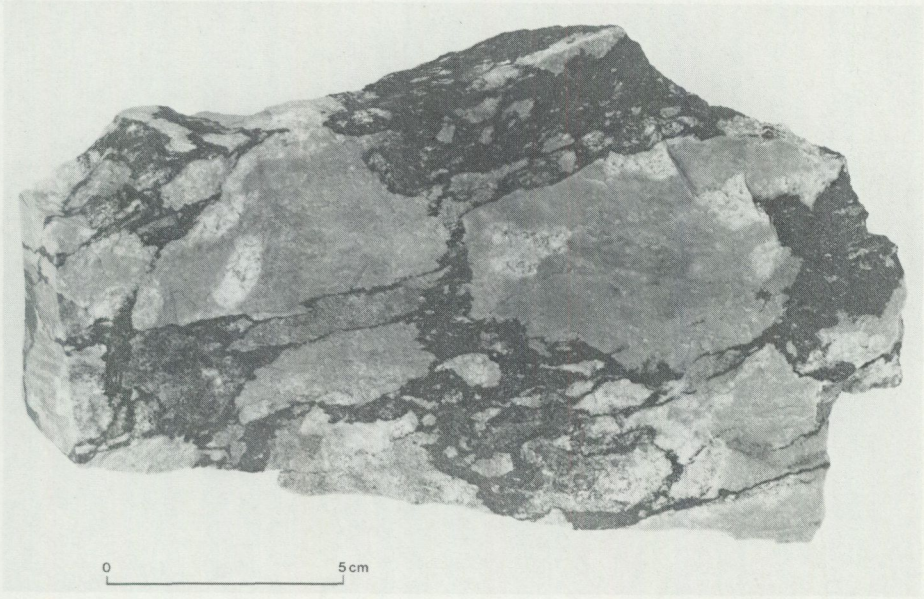


Fig. 36. Apatite-bearing magnetite ore brecciating acid volcanite belonging to the Kiruna porphyries. Henry iron ore deposit, Kiruna. After R. Frietsch.



Fig. 37. Conglomerate belonging to the Bälunge formation. Pebbles are of granite and basic volcanics. Fagervik, 20 km south-west of Luleå. Photo Th. Lundqvist.



Fig. 38. Perthite granite (K=quartz). Tjärrokätje, south-west of Fjällåsen, Norrbotten County. 2 nic., 6x. After Ödman.



Fig. 39. Scapolite in basic metavolcanite of the Vittangi Greenstone Group. Hosiojärvi, Vittangi region. (A match is used for scale.) Photo B. Eriksson.

PRISKLASS E

Distribueras genom
LiberTryck
162 89 VÄLLINGBY

Växjö 1979, C. Davidsons Boktryckeri AB
Printed in Sweden

ISBN 91-7158-185-5