Caledonian structural evolution and tectonostratigraphy in the Rombak-Sjangeli Window and its covering sequences, northern Scandinavian Caledonides

GERHARD BAX

Bax, G. 1989: Caledonian structural evolution and tectonostratigraphy in the Rombak-Sjangeli Window and its covering sequences, northern Scandinavian Caledonides. *Nor. geol. unders. Bull. 415*, 87-104.

The tectonostratigraphy and Caledonian structural evolution of an area in and around the northeastern corner of the Rombak-Sjangeli Window (RSW) in the northern Scandinavian Caledonides is described. The investigated area comprises four main tectonostratigraphic units, established during southeast-directed, piggy-back thrusting onto the Baltoscandian Platform. The lowermost exposed unit is composed of Svecokarelian crystalline rocks of the allochthonous RS-Complex with its Vendian to Cambrian sedimentary cover of the Gearbeljávri Formation. Lithological and structural comparisons of this unit with the Rautas Complex in the east favour a correlation of both units. Slivers of locally derived crystalline and sedimentary rocks are arranged in isolated duplexes of the Hoiganjávri Complex. Detailed mapping has revealed the composite nature of the overlying mylonitized Abisko Nappe Complex. The uppermost preserved portions of the nappe sequence are dominated by metasediments of the Seve-Köli Nappe Complex. Metamorphic grade increases in tectonically higher and consequently farther-travelled nappe units. Scandian thrusting (T_1) postdated the peak of Caledonian metamorphism.

'Basement'-cover interaction can be studied around several minor windows and klippen at the northeastern margin of the RSW. Faulting in the RS-Complex induced folding (partly cross-folds) in the overriding nappes during two (D_3 and D_4) of at least five phases of Caledonian deformation. N-S-trending high-angle faulting during D_4 locally caused back-thrusting structures and was accompanied by emplacement of sulphide-bearing quartz veins. Movement along pre-existing Caledonian ductile shear zones under brittle conditions resulted in the formation of pseudotachylite.

Gerhard Bax, Institut für Geologie und Paläontologie am Fachbereich Geowissenschaften der Philipps-Universität, Lahnberge, D-3550 Marburg/Lahn (West-Germany).
Present adress: Norges geologiske undersøkelse, Postboks 3006-Lade, N-7002 Trondheim (Norway).

Introduction

The westerly dipping metamorphic nappe pile of the Scandinavian Caledonides is deeply eroded, thereby exposing several 'basement' culminations (Fig. 1). These are arranged in two parallel belts (Vogt 1922, fig. 3) along the strike of the mountain belt. Whereas the easternmost tectonic 'basement' windows, situated less than 100 km west of the present erosional thrust front, are commonly rimmed by a sedimentary cover sequence beneath a stack of allochthonous units, most of the basement culminations along the Norwegian coast lack cover sequences. The latter category, which includes, for example, the Lofoten terrane, is often referred to as the western, basal or basement gneisses (Griffin et al. 1978, Bryhni & Sturt 1985, Gorbatschev 1985).

A westward increase in the degree of deformation and metamorphism of the cover sediments is related to their successively greater involvement in the Caledonian orogenesis. In most of the windows the sediments have been treated as a continuation of the autochthonous sedimentary sequences occurring in the foreland in front of the orogen (Holmquist 1910, Kulling 1960b & 1972, Nicholson & Rutland 1969, Wilson & Nicholson 1973, Gustavson 1978). Some windows are of a composite nature, with thrust repetition of the basement-cover relationship, e.g. the Nasafjäll Window (Du Rietz 1949, Thelander et al. 1980) and the Grong-Olden Culmination (Asklund 1938, Gee 1980). In northern Norway, no lower tectonic units have been found beneath the Precam-

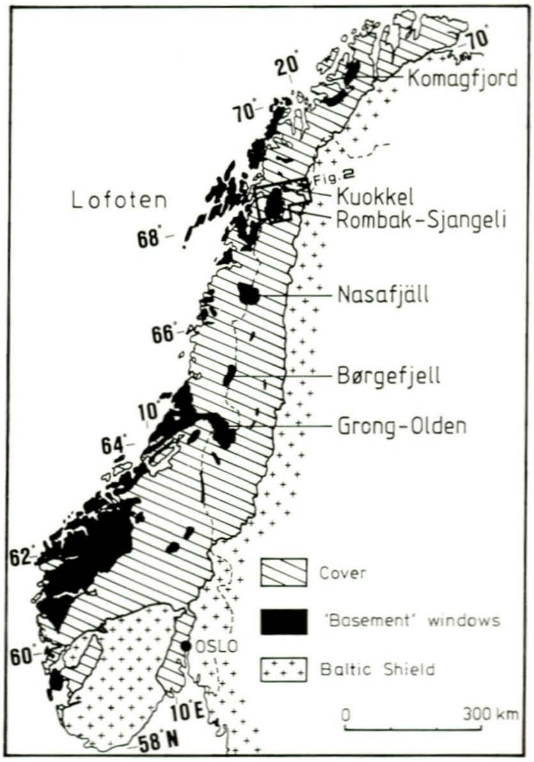


Fig. 1. Major 'basement' windows in the Scandinavian Caledonides.

brian crystalline rocks of the Komagfjord (Reitan 1963) and Alta-Kvænangen Windows, but an involvement in major Caledonian deformation resulting in an allochthonous position, at least for the Komagfjord window rocks, has been suggested by Chapman et al. (1985) and Gayer et al. (1987). Previous investigations of the Børgefjell (Greiling 1982) and the Rombak-Sjangeli Windows (see next section) show the 'basement' rocks as the lowermost exposed unit, directly overlain by the Middle Allochthon (Gee & Zachrisson 1979). In the present study the tectonostratigraphy of the rocks in and around the Rombak-Sjangeli Window is described and structural arguments for an allochthonous position of the window rocks will be presented.

Regional geology in and around the Rombak-Sjangeli Window

The Rombak-Sjangeli Window (RSW) is a dome-shaped 'basement' culmination which is slightly elongated along the NNE-SSW trend. A 'binomial' designation is used here (instead of Rombak Window) in order to avoid confusion with the established term Rombak Group (Strand 1960, p. 163), which refers to rocks of the overlying allochthon. The RSW covers an area of about 1900 km^2 north of latitude 68°N, along both sides of the border between Sweden and Norway (Fig. 2).

To the northwest, rocks of the RSW disappear under the moderately westward-dipping floor thrust of the overlying nappe pile of the Ofoten Synform (Gustavson 1972) which includes, in its lower parts, rock units correlated by Vogt (1922) with those of the Middle Allochthon (nappe 4 of Binns, 1978) in the Torneträsk area. According to Binns (1978) the highest preserved nappe unit (Binns: nappe 7) in this part of the Scandinavian Caledonides appears along the axial trace of the synform 30 km to the west of the RSW. It is represented by the Niingen Schist (Vogt 1922, 1942 & 1950) or the Niingen Group (Gustavson 1966). No remnants of the unconformable sedimentary cover have been found along the western margin of the RSW except for some isolated occurences along the Skjomenfjord (Birkeland 1976) and two others between Rombaken and Beisfjorden (Vogt 1950). On the basis of tectonic relationships along the western edge of the RSW, Hodges et al. (1982) proposed an A-type subduction zone bordering this window.

The westerly dip of the metamorphic nappe pile around the RSW is replaced in the south (Hodges 1985) and in the north (Tull et al. 1985) by a more or less gentle inclination of the floor thrust towards the exterior of the window. Traces of the sedimentary cover, sandwiched between the 'basement' rocks and the covering nappes, become quite common east of 17°40' E. These units were described in the south by Kulling (1964, pp. 60-66, figs. 30-36, cf. Kautsky & Tegengren 1952) and along the northern margin of the RSW by Tull et al. (1985, fig. 4).

Some minor windows also occur to the east of the RSW. The northernmost, largest one, the Kuokkel Window, occupies an area of about 80 km^2 and is separated from the RSW by a more than 184m-deep downfolded synform (Kulling 1964, p. 90) of the Middle Allochthon (Fig. 2) north of Vassijaure station (Plate 1). This synform can be followed (Plate 1) to about 20 km south of Vassijaure station, and is accompanied by two minor tectonic

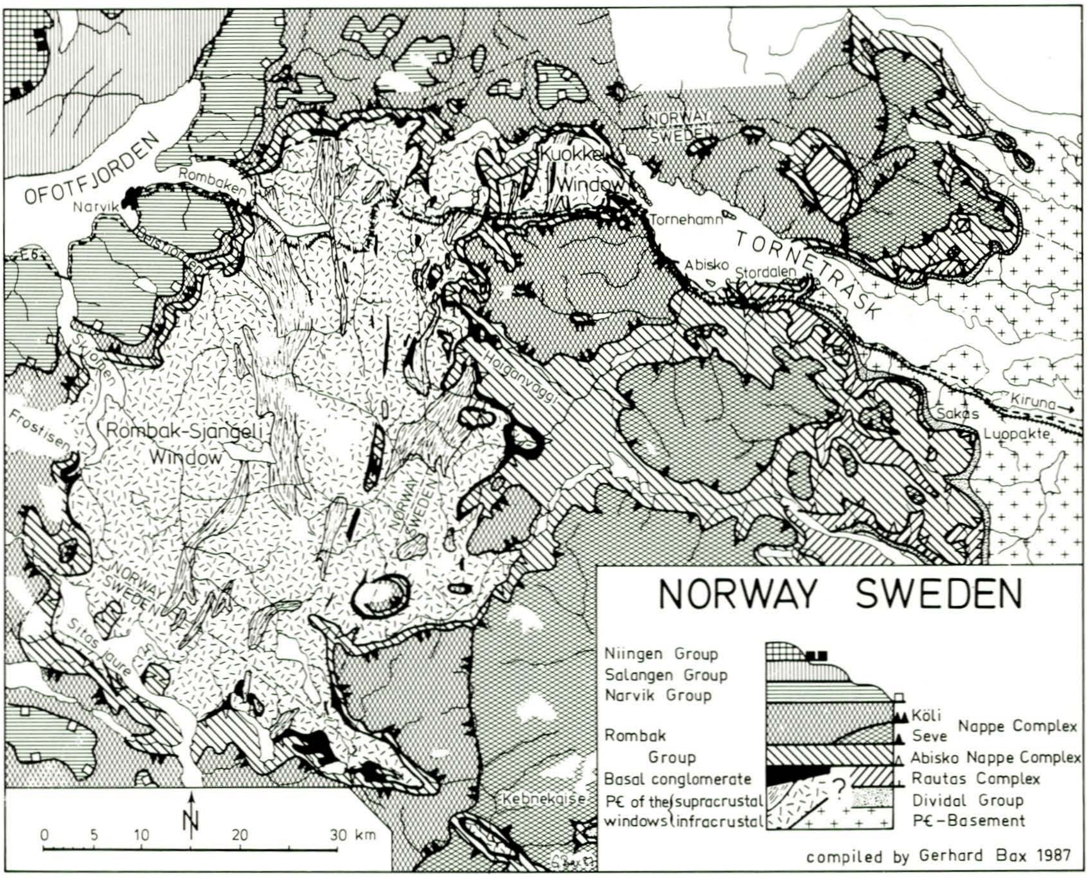


Fig. 2. Tectonostratigraphic map compilation for the Rombak-Sjangeli Window and adjacent areas based on Petersson (1897), Vogt (1950), Ödman (1957), Kulling (1964), Gustavson (1966, 1972 and 1974), Birkeland (1976), Hodges (1985), Tull et al. (1985), Lindström et al. (1985), Lindström (1987), Kathol (1987) and unpublished data of M. Johnsson. For location see Fig. 1.

windows (each less than 1 km^2) along its eastern margin. Where this Middle Allochthon synform is split by erosion along the Hoiganvággi valley, the tectonic window (Kulling 1964, fig. 22 and Bax 1986, fig. 1) — her called Alip Hoigan Window — is separated from the RSW by a downwarped and locally imbricated sedimentary cover. The small Vuolip Hoigan Window is located about 2 km to the southeast around the outlet of Hoiganjávri. In the uppermost part of the valley Vássevággi a newly discovered window (this study) — the Vásse Window — is exposed east of the synform. Following the trend of the southern margin of the RSW to the southeast, the Singis Window (Kulling 1964, Plate 1) appears southeast of Kebnekaise. This window was considered to be parautochthonous by Kulling (1964, p. 138), but he did not include it in his Rautas Complex (Kulling 1950a) of the Lower Allochthon (Gee & Zachrisson 1979). Because of lithological similarities (see Plate 1), rocks of the Rombak-Sjangeli, Kuokkel, Vásse and Hoigan Windows are here included in the same tectonostratigraphic unit.

Steeply inclined supracrustal sequences (fig. 2 in Holmquist 1903), commonly arranged in approximately N-S and NNE-SSW-trending stripes and lenses, are thought to represent the oldest units in the Norwegian part of the RSW (Vogt 1950, Birkeland 1976). Metamorphic grade reached amphibolite facies (P>6kb, T=575-600°C), according to Sawyer (1986). These rocks have been a target for exploration because they are associated with ore deposits in Norway (Korneliussen et al. 1986) and Sweden (Petersson 1897, Romer, this volume). The age relationship between these units and migmatized supracrustal rocks in the Swedish part of the RSW (map of Johansson 1955 in Ödman 1957, fig. 25) and the Kuokkel window (Adamek 1975, Plate 1) is still uncertain. The sub-vertical, westerly dipping, Kopparåsen greenstone belt, in the Kuokkel Window, with its stratabound uraninite, magnetite and sulphide mineralization (Adamek 1975), appears to continue south-southeastwards under the overlying nappes as suggested by Petersson (1897) and to reappear as the Sjangeli greenstones (cf. Romer, this volume). Minor amounts of similar greenstones, present in the Hoigan window, seem to confirm this assumption, although some lateral and vertical disruption must be taken into account.

The supracrustal rocks are intruded by plutonic rocks of different compositions that form the main part of the windows. Rb/Sr ages of these plutonic rocks are 1715±90 Ma (Heier & Compston 1969) and 1780±85 Ma (Gunner 1981).

The part of the Torneträsk section lying between Tornehamn (Bax 1984) in the west and Stordalen (Dworatzek 1976, Lindström et al. 1985) in the east, represents the shortest distance (about 19 km) between the Precambrian rocks of the Baltic craton and the linear belt of basement windows within the Scandinavian Caledonides (cf. Gee et al. 1985). At the western end of the Torneträsk section, the Middle Allochthon (Abisko Nappe of Kulling 1960a; here called the Abisko Nappe Complex because of its composite tectonic nature), which overlies the Kuokkel Window, dips to the southeast beneath the level of Torneträsk (341m.a.s.l.). The base of the Abisko Nappe Complex reappears 12 km to the southeast on top of the Rautas Complex of the Lower Allochthon (Fig. 2).

The Rautas Complex is composed of variably deformed Precambrian igneous rocks with attached sedimentary cover sequences. It reaches a maximum thickness of about 400 m around Stordalen, but pinches out tectonically north of Sakas (Lindström et al. 1985). At the present erosional thrust front around Luopakte, the Lower Allochthon is represented by tectonic slices containing calcareous sediments with Lower Cambrian trilobites, which are also present in the underlying autochthonous beds (Ahlberg 1979).

The autochthonous sedimentary sequence (Dividal Group) of Vendian and Cambrian age (Vidal 1979) rests unconformably on Svecokarelian crystalline rocks of the Baltic Shield to the north and south of Torneträsk (Fig. 2). The most complete section of these shelf deposits, comprising both the Middle to Upper Cambrian Alum Shale and the underlying Torneträsk Formation (cf. Thelander 1982) is exposed at Luopakte (Moberg 1908). To the northwest the almost unfolded sole thrust of the overlying nappes truncates successively lower portions of the Dividal Group. Around Stordalen (about 24 km northwest of the thrust front), only the basal conglomerate is preserved (Lindström et al. 1985). Neither the sediments of the Dividal Group nor those of the Rautas Complex in this area were exposed to P/T conditions exceeding those of very low-grade metamorphism (classification of Winkler 1979).

The variably mylonitized igneous and sedimentary rocks of the Abisko Nappe Complex were metamorphosed up to biotite grade during the Caledonian orogenesis. These rocks can be followed, with varying thickness, from the thrust front in the southeast to (at least) the Norwegian border (Björklund 1985) in the northwest.

The overlying, medium-grade (amphibolite facies) Upper Allochthon (Gee & Zachrisson 1979) east of Abisko, is dominated by typical Seve rocks (Zachrisson 1974), represented mainly by amphibolites, foliated mylonites and gneisses (Lindström et al. 1985). These Seve rocks branch out to the north and west of Abisko underneath the Köli units. Consequently, no Seve remnants are known to occur on the western side of the RSW (Zachrisson 1973, Hossack 1983). The Köli succession in the Torneträsk area is dominated by impure marbles and graphite schists alternating with mica schists containing variable amounts of garnet. Minor occurrences of amphibolite and garbenschiefer are concentrated in the Upper portions of the sequence.

Tectonostratigraphy

Rombak-Sjangeli Complex

The lowermost tectonostratigraphic unit exposed in the study area consists of crystalline Svecokarelian rocks of the RSW (Plate 1). A possible tectonic lower boundary of this unit, here called Rombak-Sjangeli Complex (RSC), is discussed later (structural section).

The dominant NNE-SSW trend of the supracrustal rocks is clearly demonstrated by an at least 200 m-thick strip of brown, rusty mica schist (Plate 1) and quartzite, which enters the study area southwest of Stuor Gearbil. It continues with variable, sometimes sub-vertical, WNW-dip to Láirečorru, where it is cut of by an westward-dipping, late Caledonian, high-angle normal fault. The supracrustal rocks have a distinct foliation that is defined by the planar orientation of biotite flakes in a quartz-feldspar matrix. The rusty appearance is due to disseminated hematite. To the west of this stripe and Láirečorru, an anastomosing network of similar mica schists is intruded by apophyses of the younger Vassijaure Granite (Holmquist 1903, Fig. 1), which contains xenoliths of mica schist. The coarse-grained Vassijaure Granite shows an augen texture parallel to lithological boundaries. This rock-type, also known as the Rombak Granite, is common over large areas of both the RSW and the Kuokkel Window (Holmquist 1903, Adamek 1975, Bax 1984). It is characterized by 1-3cm-long feldspar augen mantled by biotite, hornblende and minor amounts of sphene, apatite, epidote, rutile, tourmaline and ore minerals.

The areas to the east of the mica schist and between Láirečorru and Vuoiddasriidda are dominated by fine-grained granitoid rocks with a migmatitic appearance, which include layers of mica schist. These rocks reappear in the Hoigan and Vásse Windows. A lobe of supracrustal rocks extends from the Sjangeli area (Romer, this volume) in the south up to Gearbeljávri, were it disappears beneath the overthrusted rocks. Amphibolite within this supracrustal sequence is abundantly exposed along the eastern shore of Gearbeljávri, and its northern continuation reappears in the Alip Hoigan Window. The Vassijaure Granite dominates in the Vuolip Hoigan Window.

Sulphide-bearing veins are concentrated parallel to lithological boundaries along both sides of the border between Norway and Sweden. Most of these calcite-hosted galena occurrences were discovered and briefly described by Löfstrand (1894). Galena-, sphalerite- and fluorite-bearing calcite veins around Svangeråive were described more recently by Johansson (1983, 1984). Although the age of these mineralizations is still unknown, they must be younger than the Svecokarelian orogeny, as the veins cut through all accompanying structures. No contact relations with the sedimentary cover or Caledonian structures have been observed and so their relationship to the Caledonian deformation remains unknown. Caledonian sulphide-bearing quartz veins in the RSC are discussed later.

Gearbeljávri Formation

The crystalline rocks of the RSW are overlain unconformably by a clastic succession, here informally called the Gearbeljávri Formation, which occurs widely at the base of the overlying nappes (Plate 1; cf. Brown & Wells 1966, fig. 2). Where this succession is missing, as in Vássevággi or around parts of the southern edge of Stuor Gearbil, the floor thrust of the Middle Allochthon is hard to trace.

The impure, quartzitic, basal parts of the succession reach a maximum thickness of about 10 m in the southern part of the area and are commonly in depositional contact with the underlying crystalline rocks. They show evidence for lateral variations in depositional environment. The most common lithology of the Gearbeljávri Formation is an arkosic metasandstone with irregularly distributed, rounded quartz pebbles. The depositional contact with the underlying crystalline rocks is either sharp, with no obvious grading in the metasandstone, or transitional, where it rests on a pre-Caledonian weathered zone. In places, locally derived coarse sedimentary breccias are present. These diamictites (cf. Flint et al. 1960a, 1960b) have been described by Brown & Wells (1966) as tillites, but the present author has found no convincing evidence (see Harland et al. 1966, Flint 1975) for a glaciogenic origin in the field. Channel-deposited, grain-supported, gravel beds occur in the Vuolip Hoigan Window and around Gearbeljávri. The basal metasandstone, which is quite resistant to weathering, is overlain by an alternation of intensively sheard brownish slates and quartzites which is up to a few metres thick.

A partly reworked regolith is regarded as the source of the metasandstone member, and the alternation of slates and quartzites indicates the influence of a more uniform (possibly marine) environment. A post-Varangerian (Vendian) age (Vidal 1979, Fig. 1) can be proposed for the Gearbeljávri Formation based on correlation with the lower sandstone member (Thelander 1982) of the autochthonous Torneträsk Formation. This implies a maximum age of 668±23 Ma (Pringle 1973), as no definite tillites have been found in the study area.

In contrast to its counterparts in the autochthonous Torneträsk Formation further east or in the Rautas Complex, the Gearbeljávri Formation contains ubiquitous biotite in the form of microscopic flakes arranged along shear planes. In places the biotite is accompanied by epidote, but chlorite is restricted to plans of younger movements.

Hoiganjávri Complex

The Hoiganjávri Complex occurs between the Gearbeljávri Formation and the floor thrust of the Middle Allochthon. It is composed of metasediments and locally derived crystalline rocks. The metasediments appear to represent the sedimentary overburden of the Gearbeljávri Formation, which has been detached along decollements. These rocks were described by Kulling (1960a, fig. 5; 1964, fig. 23) as 'possibly parautochthonous, quartz-veined, fine-folded phyllite rocks'. They contain variable amounts of detrital quartz and are regarded here as metagreywackes. It is hard to estimate their primary thickness due to internal folding and imbrication, but it does not seem to exceed 50 m. Where the uppermost parts of the succession are preserved under their roof thrust, the phyllites become darker upwards in the section and pass into graphite schists which are at most 10 m thick.

No lithological counterparts to the phyllites of the Hoiganjávri Complex exist in the autochthonous Torneträsk Formation or in the overthrust Rautas Complex east of Abisko. The graphite schists can be correlated with the quite radioactive Alum Shale Formation (Bergström & Gee 1985, p. 259) from the upper part of the Dividal Group. Radioactivity measurements on the metasediments of the Hoiganjávri Complex (Author's unpubl. data) support this assumption.

Horses of locally derived crystalline rocks are common in two major duplexes of the Hoiganjávri Complex. In the southern part of Láirečorru a 'herd' of these horses is intercalated with strongly sheared graphite schists. The duplex at the southern shore of Hoiganjávri (locus typicus for the complex) consists mainly of crystalline rocks. In both cases the crystalline components are concentrated in the foreland-facing parts of the duplexes (Plate 1). A single granitoid thrust slice appears south of Likta on top of the Gearbeljávri Formation. The basal metasandstone has not been observed in depositional contact upon the basement horses of the Hoiganjávri Complex.

Mineral assemblages in the phyllites of the Hoiganjávri Complex indicate conditions of low-grade (biotite) metamorphism, similar to those reported from the Gearbeljávri Formation. Some of the crystalline rocks contain large amounts of postkinematic stipnomelane.

Abisko Nappe Complex

The Middle Allochthon is represented in the study area by variably mylonitized Precambrian crystalline rocks overlain by quartzo-feldspathic so-called 'hardschists' (Pettersen 1887, p. 420; regarded as allochthonous by Törnebohm in 1901) of the Abisko Nappe Complex (ANC). In the actual study area the affiliation of these rocks to the ANC is based on the continuation of this unit along Hoiganvággi towards the type locality at Abisko (cf. Fig. 2).

In contrast to the general westward thinning trend of the allochthon in the Swedish Caledonides (Gee & Zachrisson 1979), rocks of the Abisko Nappe Complex thicken from northeast to southwest beneath the Upper Allochthon in the high mountains west of Abisko. Going southwestwards, successively lower units are exposed in the ANC, as the floor thrust of the Middle Allochthon cuts up section from southwest to northeast. Around Tornehamn, at the southeastern corner of the Kuokkel Window, the ANC is, at most, 40m thick and consists mainly of hardschist with some 10 m of mylonitized crystalline rocks at the base (Bax 1984). The metabasites were regarded by Kulling (1964) as derivatives of Precambrian basic igneous rocks and are quite common along the easternmost rim of the RSW (cf. Kulling 1964, Plate 1).

Rocks of the Abisko Nappe Complex are

represented in the klippen structures of Gatter-oaivi, Láirečorru and Stuor Gearbil. They also constitute the up to 300 m and almost vertical cliffs around Vássečohkka, Vuoiddasriidda and Jorba Gearbil. There, two sheets of mainly granitoid mylonites occur, separated by a layer of the above-mentioned metabasites that is up to 100 m thick. The lower granitoid sheet shows rapid thickness variations and in places disappears, due to hanging-wall cut-offs along the floor thrust. The upper granitoid sheet thins out to the northeast and is replaced by increasing amounts of hardschist. Local occurrences of metabasites cap the upper granitoid sheet. Both granitoid sheets consist of similar lithologies, and are only distinguishable by their field relationships. The rocks of both layers are generally well foliated. However, lenses of coarse-grained, almost undeformed granite of the ANC with augen textures are common in the hinges of early-generation folds. The largest occurrence of these relatively undeformed rocks caps Satnjarasčorru in the southeastern part of the map area (Plate 1). The author regards these rocks as remnants of the granitic protolith preserved from deformation. However, Brown & Wells (1966) interpreted them as locally derived 'tectonic inclusions of basement gneiss' surrounded by parautochthonous mica schist. Deformation took place under conditions of low-grade metamorphism and results in rocks of the mylonite series (protomylonite - mylonite - ultramylonite) of Sibson (1977).

The less deformed granitoids are L-tectonites with grain elongations parallel to the main NW-SE trend of the main Caledonian thrust movement. In thin-section they are protomylonites showing brittle behaviour of the different feldspars (mostly microcline, perthite, albite and oligoclase) and dynamic recrystallization of quartz (cf. White 1977, Simpson 1985). The mylonitization is accompanied by an overall grainsize reduction (Fig. 3). With increasing deformation the feldspar are replaced by sericite (Andreatta 1954, Williams & Dixon 1982), and quartz clasts show core and mantle structures (White 1976). Deformation of biotite resulted in primary kink bands (Etheridge et al. 1973). Alternations of protomylonites, mylonites and even intensely foliated ultramylonites commonly occur on the scale of thin-sections. Epidote is concentrated along C-planes and recrystallized biotite flakes mark remaining S-planes (cf. Berthé et al. 1979).

Fig. 3. Protomylonitic texture in a granitoid of the Abisko Nappe Complex normal to S- and C-planes. Partly dynamically recrystallized quartz is left white in the drawing. Feldspars are stippled and sericite is indicated by hachures. Hematite and ilmenite are shown in black. Sense of shear is sinistral.

Centimetre- to metre-thick intercalations of hardschists are concentrated in the upper parts of the granitoid layers. Although the origin of these rocks still remains unclear (cf. Holmquist 1903, Quensel 1916, Brouwer 1937, 1940a & b), they are regarded here as products of intense mylonitization of quartzofeldspathic sedimentary protoliths of unknown age. In thin-section, these well foliated rocks show ultramylonitic or blastomylonitic textures (Higgins 1971), depending on their primary quartz contents. Calcareous intercalations in the hardschists occur along the north-western edge of Stuor Gearbil and south of Vassijaure railway station. A thin carbonate layer appears underneath the lower granitoid layer and above the floor thrust in the southern part of Láirečorru.

Björklund (1985) distinguished up to six thrust-sheets of Precambrian gneissic granitoids in the Akkajaure Nappe Complex, each overlain by a thin sedimentary veneer. The hardschists in the Middle Allochthon west of Abisko may represent counterparts of less deformed sediments in the Akkajaure Nappe Complex. However, intense shearing and recumbent folding prevent the establishment of a detailed internal tectonostratigraphy in the granitoid layers of the Abisko Nappe Complex (ANC).

The intercalated chlorite-schist layer also contains less deformed inclusions of the supposed protolith. These relics appear in the form of massive metabasites that reveal nematoblastic textures with hornblende, biotite, epidote, tourmaline, minor quartz, oligoclase, calcite and magnetite in thin-section. The more common chlorite schists are characterized by lepidoblastic textures, with chlorite and epidote replacing the pre-existing mafic constituents of the suspected protolith. Thin intercalations of graphitic schists accompany the chlorite schists in varying amounts. Locally, marbles are also intercalated in the chlorite schists east and west of Hoiganjávri, east of the top of Stuor Gearbil, and along the southwestern slope of Vássečohkka.

Lenses of metabasite which overlie the upper granitoid layer were previously interpreted as remnants of the Seve unit (fig. 1 in Bax 1986), but are here considered as part of the Abisko Nappe Complex. This reinterpretation is based on the detection of similar lithologies in the lower chlorite schist layer, and on the interfingering of these metabasites and accompanying chlorite schists with hardschists of the ANC. Their occurrence in lenses beneath the floor thrust of the Upper Allochthon can be explained as footwall cutoffs.

The obviously pre-Caledonian, medium-grade assemblage in the crystalline rocks of the ANC is overprinted by Caledonian low-grade dynamic metamorphism. Minor occurrences of garnet are restricted to the nappe boundaries.

Seve-Köli Nappe Complex

Less attention has been paid to the rocks of the Upper Allochthon and only a brief summary is given here. According to Kulling (1960a, Fig. 5), the Köli succession of the Upper Allochthon in the present study area begins with an almost continuous layer of impure calcite marble with intercalated, distorted siliceous fragments. This definition is used here, as the several metre thick marble seals the footwall cutoffs under the roof thrust of the Middle Allochthon. Graphitic schists dominate the lowermost 20 m of the Upper Allochthon in the western part of the study area. The succession continues with mica schists, containing different amounts of quartz, calcite and garnet. Sheets and slices of amphibolite and kyanite-bearing garbenschiefer occur in different parts of the Upper Allochthon west of Abisko. The age of the Köli rocks in this part of the mountain belt is unknown but Kulling (1972, p. 263) suggested a Middle Ordovician age, based on lithostratigraphic correlations with fossiliferous units in the central Scandinavian Caledonides. No higher tectonic unit, correlatable with the Narvik Group (cf. Fig. 2), seems to be present in the mountain range west of Abisko.

Structural development

The Caledonian structural history of the area investigated is illustrated schematically in Fig. 4, where the creation of structures is related to 5 phases of deformation (D_1 to D_5). Structural alements such as thrusts (T), foliations or cleavages (S), folds (F) and lineations (L) are indicated with their respective deformation phase subscript. Despite the temporal subdivision, the different deformation phases and related structures should be considered as elements of a more or less continuous process.

The chronological classification of the different structures is complicated by the fact that structures of more than two generations are rarely present in cases of obvious overprinting. Using only one of the features style, orientation or symmetry of folds as a criterion for establishing a structural chronology can lead to erroneous results (cf. Park 1969). Structural terms are used here in accord with Boyer & Elliott (1982) and Butler (1982).

From D_3 onward, movements in the RS-Complex played an important role for the structural development of the overlying allochthon by initiating and modifying its structures during the emplacement (Bax 1984, 1986). Corresponding tectonic features can be dated by the interaction of related structures in the RSC, even when deformation changes style across nappe boundaries (Bax 1987). It is assumed that pre-existing fabrics in the RSW were reactivated in Caledonian times.

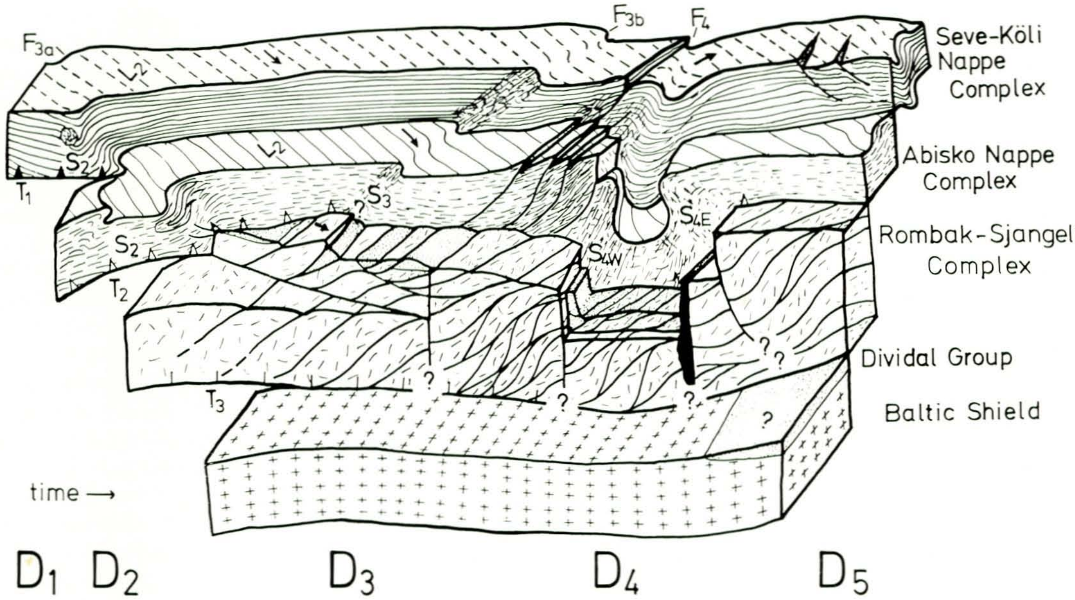


Fig. 4. Structural development in the study area during 5 phases of deformation, looking north. The development of the oldest structures is shown at the left margin of the figure and the structural evolution can be followed in time from left to right (D_1 to D_5) in the involved tectonostratigraphic units. Illustrations of overprinting features are kept to a minimum in order to preserve clarity in the diagram. The Gearbeljávri Formation is stippled and crystalline rocks of the Hoiganjávri Complex are marked by a pattern of dots and hachures. Quartz veins are shown in black.

D₁

Because D_2 with its penetrative foliation (S_2) is ubiquitous in both the Upper and the Middle Allochthons and in parts of the underlying units, most of the older structural elements are either extinguished or their genetic relationships are difficult to reconstruct because of reorientation (Lindström 1961). Traces of deformation events older than D_2, here summarized under D_1, are preserved in the higher metamorphic parts of the Köli as inclusion trails (S_1) in porphyroblasts (mostly garnet) or as rootless intrafolial folds, present in single outcrops, which are scattered throughout the entire allochthonous sequence.

The floor thrust (T_1) of the Upper Allochthon was developed during D1 and underwent deformation during all later phases. During this early phase the medium-grade Köli was superposed upon the low-grade Middle Allochton. Thrusting postdates the peak of Caledonian metamorphism. Hangingwall and footwall cutoffs along T_1 represent, in some cases, remains of bedding or foliations.

D₂

D_2 represents the main phase of overthrusting, when the Middle Allochthon started to migrate along T_2 on top of rocks which were to become the RSC and its sedimentary cover. During this phase the ubiquitous foliation S_2 was formed during simple shearing of all involved tectonic units. A NW-SE lineation (L_2 on Fig. 4), present within S_2, is parallel to the supposed SE transport direction (Lindström 1958). L_2 appears as a preferred orientation of porphyroblasts and clasts and is interpreted (cf. Kvale 1953) as an a-lineation in the sense of Sander (1948). Pebble elongations in the Gearbeljávri Formation parallel to L_2 testify to the influence of the overiding nappe pile during D_2.

The Abisko Nappe Complex is characterized by the repetition of a succession consisting of basal granitoid mylonite, intercalated and overlain by hardschists and capped by variably mylonitized metabasites. Isoclinal folding can be excluded as an explanation for the repetition, because the tectonic layering is rhytmic,

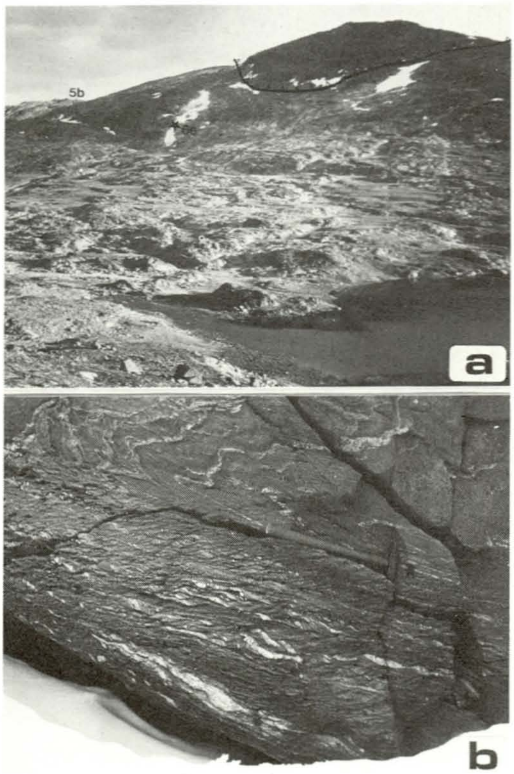


Fig. 5. D_3 structures in the Rombak-Sjangeli Complex (RSC): a) Westward-dipping low-angle ductile shear-zones in Hoiganväggi. View looking SSE. Base of the ANC at Stuor Gearbil marked by black line. Note the high-angle fault in the centre of the picture. Width of section at the horizon is 2 km. b) D_3 shear-zone with extensional crenulation cleavage. View looking SSE. Hammer (55 cm) as scale. Sinistral sense of shear.

not symmetric. The mylonitic character of the penetrative S_2 foliation makes it almost impossible to localize the critical shear horizons. Even if the superposition of the hardschists on the granitoids is of a primary depositional nature, this interpretation implies at least important movement beneath every granitoid slice where both lithologies alternate in vertical section. This alternation of basement and cover rocks is similar to the internal structure of the Akkajaure Nappe Complex (Björklund 1985) and the Middle Allochthon in the north-central Scandinavian Caledonides (Greiling 1985).

Uncertainty concerning the origin of the metabasites further complicates a palinspastic reconstruction. Because they are partly underlain by hardschists, at least two continuous thrusts are required beneath the metabasites in the ANC if they are to be regarded as overthrusted Precambrian basement (cf. Kulling 1964). An alternative interpretatioon of the metabasites as Caledonian magmatic rocks would imply that the base of the upper granitoid layer acted as the major internal thrust, resulting in a doubling of the sequence.

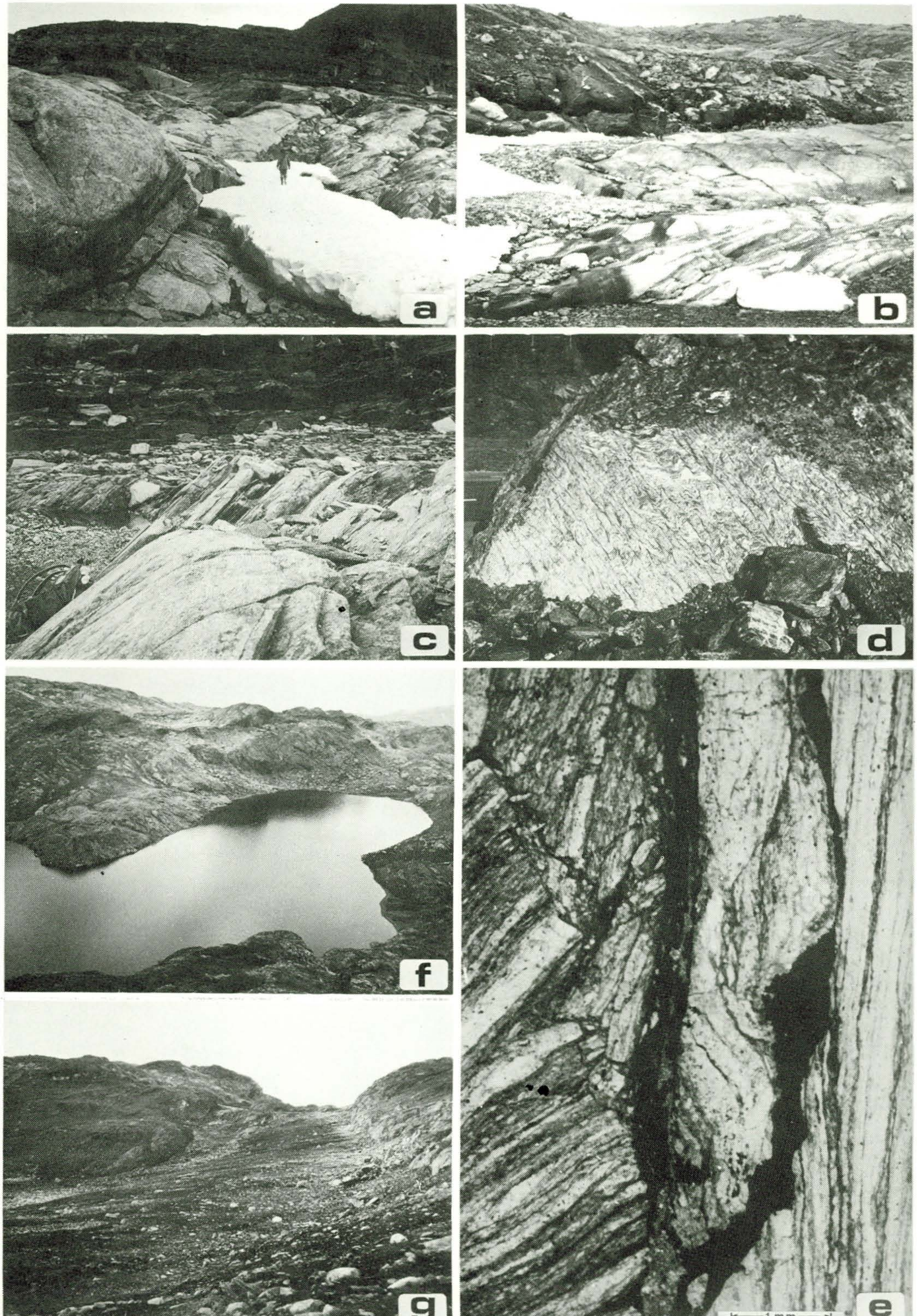
In either case, the internal thrusting and imbrication occurred prior to the final establishment of the penetrative S_2 foliation, which has overprinted any pre-existing discordances. Any internal thrusts are, together with S_2, postdated by the floor thrust (T_2) of the ANC, which on a local scale cuts up section to the east. The strike of hanging-wall cut-offs along T_2 to the northeast and southwest (Plate 1) indicates local-scale, gentle folding about NW-SE-trending axes to or during overthrusting. Later reactivation of T_2 (possibly during D_4) under an elastico-frictional regime (Sibson 1977) is documented by a thin veneer of pseudotachylite at the base of the Abisko Nappe Complex near Tornehamn (Bax 1984).

D_3

During D_3 the RSC started to play an active role in the structural evolution of the study area. Overthrusting along T_2 continued, and movements in the RSC began to both initiate and influence structures in the overriding nappe pile.

The movement toward the SE encroached on the crystalline rocks of the RSW and their sedimentary cover, where imbrication produced the horses of the Hoiganjávri Complex until they finally became arranged into several lens-shaped duplexes. Accumulation of basement-derived horses in the foreland-facing

Fig. 6. a) Leading edge of a RSW horse underneath undisturbed Gearbeljávri Formation southwest of Likta. View looking N. b) Gearbeljávri Formation overthrusted by crystalline rocks of the RSC south of Likta. View looking NW. c) Imbrication in the Köli at Skåpakte looking N. d) S_{4W} crenulation cleavage at Vassijaure station looking to the N. Outcrop is about 2 m in diameter. e) Pseudotachylite vein from D_4 fault bounding the Stuor Gearbil klippe to the E. For location see Fig. 6a. f) D_4 high-angle reverse fault bounding the Láirečorru klippe to the W. View looking NW. g) D_4 high-angle normal fault bounding the Láirečorru klippe to the E. View looking N. Width of col on the horizon about 60 m.


a
b
c
d
f
g
1 mm
e

parts of these duplexes suggests a forward-propagating imbrication, which involved successively lower stratigraphical levels during coeval updoming of the RSC. Branch- and tip-line configurations (Plate 1), together with internal orientations of mylonitic foliations (cf. synoptic diagram south of Hoiganjávri on Plate 1) and a-lineations, indicate SE-directed thrusting during formation and emplacement of the Hoiganjávri Complex.

Segmentation of the RSC continued under conditions causing ductile behaviour in quartzo-feldspathic rocks (quasi-plastic regime of Sibson 1977). Parts of the Gearbeljávri Formation involved in thrusting in the uppermost parts of the RSC demonstrate the compressional nature of the deformation (Fig. 6b). The orientation of NW-SE-elongated pebbles in this formation beneath RSC horses indicate NW-SE-trending dislocations, similar to those in the Hoiganjávri Complex.

Ductile shear-zones or ductile deformation zones (DDZ: Mitra 1978) generally follow lithological boundaries, or utilize already foliated rocks. About 100 m below T_2 on the northern slope of Stuor Gearbil, one flat-lying DDZ (Fig. 5b) exhibits SE-dipping extensional crenulation cleavages (ecc: Platt 1979, 1984). In the vicinity of the leading edges of the resulting horses most of the observed DDZs swing into parallelism with the roof thrust T_2 or the depositional contact of the Gearbeljávri Formation (Fig. 6a).

Geometrical considerations (see next section) require a master sole thrust (T_3) at the base of the RSC. However, unpublished investigations by the present author and published geological maps from different parts of the RSW have not revealed any possible outcrops of this assumed sole thrust. The exposed base of the Rautas Complex may be regarded as the emergent eastward continuation of T_3.

During D_3, parts of the nappe complexes were deformed round NE-SW-striking fold axes. These folds are termed F_{3b}, where b stands for fold axis parallel to the tectonic B direction. F_{3b} is always overturned to the SE and is usually accompanied by an axial plane cleavage (S_3).

The window through the Upper Allochthon east of Gorsajökeln exhibits intensely imbricated granitoid mylonites and hardschists of the Abisko Nappe Complex. Previously mylonitized quartzo-feldspathic rocks are here truncated by NW-dipping shear-zones. Phyllonites around the tip-lines of quartzo-feldspathic horses suffered complex folding, with axes both parallel (see below) and normal to the inferred trend of dislocation. The southeastern part of the study area (Plate 1) is dominated by imbrications (Fig. 6c) which involve both the Middle and the Upper Allochthon. It remains unclear if (and how) these imbrications are related to those in the RSC (cf. fig. 2 in Bax 1986).

Another type of fold structure that is, at least partly, related to D_3 is represented by the widespread and approximately NW-SE-striking transverse folds or cross-folds (cf. Rast & Platt 1957). These cross-folds are termed F_{3a}. Lindström (1961, p. 152) found these transverse folds to be overturned equally to the SW and the NE and he (1961, fig. 5) interpreted the axial trends of minor folds as a result of reorientation of earlier folds towards parallelism with the stretching direction. This explanation is widely accepted (e.g. Sanderson 1973, Escher & Watterson 1974) and appears to be valid for most tight to isoclinal, minor F_{3a} folds observed in the area.

An explanation for the transverse trend of large-scale, open cross-folds, with wavelengths of several metres to kilometres, by reorientation is more problematic. In the Middle Allochthon many of these structures are accompanied by NW-SE-trending high-angle faults in the directly underlying RSC. The resulting horst-and-graben structures acted as sidewall or lateral ramps (Bax 1984) during final stages of overthrusting. This mechanism was clearly active during translation in the Likta area, where parts of the overriding rocks moved obliquely on a staircase trajectory while undergoing transverse folding and imbrication. The enveloping surfaces (Faltenspiegel) of these cross-folds are parallel to the SW-inclined slope of the 'basement surface'. Vergencies here tend to the southwest. Around Tornehamn (Bax 1984), where this 'basement surface' is inclined to the northeast, enveloping surfaces dip and vergencies face likewise to the northeast.

Lineations on the NW-SE faults indicate a strike-slip component of movement, which exceeds the vertical component. The strike of this group of late D_3 faults varies considerably. They commonly intersect horses of the RSC (south of Vuoiddasriidda), but they are themselves cut off by approximately N-S-trending high-angle D_4 faults in Láirevággi. In places they are overlain by undisturbed duplexes of the Hoiganjávri Complex.

D_4

The phase D_4 is characterized by large-scale faulting of the RSC (cf. Fig. 5a) accompanied by folding of the overlying units. One of the resulting (N-S to NNE-SSW-striking) structures has been mentioned above. Others are, e.g., the klippen (cf. Plate 1.) of Gatteroavi, Láirečorru and Stuor Gearbil. These synformal outliers of the Abisko Nappe Complex owe their preservation to downfaulting during D_4 (cf. Figs 6f & 6g). Goldschmidt (1912) used the term Faltungsgraben for similar structures, created without ruptural deformation.

Displacement along almost vertical, normal and reverse shear-zones took place initially under a QP-regime, resulting in rocks of the mylonite series (Sibson 1977). During the final stages of continued movement, or perhaps caused by reactivation, dislocation resulted in the local formation of pseudotachylite (Fig. 6e). Sibson (1975) described pseudotachylite as a product of rapid (seismic) transient sliding on extremely brittle faults. Frictional melting at shallow depth (Sibson 1977:<10-15 km) is widely accepted (e.g. Allen 1980, Maddock 1983; but cf. Wenk 1978) as the generating mechanism.

The N-S to NNE-SSW-striking faults are locally accompanied by sulphide-bearing quartz veins. Sheet-like veins are partly involved in late D_4 folding (cf. Johansson 1980). Kappa-configurations (Tischer 1962) in synoptic B-diagrams for the adjoining rocks of the Hoiganjávri Complex on Stuor Gearbil (see Plate 1) testify to the influence of the largest observed vein (about 800 m long and up to 60 m wide) during D_4.

High-angle D_4 faults usually vary in dip between 90-60° both to the east and to the west. Eastward-inclined reverse faulting produced pop-up back-thrusts in the telescoped RSC (but cf. Andresen & Cashman 1984, and Cashman this volume). Holmquist described (1903, p. 70) and illustrated (op.cit., figs. 11—13) some of these structures.

D_4-related folding (F_4) in the graben-bound synforms distinctly deforms all pre-existing structures. The originally oblique trending (NW-SE), ubiquitous L_2 lineation can be used to determine pre-D_4 tectonostratigraphic wayup even in overturned F_4 structures. Vergencies of F_4 usually tend to the east, except in areas influenced by (pop-up) back-thrusting. Accompanying axial-plane cleavages (S4) dip to the west in the western parts of the synforms, but they adopt the orientation of the faults which bound the synforms to the east. Close to these faults, S_4 can become the dominant foliation instead of S_2. Westward-dipping S_4 is called S_{4W} and the S_4 related to back thrusting, S_{4E} (Fig. 6d). Intersection of S_{4W} and S_{4E} results in N-S-trending S_4 lineations, which, in the phyllitic part of the Hoiganjávri Complex, can give rise to pencil cleavage. D_4-related structures die out in successively higher levels of the allochthonous sequence.

Large-scale, E-W-trending, tight, upright folds occur in the Upper Allochthon east of Vuoiddasriidda. Minor, isolated fold structures are present in different parts of the study area. It remains unclear whether these folds are the result of a general, post-D_4 N-S compression, or if they represent D_4 cross-folds.

D_5

Generally eastward-dipping, closely spaced (some ten metres) normal faults in the Köli east of the present study area are related to D_5. SE-plunging striations on the slickensides indicate the direction of extensional faulting, which was possibly driven by the force of gravity.

Arguments for an allochthonous position of the Rombak-Sjangeli Complex

As mentioned above, almost all previous tectonostratigraphic compilations presume an autochthonous position for the rocks of the RSW. Only Asklund (1946, p. 245) and Vogt (1941) discussed an allochthonous position for the RSW, but this assumption was censured by Kulling (1950b, p. 482). Gee et al. (1985) regarded the RSW as parautochthonous.

Clarification of the tectonostratigraphic position of the RSW and related tectonic windows (see Fig. 1) is a fundamental prerequisite to palinspastic reconstructions and nappe correlations in the Caledonides. It would also help to identify migration paths and possible sources for the ore-bearing fluids that led to the formation of hydrothermal deposits in and around the RSW.

The interpretation of the RSW as an non-transported westerly continuation of the Baltic Shield is commonly (e.g. Kulling 1964) based on lithostratigraphic correlation of its sedimentary cover (Gearbeljávri Formation) with the autochthonous Dividal Group (Hyolithusserie of Kulling 1964) at the eastern margin of the Caledonides. This argument is not convincing, because the undoubtedly allochthonous Rautas Complex (Lower Allochthon) contains extensive and far better preserved equivalents of the Dividal Group. Lithostratigraphic correlation between the two latter units is possible down to the rank of members or even beds (cf. Dworatzek 1976). Up to 80 m-thick alternations of sand and siltstones, characterizing both the Torneträsk Formation (Thelander 1982) of the Dividal Group and the main parts of the sedimentary rocks of the Rautas Complex, are reduced in the west to the upper few metres of the Gearbeljávri Formation. On the other hand, no counterparts to the metagreywackes of the Hoiganjávri Complex exist in the Dividal Group below the Alum Shale Formation (Thelander 1982).

Another problem arising with an autochthonous interpretation of the RSW concerns the derivation of the Rautas Complex. Kulling (1964, p. 67) supposed a possible root zone for the Rautas Complex in the RSW around the border between Norway and Sweden. Lithostratigraphic comparisons between the Rautas sediments with both the Gearbeljávri Formation and the Hoiganjávri Complex (see above), however, exclude this possibility. Additionally, a higher grade of metamorphism is to be expected for a Rautas Complex derived from, or transported over the RSW during downward-propagating thrusting of the Caledonian nappe pile. The partly imbricated, up to 200 m-thick succession of Rautas sediments is considered to be generally anchimetamorphic (Lindström et al. 1985) in contrast to the low-grade ('biotite grade') Gearbeljávri Formation and metasediments of the Hoiganjávri Complex. A root zone for the Rautas Complex between hypothetically autochthonous windows and the westernmost occurrences of autochthonous Dividal Group (eg. between Tornehamn and Stordalen on Fig. 2) can be excluded, because the telescoped Rautas sediments (cf. figs. 40 & 41 in Kulling 1964), exposed over 25 km along the Torneträsk section (cf. fig. 2 in Lindström et al. 1985), require a basin larger than the available 19 km-wide zone between Tornehamn and Stordalen for their deposition.

The fact that the roof thrusts of the RS- and the Rautas Complexes suffered the same style of folding supports a correlation of both units. The sole thrust of the nappe pile in the eastern part of the Torneträsk section (probably correlatable with T_3) cuts up section to the east. It remains non-folded below both the Rautas Complex and the Abisko Nappe Complex (cf. Lindström et al. 1985).

In any case, the Rautas Complex either joins or underlies the RS-Complex (RCS) west of Abisko. Therefore, the RSC is here included in the Lower Allochthon. SE-directed displacement of the Rautas Complex at Stordalen is estimated to exceed the 20 km of its uninterrupted occurrence on top of the Dividal Group along the Torneträsk section (cf. fig. 2 in Lindström et al. 1985). Any detected (subsurface) occurrence of Dividal Group (Fig. 4) underneath the Lower Allochthon west of Stordalen would increase the minimum estimate of displacement for this Lower Allochthon. Internal shortening due to imbrication in the RSC additionally demands westward increasing displacement along T_3.

Summary and conclusions

An area of about 200 km² around the northeastern corner of the RSW has been mapped at a scale of 1:10,000 in order to clarify the relationships between the structural basement of the RSW and its Caledonian nappe cover. Four tectonostratigraphic units, corresponding mainly to Kulling's (1964) classification in the upper parts of the section, were identified.

- (iv) The medium-grade metamorphosed Köli of the Seve-Köli Nappe Complex.
- (iii) The composite Abisko Nappe Complex overprinted by low-grade dynamometamorphism.
- (ii) The locally derived Hoiganjávri Complex, exposed in isolated duplexes.
- (i) The imbricated RS-Complex in stratigraphic association with the low-grade Vendian to Cambrian Gearbeljávri Formation.

Piggy-back thrusting towards the foreland is regarded as the mechanism for the piling up of this nappe sequence. Scandian thrusting (T_1) at the base of the medium-grade Upper Allochthon (Seve-Köli Complex) postdates the

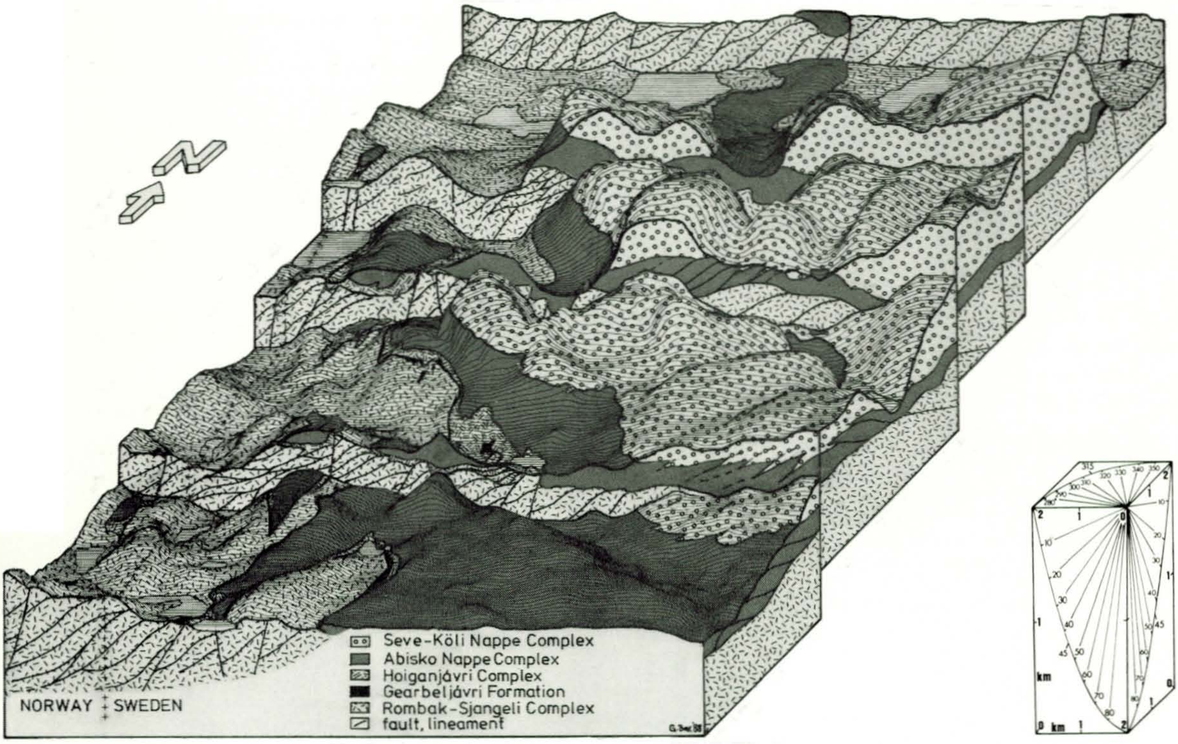


Fig. 7. Block diagram showing the geology of the study area (cf. Plate 1) at the surface and in cross-sections. The vertical scale is 2.5 times that of the horizontal.

peak of Caledonian metamorphism. Shearing and overthrusting (D_2) of the Middle Allochthon (Abisko Nappe Complex) occurred under conditions of low-grade metamorphism. Involvement (D_3) of the RSC (metamorphised at medium-grade during the Svecokarelian orogeny), the Gearbeljávri Formation and the Hoiganjávri Complex in the Caledonian orogeny took place under similar conditions. High-angle, N-S-striking faulting in the RSC and F_4 folding in overlying units were accompanied by emplacement of sulphide-bearing quartz veins. Uplift during D_4 resulted finally in rock products (pseudotachylites, cataclasites and breccias) of the elastico-frictional regime (Sibson 1977).

The exposed nappe boundaries (T_1 and T_2) suffered folding due to deformation in the underlying units. (Re)activation of pre-Caledonian structures in the RSC during D_3 resulted in frontal, lateral or oblique ramps forming beneath coeval southeastward thrusting along T_2. This footwall (ramp and flat) topography gave rise locally to F_{3a} cross-folds in the overriding allochthon. The creation of many more cross-folds in the orogen (cf. Lindström 1961) is probably explicable by simultaneous development of 'basement' culminations (but cf. Steltenpohl & Bartley 1988).

The present structure and position of the RSW 'basement' culmination (and possibly those of related culminations) is explicable by strain hardening, while passing the ductile/brittle transition zone during final upthrusting along T_3.

Acknowledgements

This paper summarizes results of my doctoral thesis at the Philipps-Universität in Marburg (West Germany) under supervision of M. Lindström and H. Zankl. To both of them go my sincere thanks for their encouragement during all phases of my geological education at the Philipps-Universität. Parts of the research were performed at Stockholms Universitet under the stimulating and gratefully acknowledged supervision of M. Lindström. I would also like to express my deep appreciation to the numerous members of both institutes for their support to the present study in the form of advice and practical help. The warm hospitality of the staff of the Abisko Scientific Research Station is greatly acknowledged. D.G. Gee and E. Zachrisson are thanked for stimulating discussions in the field. The English version of the manuscript benefited from linguistic help by A.R. Cruden and K.H. Sutton. The referees P.H. Casman, S.W. Sawyer and one anonymous referee are thanked for their comments which greatly improved the manuscript. Parts of the study were financed by a grant from the Philipps-Universität and fieldwork was supported by DAAD, KVA and SGU. Teddy M. Blomberg prepaired the photographs.

References

Adamek, P.M. 1975: Geology and mineralogy of the Kopparåsen uranite-sulphide mineralization, Norrbotten County, Sweden. *Sver. geol. unders. C 712,* 169 pp.

Ahlberg, P. 1979: Early Cambrian trilobites from Mount Luopakte, northern Sweden. *Sver. geol. unders., C 765,* 12 pp.

Allen, A.R. 1980: Mechanism of frictional fusion in fault zones. *J. Struct. Geol. 1,* 231—243.

Andreatta, C. 1954: Über die Verglimmerung der Plagioklase in der tektonischen Metamorphose. *Tscherm. miner. petrogr. Mitt. 4,* 350—359.

Andresen, A. & Cashman, P.H. 1984: Extensional faulting during nappe emplacement, Scandinavian Caledonides. Abstr. with prog. *97 th. ann. meeting Geol. Soc. Am., Reno, Nevada. 16,* p. 431.

Asklund, B. 1938: Hauptzüge der Tektonik und Stratigraphie der mittleren Kaledoniden in Schweden. *Sver. geol. unders. C 417,* 99 pp.

Asklund, B. 1946: En återblick pa den svenska fjällkedjeforskningen. *Geol. För. Stockh. Förh. 68,* 212—250.

Bax, G. 1984: *Geologie des Tornehamngebietes am Westufer des Torneträsk, Schwedish - Lappland.* Unpubl. Dipl. Thesis, University of Marburg (West-Germany), 154 pp.

Bax, G. 1986: Basement involved Caledonien nappe tectonics in the Swedish part of the Rombak-Sjangeli Window. *Geol. För. Stockh. Förh. 108,* 268—270.

Bax, G. 1987: Detachment systems in different tectonostratigraphic units of the northern Scandinavian Caledonides. *Terra Cognita 7,* p. 48.

Bax, G. 1988: *Kaledonische Strukturentwirklung und Tektonostratigraphie im Rombak-Sjangeli Fenster und den randlich überlagernden Einheiten, nördliche Skandinavische Kaledonien.* Unpubl. Doctoral Thesis, University of Marburg (West Germany), 99 pp.

Bergström, J. & Gee, D.G. 1985: The Cambrian in Scandinavia. *In* D.G. Gee & B.A. Sturt (eds.) *The Caledonide orogen — Scandinavia and related areas.* John Wiley & Sons, Chichester, 247—271.

Berthé, D., Choukroune, P. & Jegouzo, P. 1979: Orthogneiss, mylonite and non coaxial deformation of granites: the example of the South Armorican Shear Zone. *J. Struct. Geol. 1,* 31—42.

Binns, R.E. 1978: Caledonian nappe correlation and orogenic history in Scandinavia north of lat 67°N. *Geol. Soc. Am. Bull. 89,* 1475—1490.

Birkeland, T. 1976: Skjomen, berggrunnsgeologisk kart N10 - M. 1—100,000. *Nor. geol. unders.*

Björklund, L. 1985: The Middle and Lower Allochthons in the Akkajaure-Tysfjord area, northern Scandinavian Caledonides. *In* D.G. Gee & B.A. Sturt (eds.) *The Caledonide orogen — Scandinavia and related areas.* John Wiley & Sons, Chichester, 515—528.

Boyer, S.E. & Elliott, D. 1982: Thrust systems. *Bull. Am. Ass. Petrol. Geol. 66,* 1196—1230.

Brouwer, H.A. 1937:Über metamorphe Gesteine am Torne Träsk (Lappland). *Ned. Akad. Wet., Amsterdam, Proc. 40,* 414—421.

Brouwer, H.A. 1940a: Metamorphic Differentation in hartschiefer of Northern Sweden. *Ned. Akad. Wet., Amsterdam, Proc. 43,* 142—148.

Brouwer, H.A. 1940b: Über die Bildung von Hartschiefern am Törne Träsk in Lappland. *Geol. Rundsch. 31,* 154—162.

Brown, B.R. & Wells, M.K. 1966: A contribution to the geology of the Vassijaure-Sjangeli area of Swedish Lappland. *Geol. För. Stockh. Förh. 87,* 527—547.

Bryhni, I. & Sturt, B.A. 1985: Caledonides of southwestern Norway. *In* D.G. Gee & B.A. Sturt (eds.) *The Caledonide orogen — Scandinavia and related areas.* John Wiley & Sons, Chichester, 89—107.

Butler, R.W.H. 1982: The terminology of structures in thrust belts. *J. Struct. Geol. 4,* 239—245.

Chapman, T.J., Gayer, R.A. & Williams, G.D. 1985: Structural cross-sections through the Finnmark Caledonides and timing of the Finnmarkian event. *In* D.G. Gee & B.A. Sturt (eds.) *The Caledonide orogen — Scandinavia and related areas.* John Wiley & Sons, Chichester, 593—609.

Du Rietz, T. 1949: The Nasafjäll region in the centre of the Scandinavian Caledonides. *Geol. För. Stockh. Förh. 71,* 243—252.

Dworatzek, M. 1976: *Geologie des Ostrandes der skandinavischen Kaledoniden im westlichen Stordalengebiet am Torneträsk im nördlichen Schweden.* Unpubl. Dipl. Thesis, University of Marburg (West-Germany), 219 pp.

Etheridge, M.A., Hobbs, B.E. & Paterson, M.S. 1973: Experimental deformation of single crystals of biotite. *Contr. Min. Petrol. 38,* 21—36.

Escher, A. & Watterson, J. 1974: Stretching fabrics, folds and crustal shortening. *Tectonophysics 22,* 223—231.

Flint, R.F. 1975: Features other than diamicts as evidence of ancient glaciations. *In* Wright & Moseley (eds.) *Ice ages: ancient and modern.* Seel House Press, Liverpool, 121—136.

Flint,. R.F., Sanders, J.E. & Rogers, J. 1960a: Symmictite: a name for nonsorted terrigenous sedimentary rocks that contain a wide range of particle sizes. *Geol. Soc. Am., Bull. 71,* 507—510.

Flint, R.F., Sanders, J.E. & Rogers, J. 1960b: Diamictite: a substitute term for symmictite. *Geol. Soc. Am., Bull. 71,* 1809—1810.

Gayer, R.A., Rice, A.H.N., Roberts, D., Townsend, C. & Welbon, A. 1987: Restoration of the Caledonian Baltoscandian margin from balanced cross-sections: the problem of exess continental crust. *Trans. Royal Soc. Edinb. Earth Sciences, 78,* 197—217.

Gee, D.G. 1975: A tectonic model for the central part of the Scandinavian Caledonides. Am. J. Sci. 275 A, 468—515.

Gee, D.G. 1980: Basement-cover relationsships in the central Scandinavian Caledonides. *Geol. För. Stockh. Förh. 102,* 455—474.

Gee, D.G. & Zachrisson, E. 1979: The Caledonides in Sweden. *Sver. geol. unders. C 769,* 148 pp.

Gee, D.G., Kumpulainen, R., Roberts, D., Stephens, M.B., Thon, A. & Zachrisson, E. 1985: Scandinavian Caledonides, tectonostratigraphic map. *Sver. geol. unders. Ba 35.*

Goldschmidt, V.M. 1912: Geologisch-petrographische Studien im Hochgebirge des südlichen Norwegens. II. Die kaledonische Deformation der südnorwegischen Urgebirgstafel. *Videnskapsselskapets skr. I. mat.-nat. kl. 19,* 3–11.

Gorbatschev, R. 1985: Precambrian basement of the Scandinavian Caledonides. *In* Gee, D.G. & Sturt, B.A. (eds.) *The Caledonide orogen — Scandinavia and related areas.* John Wiley & Sons, Chichester, 197–212.

Greiling, R. 1982: Precambrian basement complexes in the north-central Scandinavian Caledonides and their pre-Caledonian tectonic evolution. *Geol. Rundschau 71,* 85–93.

Greiling, R. 1985: Strukturelle und metamorphe Entwicklung an der Basis grosser, weittransportierter Deckeneinheiten am Beispiel des Mittleren Allochthons in den zentralen Skandinavischen Kaledoniden (Stalon-Dekkenkomplex in Västerbotten, Schweden). *Geotekt. Forsch. 69,* 129 pp.

Griffin, W.L., Taylor, P.N., Hakkinen, J.W., Heier, K.S., Iden, I.K., Krogh, E.J., Malm, O., Olsen, K.I., Ormaasen, D.E. & Tveten, E. 1978: Archaean and Proterozoic crustal evolution in Lofoten - Vesterålen, N Norway. *J. geol. Soc. London 135,* 629–647.

Gunner, J.D. 1981: A reconnaissance Rb-Sr study of Precambrian rocks from the Sjangeli-Rombak window and the pattern of initial $^{87}Sr/^{86}Sr$ ratios from northern Scandinavia. *Nor. Geol. Tidsskr. 61,* 281–290.

Gustavson, M. 1966: The Caledonian mountain chain of the Southern Troms and Ofoten areas. Part I. Basement rocks and Caledonian meta-sediments. *Nor. geol. unders. 239,* 162 pp.

Gustavson, M. 1972: The Caledonian mountain chain of the Southern Troms and Ofoten areas. Part III. Structures and structural history. *Nor. geol. unders. 283,* 56 pp.

Gustavson, M. 1978: Caledonides of north-central Norway. *Geol. Sur. Canada, Paper 78–13,* 25–30.

Harland, W.B., Herod, K.N. & Krinsley, D. 1966: The definition and identification of tills and tillites. *Earth-Science Rewiews 2,* 225–256.

Heier, K.S. & Compston, W. 1969: Interpretation of Rb-Sr age patterns in high-grade metamorphic rocks, North Norway. *Nor. Geol. Tidsskr. 49,* 257–283.

Higgins, M.W. 1971: Cataclastic rocks. *U.S. Geol. Surv. Prof. Paper 687,* 97 pp.

Hodges, K.V. 1985: Tectonic stratigraphy and structural evolution of the Efjord - Sitasjaure area, northern Scandinavian Caledonides. *Nor. geol. unders. Bull. 399,* 41–60.

Hodges, K.V., Bartley, J.M. & Burchfiel, B.C. 1982: Structural evolution of an A-type subduction zone, Lofoten - Rombak area, northern Scandinavian Caledonides. *Tectonics 1,* 441–462.

Holmquist, P.J. 1903: En geologisk profil öfver den Skandinaviska fjällkedjan vid Torneträsk. *Geol. För. Stockh. Förh. 25,* 27–78.

Holmquist, P.J. 1910: Die Hochgebirgsbildungen am Torneträsk in Lappland. *Geol. För. Stockh. Förh. 32,* 913–983.

Hossak, J.R. 1983: A cross-section through the Scandinavian Caledonides constructed with the aid of branch-line maps. *J. Struct. geol. 5,* 103–111.

Johansson, Å. 1980: Occurrence and deformation of some sulphide-bearing quartz veins in the Nasafjället area, Swedish Caledonides. *Nor. geol. unders. 360,* 113–122.

Johansson, Å. 1983: Descriptions of Caledonian sulfide-bearing veins in Sweden. *In* S. Lindblom (ed.) *ORG 83 — Annual Report of the Ore Research Group.* Stockholm Univ. 1983, 151–166.

Johansson, Å. 1984: Fluid inclusion and stable isotope studies on some Caledonian sulfide-bearing veins in Sweden. *Econ. geol. 79,* 1736–1748.

Kathol, B. 1987: The Váivvančohkka Nappe, Torneträsk area, northern Swedish Caledonides. *Geol. Förh. Stockh. Förh.* 109, 350-353.

Kautsky, F. & Tegengren, F.R. 1952: Die Geologie der Umgebung des Tuoddarjaure am Südrande des Sjangelifensters. *Geol. För. Stockh. Förh. 74,* 455–474.

Korneliussen, A., Tollefsrud, J.I., Flood, B. & Sawyer, E. 1986: Precambrian volcano-sedimentary sequences and related ore deposits, with special reference to the Gautelisfjell carbonate-hosted gold deposit, Rombaken basement window, Northern Norway. *Nor. geol. unders. Unpubl. report 86.193,* 46 pp.

Kulling, O. 1950a: Berggrunden söder om Torneträsk. *Geol. För. Stockh. Förh. 72,* 454–472.

Kulling, O. 1950b: Bidrag till diskussionen om Torneträskberggrunden. *Geol. För. Stockh. Förh. 72,* 481–485.

Kulling, O. 1960a: The Caledonian Mountain Chain in the Torneträsk-Ofoten area, Northern Scandinavia. *Part of the guide to excursions Nos A 25 and C 20. Int. Geol. Congr. XXI Session.* Stockholm.

Kulling, O. 1960b: On the Caledonides of Swedish Lappland. *In* Magnusson, N.H., Thorslund, P., Brotzen, F., Asklund, B. & Kulling, O.: *Description to accompany the map of the Pre-Quarternary rocks of Sweden. Sver. geol. unders. Ba 16,* 150–177.

Kulling, O. 1964: Översikt över norra Norrbottensfjällens kaledonberggrund (with English summary). *Sver. geol. unders. Ba 19,* 166 pp.

Kulling, O. 1972: The Swedish Caledonides. *In* Strand, T. & Kulling, O. (eds.) *The Scandinavian Caledonides.* John Wiley & Sons, Chichester, 151–285.

Kvale, A. 1953: Linear structures and their relation to movement in the Caledonides of Scandinavia and Scotland. *J. geol. Soc. London 54,* 51–73.

Lindström, M. 1958: Tectonic transports in the Caledonides of northern Scandinavia east and south of the Rombak-Sjangeli window. *Publ. Inst. Mineral. Paleontol. Quaternary Geol.* Univ. Lund 43, 14 pp.

Lindström, M. 1961: Beziehungen zwischen Kleinfaltenvergenzen und anderen Gefügemerkmalen in den Kaledoniden Skandinaviens. *Geol. Rundsch. 51,* 144–180.

Lindström, M. 1988: Northernmost Scandinavia in the geological perspective. *Eco. Bull. 38,* 17–37.

Lindström, M., Bax, G., Dinger, M., Dworatzek, M., Erdtmann, W., Fricke, A., Kathol, B., Klinge, H., Pape, P.v. & Stumpf, U. 1985: Geology of a part of the Torneträsk section of the Caledonian front, northern Sweden. *In* D.G. Gee & B.A. Sturt (eds.) *The Caledonide orogen — Scandinavia and related areas.* John Wiley & Sons, Chichester, 507–513.

Löfstrand, G. 1894: Gångformiga malmbildningar i Norrbotten. *Geol. För. Stockh. Förh. 16,* 131–150.

Maddock, R.H. 1983: Melt origin of fault-generated pseudotachylytes demonstrated by textures. *Geology 11,* 105–108.

Mitra, G. 1978: Ductile deformation zones and mylonites: the mechanical processes in the deformation of crystalline basement rocks. *Am. J. Sci. 278,* 1057–1084.

Moberg, J.C. 1908: Bidrag till kännedomen om de kambriska lagren vid Torneträsk. *Sver. geol. unders. C 212,* 30 pp.

Nicholson, R. & Rutland, R.W.R. 1969: A section across the Norwegian Caledonides; Bodø to Sulitjelma. *Nor. geol. unders. 260,* 86 pp.

Park, R.G. 1969: Structural correlation in metamorphic belts. *Tectonophysics 7,* 323—338.

Petersson, W. 1897: Om de geologiska forhållandena i trakten omkring Sjangeli koppermalmsfält i Norrbottens län. *Geol. För. Stockh. Förh. 19,* 296—306.

Pettersen, K. 1887: De geologiske bygningsforholde langs den nordlige side af Torne träsk. *Geol. För. Stockh. Förh. 9,* 420—433.

Platt, J.P. 1979: Extensional crenulation cleavage. *J. Struct. Geol. 1,* 95—96.

Platt, J.,P. 1984: Secondary cleavages in ductile shear zones. *J. Struct. Geol. 6,* 439—442.

Pringle, J.R. 1973: Rb/Sr age determinations on shales associated with the Varanger Ice Age. *Geol. Mag. 109,* 465—472.

Quensel, P. 1916: Zur Kenntnis der Mylonitbildung, erläutert an material aus dem Kebnekaisegebiet. *Geol. Inst. Univ. Uppsala Bull. 15,* 91—116.

Rast, N. & Platt, J.I. 1957: Cross-folds. *Geol. Mag. 94,* 159—167.

Reitan, P. 1963: The geology of the Komagfjord tectonic window of the Raipas suite, Finnmark, Norway. *Nor. geol. unders. 221,* 71 pp.

Romer, R.L. 1989: Implication of isotope data on the metamorphism of the basic metavolcanites from the Sjangeli Window, northern Sweden. *Nor. geol. unders.* 415, 39—56.

Sander, B. 1948: *Einführung in die Gefügekunde der geologischen Körper.* Springer, Wien; 215 pp.

Sanderson, D.J. 1973: The development of folds oblique to the regional trend. *Tectonophysics 16,* 55—70.

Sawyer, E.W. 1986: Metamorphic assemblages and conditions in the Rombak basement window. *Nor. geol. unders. Unpubl. report 86.168,* 25 pp.

Sibson, R.H. 1975: *Generation of pseudotachylyte by ancient seismic faulting. Royal Astron. Soc. Geophys. Jour. 43,* 775—794.

Sibson, R.H. 1977: Fault rocks and fault mechanism. *Geol. Soc. London 133,* 191—213.

Simpson, C. 1985: Deformation of granitic rocks across the brittle-ductile transition. *J. Struct. Geol. 7,* 503—511.

Steltenpohl, M.G. & Bartley, J.M. 1988: Cross folds and back folds in the Ofoten-Tysfjord area, north Norway, and their significance for Caledonian tectonics. *Geol. Soc. Am. Bull. 100,* 140—151.

Strand, T. 1960: Cambro-Silurian deposits outside the Oslo region. *In* O. Holtedahl (ed.) *Geology of Norway.* Nor. geol. unders. Bull. 208, 151—165.

Thelander, T. 1982: The Torneträsk Formation of the Dividal Group, northern Swedish Caledonides. *Sver. geol. unders. C 789,* 41 pp.

Thelander, T., Bakker, E. & Nicholson, R. 1980: Basement-cover relationships in the Nasafjället Window, central Swedish Caledonides. *Geol. För. Stockh. Förh. 102,* 569—580.

Tischer, G. 1962: Über Kappa-Achsen. *Geol. Rundsch. 52,* 426—447.

Törnebohm, A.E. 1901: Om formationsgrupperna inom det nordligaste Skandinavien. *Geol. För. Stockh. Förh. 23,* 206—218.

Tull, J.F., Bartley, J.M., Hodges, K.V., Andresen, A., Steltenpohl, M.G. & White, J.M. 1985: The Caledonides in the Ofoten region (68° - 69°N), north Norway: key aspects of tectonic evolution. *In* D.G. Gee & B.A. Sturt (eds.) *The Caledonide orogen — Scandinavia and related areas.* John Wiley & Sons, Chichester, 553—568.

Vidal, G. 1979: Acritarchs and the correlation of the Upper Proterozoic. *Publ. Inst. Mineral. Paleontol. Quaternary Geol. Univ. Lund 219,* 22 pp.

Vogt, T. 1922: Bidrag til fjeldkjedens stratigrafi og tektonik. *Geol. För. Stockh. Förh. 44,* 714—739.

Vogt, T. 1941: Trekk av Narvik - Ofoten-traktens geologi. *Nor. Geol. Tidsskr. 21,* 198—213.

Vogt, T. 1950: Kartblad Narvik 1 : 100,000. *Nor. geol. unders.*

Wenk, H.R. 1978: Are pseudotachylites products of fracture or fusion? *Geology 6,* 507—511.

White, S. 1976: The effects of strain on the microstructures, fabrics and deformation mechanisms in quartzite. *Phil. Trans. R. Soc,. Lond. A 283,* 69—86.

White, S. 1977: Geological significance of recovery and recrystallization processes in quartz. *Tectonophysics 39,* 143—170.

Williams, G. & Dixon, J. 1982: Reaction and geometrical softening in granitoid mylonites. *Textures and Microstructures 4,* 223—239.

Wilson, M.R. & Nicholson, R. 1973: The structural setting and geochronology of basal granitic gneisses in the Caledonides of part of Nordland, Norway. *J. geol. Soc. London 129, 365—387.*

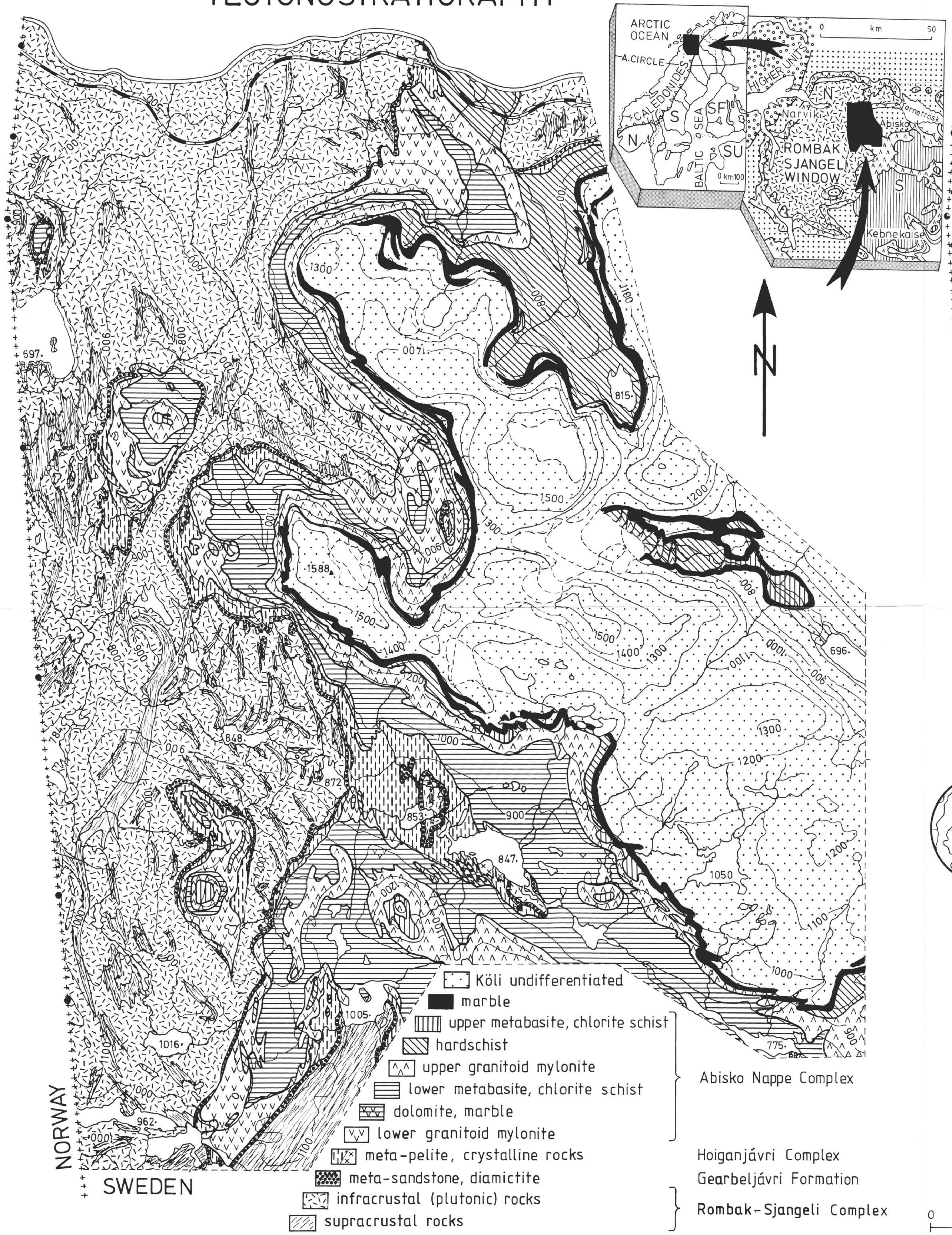
Winkler, H.G.F. 1979: *Petrogenesis of metamorphic rocks.* 5th ed., Springer, New York, 348 pp.

Zachrisson, E. 1973: The westerly extension of Seve rocks within the Seve-Köli nappe complex in the Scandinavian Caledonides. *Geol. För. Stockh. Förh. 95,* 243—251.

Zwart, H.J. 1974: *Structure and metamorphism in the Seve-Köli Nappe Complex (Scandinavian Caledonides) and its implications concerning the formations of metamorphic nappes. Centenaire de Cristallins, Liège 2,* 129—144.

Ödman, O.H. 1957: Beskrivning till berggrundskarta över urberget i Norrbottens län (with English summary). *Sver. geol. unders. Ca 41,* 151 pp.

TECTONOSTRATIGRAPHY



STRUCTURE