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EBBE ZACHRISSON

THE REMDALEN SYNCLINE

STRATIGRAPHY AND TECTONICS

WITH NINE PLATES IN A SEPARATE FOLDER



STOCKHOLM 1964

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ABSTRACT

This paper presents an investigation of the low metamorphic Köli rocks of the Remdalen syncline lying within the Seve-köli nappe (*stora överskjutningsskällan*) of the Caledonian mountains. (See location map, Plate I.) The westernmost part of the map area belongs to the Børgfjell massif which forms a window in the anticlinal zone along the national boundary (*riksgränsantiklinalen*).

A stratigraphic scheme of the thick geosynclinal Cambro-Silurian sequence, amounting to more than 4000 metres, is established. At three different levels quartzite conglomerates, generally associated with limestones, occur. The content of basic and acid volcanics (greenschists and quartz-keratophyres) is high, three quartz-keratophyre-bearing formations being distinguished.

Structurally the investigated area forms a well defined syncline. The major as well as associated minor structures are due to folding along both NNE-SSW main fold axes and NW-SE cross fold axes. Both directions have also been recognized by plotting on a stereogram the poles of the bedding planes for each of about 50 sub-areas. No conclusive evidence of the age relationship between the folding directions could be given. In the lower part of the nappe imbricate structures, dipping eastwards, have been rotated into this position by a later deformation which also affected the major thrust plane.

Only a few correlations with adjacent Swedish and Norwegian areas are made and the conclusions drawn are rather restricted. This is due partly to the small areal extent of the syncline but mainly to the very rapid lithologic variations of the sequence even within this restricted area. Some aspects of facies changes in the sediments and of the areal extension of effusives are discussed.

Introduction

The ore prospecting activities in the Västerbotten part of the Caledonian mountains, carried out by the Geological Survey of Sweden, were taken up again after the second world war. In the years 1946—1947 and in 1957 electro-magnetic ground measurements were performed in the Remdalen valley, covering the central part of the map area and an extension to the south-east (the Tjopasi region). The prospecting program also included searching for ore blocks, detailed geologic mapping and diamond drilling. The inadequate knowledge of the geology however, was a great drawback. For that reason State geologist Dr. G. Kautsky in 1959 set the author the task of trying to solve the stratigraphic and tectonic problems. This called for a detailed mapping of the region between the Fjällfjäll mountains and the Norwegian border.

The field work in fact had started already in 1958, but was mainly carried out during the summers of 1959—1961. Aerial photographs on the scale 1: 10.000 were used as maps in the field, and the compilation was made on an uncontrolled mosaic. This base map, reduced to the scale of 1: 25.000 is also the cartographic base of the geological map presented (Plate I). Thus rather large errors in planimetry could be expected, although the relative accuracy is rather good. Where available, geophysical maps on the scale 1: 8.000 with some geological observations made by G. Kautsky and H. Sarap have been used.

Two geological maps, covering the entire area or parts of it, have been published. The first was compiled by A. Högbom (1925) on the basis of results obtained during the prospecting period of 1918—1924, the other was published by T. Du Rietz (1941) and based on field work during the summers of 1936—1938. These results were summarized by O. Kulling in his description of the Caledonian bedrock of the county of Västerbotten (1955). The latter also gives a list of references of earlier investigations dealing with the region which the interested reader can consult (pp. 107—110).

On the Norwegian side mapping was recently carried out by T. Strand. He has presented the results of his investigations of the region to the north of the Børgfjell massif in two papers (1953 and 1955). Its southern part and the adjoining areas of Köli bedrock he has dealt with in the description of Namsvatnet map sheet (Foslie and Strand, 1956).

The present paper and accompanying map on the scale 1: 25.000 give an account of the main stratigraphic and tectonic results of the investigation in the Remdalen area. At the same time a great deal of petrographic information, including about 90 spectrochemical analyses, has been obtained, the basis of the stratigraphy being a detailed lithologic study of the rock types. As the preparation of this rather comprehensive material would, however, have delayed this report it will be published as a special paper dealing exclusively with the petro-

graphic and chemical aspects of the various rock types of the Remdalen syncline.

I should like to thank Dr. G. Kautsky, head of the Ore Prospecting Department of the Survey, and Professor S. Gavelin, Mineralogical Institute at the University of Stockholm, for their help and constructive discussions both in the field and in the office. Valuable contributions have been made by all my colleagues at the Survey.

I am also indebted to Mrs. Stina Järnefors who drew the maps, diagrams and figures, and to Mr. J. D. Cornwell who read the manuscript.

PART I

Stratigraphy

A. Stratigraphic Terminology with Relation to the Map Area

The first part of the description gives a detailed account of the stratigraphic units of the Remdalen syncline. The division is based on a thorough petrographic study of the different rock types, largely in thin sections. Consequently the nomenclature has been chosen in accordance with the lithostratigraphic terminology using the formation as a base unit, consisting of one lithological unit or an alternation of two or more lithological types or facies (Hedberg 1954, 1959, 1961, Henningsmoen 1955, 1961). Macrofossils which could be used for stratigraphic purposes have not been found in the area and as yet positive correlations with other areas have not been made. Thus the requirements of a bio- or chronostratigraphic terminology are not fulfilled. However, the frequent intercalations of volcanics, each of them representing a very short period in the geological history, constitute excellent chronostratigraphic surfaces which will probably, in the future, be of great value when making lateral correlations.

B. Autochthonous-Parautochthonous Sedimentary Rocks of the Børgefjell Window

The Børgefjell window does not constitute a part of the area investigated in detail. Nevertheless, to clarify the stratigraphic and tectonic conditions at Rainesfjället, it is necessary to give some information about the rock types within the window. The stratigraphy of these rocks has been dealt with by G. Kautsky (1948) and his results have been verified. A schematic figure is given (Fig. 1), summarizing his conclusions.

The occurrence of arkosic rocks, to some extent with conglomeratic layers, above the Saxfjäll granite in the easternmost part of the window, indicates a primary superposition of the sedimentary sequence. The main part consists of coarse quartzites or feldspathic quartzites of considerable thickness. In the field they appear as somewhat yellowish, sometimes rusty-looking rocks, rich in sericite and often showing a conchoidal fracture. The most characteristic layers are

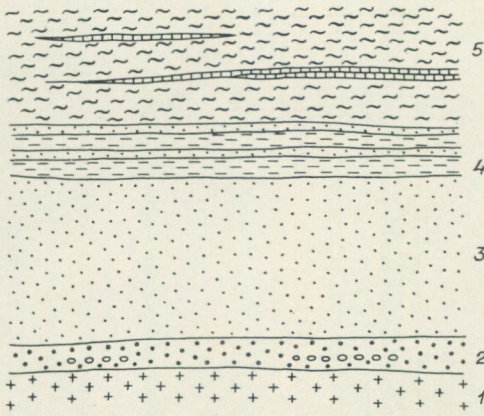


Fig. 1. Stratigraphic scheme of the sedimentary rocks of the Børgefjell massif. 1. Saxfjäll or Børgefjell Granite. 2. Arkose, sometimes conglomeratic. 3. Quartzite, feldspathic quartzite. 4. Mica-schist with beds of white or bluish glassy quartzites. 5. Dark mica-schist or phyllite with limestone horizons, upwards more calcareous.

formed by two glassy, white or bluish quartzites, each with a maximum thickness of one or a few metres, in the zone intermediate between the arkosic quartzites and the mica-schists above. The weathered surface often shows small white spots caused by the decay of feldspar grains. Dark or graphitic mica-schists and phyllites with secondary quartz veins follow above. The upper part of the sequence becomes more calcareous and sometimes thin limestones are met with.

C. Stratigraphy of the Remdalen Syncline

The following table gives the stratigraphy of the Remdalen syncline (the oldest beds at the bottom) :

Remdalen Group	
10. Frems Phyllite	
9. Remdalen Greenschist	
8. Remdalen Graphitic Phyllite	
7. Remdalen Quartzite-Conglomerate-bearing Formation	
Lasterfjäll Group	
6. Lasterfjäll Quartz-Keratophyre-bearing Formation	
5. Lasterfjäll Greenschist	
4. Western and southern part:	Eastern limb:
Fasovardo Phyllite	
Greenschist	
Kosaäive Phyllites	Lasterfjäll Calcareous Phyllite
Stekenjokk Quartz-Keratophyre	
Calcareous Phyllite	
3. Bellovare Formation	
2. Tjopasi Formation	
1. Fjällfjäll Arkose	



Fig. 2. Banded Fjällfjäll arkose with secondary veins of quartz-microcline in wrinkled, pelitic bed. Rainesfjället mountain, 1800 m SE of Fremsjön.

1. FJÄLLFJÄLL ARKOSE

Both in the western and the eastern limbs of the syncline the sequence starts with a thick arkose, which to the east of the map area forms an anticline in the Fjällfjäll mountains where it has been given the name of Fjällfjäll Arkose. It can be followed along the eastern part of the map sheet from the easternmost offset of Lasterfjället in the north down to the Saxån valley in the south. On the north-eastern part of Rainesfjället, from point 1005 and north-westwards to the Norwegian border, it occupies a rather large area. In the literature different names have been used for these rocks, reflecting varying interpretations: Lower mica-schist with quartzitic layers (Törnebohm, 1896), "granulite" (A. Högbom, 1925), granites of Fjällfjäll type (Backlund—Quensel, 1929), lowest quartzite series or bottom quartzites (Du Rietz, 1941), quartzites of Fjällfjäll type, "the oldest quartzite series" (Kulling, 1955). The layers underneath this formation are not known, and the present investigations have been concentrated on its upper part.

In the field the arkoses appear as relatively massive rocks with a regular, more or less distinct bedding (cm to dm, sometimes even up to a metre), and with colours varying between white, gray and greenish, the differences being caused by the varying content of argillitic material in the different layers. Where strong tectonic deformation has occurred lenses of red potash feldspar appear, most com-

monly in the green, chlorite-rich layers (Fig. 2). The Fjällfjäll arkose never shows a glassy appearance when broken. The rather high percentage of feldspar, chlorite and sericite is responsible for the granular or fibrous fracture surfaces.

The combination of the characteristics listed below can be used in the field to distinguish between the quartzite-looking Fjällfjäll arkoses and the quartzites of the Børgefjell massif:

Fjällfjäll arkose	Quartzites of the Børgefjell massif
Bedding in white-grey-green	Often yellowish or rusty
Red potash feldspar lenses	Missing
Granular or fibrous fracture	Often glassy, conchoidal fracture
Missing	White grains in weathered surface
Homogeneous series, thick	Mainly alternating with dark, graphitic mica-schist or phyllites
Index minerals: chlorite, sericite	Often biotite

2. TJOPASI FORMATION

Due to their poor resistance to erosion the dark-graphitic phyllites of the Tjopasi Formation form badly exposed areas. Their occurrence, however, could be mapped in rather great detail with the help of electro-magnetic measurements (see Plate VI) in the region immediately to the east of Tjopasi, the hill giving the name for the formation. Field evidence from other, better exposed areas has been used to characterize this formation. As type locality for its lower part the eastern slope of the Lasterfjäll mountain, 3 km north of Ransarån, has been chosen.

The contact against the underlying Fjällfjäll Arkose can be studied at a few localities (Fig. 3 a). The arkose passes over to a quartz phyllite in a zone only 10 cm thick. The phyllite is greenish in the lower parts, becoming darker higher up and, when overlain by a 2 m thick quartz-keratophyre, it becomes strongly graphitic. The quartz phyllites between the arkose and the quartz-keratophyric layer amount to 15—20 m and the quartz-keratophyre is overlain by a somewhat lighter quartz phyllite.

A few hundred metres further to the south the lower contact is not visible, but a rather good section exposing a higher part of the formation could be studied (Fig. 3 b). Here another quartz-keratophyre, 3 m thick, is met with, above which again occurs about 10 m of a dark quartz phyllite.

These quartz-keratophyres which are sometimes tuffitic, could be followed through scattered localities to the southern limit of the map area. In the brook to the east of Tjopasi the lower body has a considerable thickness (of the order of 50 m) and the rock shows a coarse, albite-granitic texture, whereas the upper bed seems to be mixed with sedimentary material, partly appearing as a slightly graphitic tuffite. In the eastern slope of Bellovare the quartz-keratophyric mem-

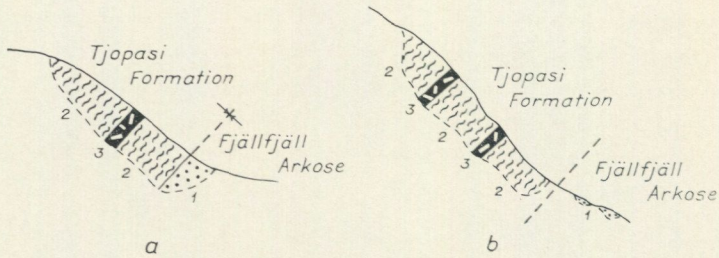


Fig. 3. Contact zone between the Fjällfjäll Arkose and the Tjopasi Formation at the type locality in the eastern part of Lasterfjället. 1. Arkose. 2. Dark quartz phyllite or graphitic phyllite. 3. Quartz-keratophyre.

bers seem to occur at a higher stratigraphic position, but because of the presumably flatter position of the formation and its wavy folding this impression could be erroneous.

The lower part of the Tjopasi Formation, as described above, does not always show up on the electromagnetic map because of the relatively pure quartz phyllites. It is succeeded, however, by more graphitic phyllites, which on the geophysical map of the Tjopasi area give rise to continuous anomalies (Plate VI). The topmost layers of the Tjopasi Formation can be studied in excellent exposures in a little brook 500 m to the north of Ransarån (Fig. 4).

In the western limb of the syncline the Tjopasi Formation is built up in the same way but the quartz-keratophyres are somewhat thicker. They are mainly coarse, bluish green or white rocks, which could be difficult to distinguish in the field from the Fjällfjäll arkose. Intercalations of dark green, more basic greenschists or greenstones have been noticed. The upper part of the formation is composed of dark, more or less strongly graphitic phyllites.

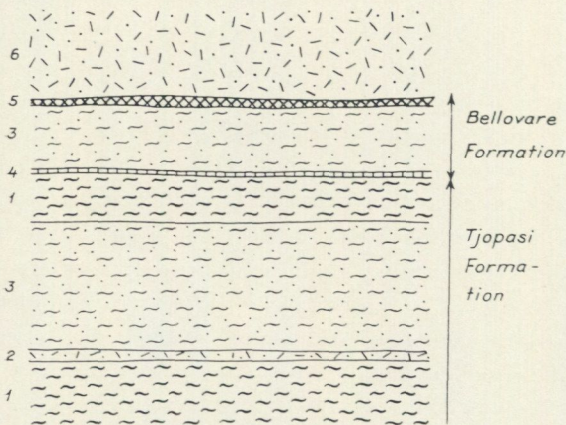


Fig. 4. Bellovare Formation and upper part of the Tjopasi Formation in the small brook 500 m N of Ransarån river (south-eastern part of Lasterfjället). 1. Graphitic phyllite. 2. Somewhat calcareous, dark phyllite. 3. Dark quartz phyllite. 4. Limestone. 5. Greenschist. 6. Calcareous phyllite. Total thickness of the sequence shown, about 100 m.

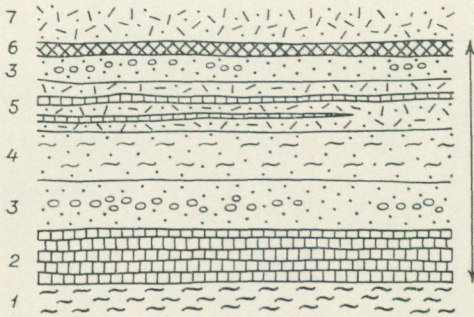


Fig. 5. Stratigraphic sequence in the eastern slope of the Bellovare mountain. 1. Graphitic phyllite. 2. Limestone. 3. Quartzite and quartzite conglomerate. 4. Dark quartz phyllite. 5. Calcareous phyllite with limestone horizons. 6. Greenschist. 7. Calcareous phyllite. Total thickness about 25 m.

3. BELLOVARE FORMATION

This formation is often very thin, and over long distances it can not be distinguished at all. Stratigraphically, however, it is of utmost importance, especially when considering correlations with adjoining areas and it will therefore be treated as a separate formation with the above name. Within the map area it is most completely developed in the steep, eastern slopes of the Bellovare mountain (Fig. 5).

Resting directly on the graphitic phyllites of the Tjopasi Formation the sequence starts with a gray-white limestone, the thickness of which is difficult to estimate because of its intricate folding. In the small hill, nearest to Froskonbäcken, it amounts to 5 m, but already a few km to the south of the map area, in the Preuntjåkko mountain, it has increased to several tens of metres. A zone of calcareous, phyllitic rocks changes into a hard, white to yellowish, almost glassy quartzite, containing extraordinarily well developed, monomikt quartzite-conglomeratic layers with up to fist-sized pebbles in a quartzitic matrix. They are followed by 5 m of quartz phyllite, sometimes strongly graphitic, 5 m of impure limestone or calcareous phyllite with dm-wide zones of gray limestone and another more or less pure quartzite with quartzite-conglomeratic layers. A 1.5 m thick, granular, partly feldspar-porphyrific greenschist forms the topmost layer of the formation.

Northwards, the moraine-covered terrain gives little information until the little brook north of Ransarån is reached (Fig. 4). Here half a metre of limestone, 15 m of graphitic quartz phyllite and a 2—3 m wide zone of calcareous greenschist occur and are considered as belonging to the Bellovare Formation. In the north-eastern corner of the map a granular, coarse greenstone appears between the graphitic phyllites of the Tjopasi Formation and the calcareous phyllites above. It has therefore a stratigraphic position similar to the greenschist layer on top of the Bellovare Formation.

In the western limb of the syncline the beds of the Bellovare Formation are even thinner. The greenschist has been observed at several localities and can be

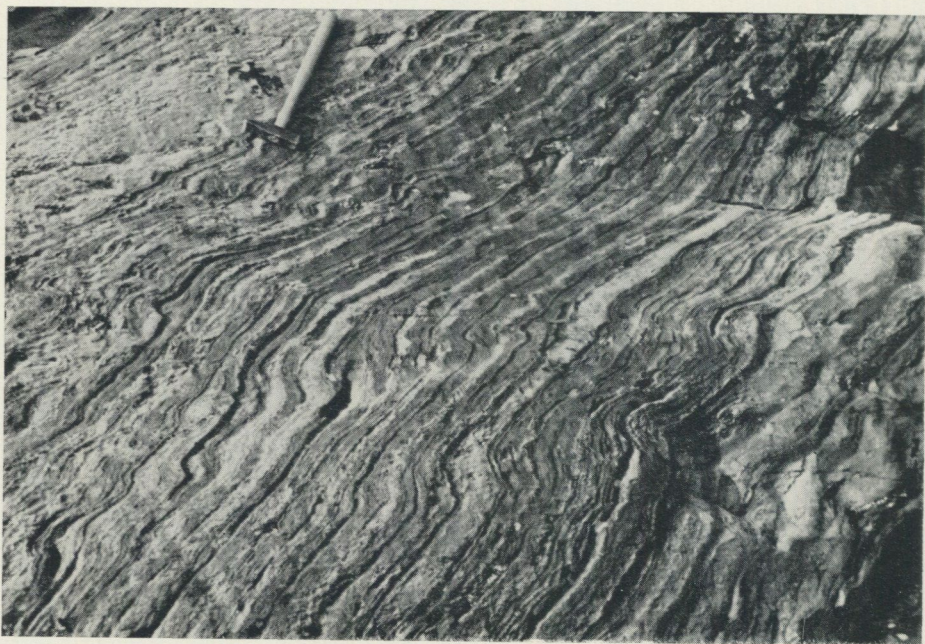


Fig. 6. Bedding in well preserved, coarse, calcareous phyllite. Saxån river, 700 m E of the Stekenjokk junction.

followed from the area to the north of Fremsjön, southwards to the west of point 1005 where it reaches a thickness of 5—6 m. Here also two horizons of grayish, pure limestone only a few cm thick occur.

4. LASTERFJÄLL CALCAREOUS PHYLLITE (Eastern Limb)

With only insignificant volcanic intercalations and nearly without facies changes the huge, calcareous phyllite in the mountains of Lasterfjället, Ruotamavardo and Tjåkkola can be followed to the south and south-west to the eastern part of Doranåje. It is usually composed of gray, very calcareous phyllites (Figs 6, 7), sometimes grading into massive, calcareous sand- or siltstones, as is the case in the Tjåkkola mountains and west of point 1007. The latter rocks are generally folded in a slightly different way to the more finegrained, argillaceous ones, now represented by wavy, strongly sheared phyllites which show a silky lustre both on the bedding planes and on the secondary s-surfaces. Less calcareous, gray, lustrous phyllites are also met with. Occasionally the calcareous phyllites look greenish as a result of a higher content of epidote and chlorite. One of the characteristics of the Lasterfjäll Calcareous Phyllite is the large number of gabbro intrusions, occurring as more or less conformable layers or lenses. Upwards this formation is succeeded by the Lasterfjäll Greenschist.



Fig. 7. North-eastwards plunging fold axes in Lasterfjäll Calcareous Phyllite. Saxån river, 1400 m W of the Stekenjokk junction.

Western and Southern Parts of the Syncline

In the western and southern part of the syncline the beds corresponding to the Lasterfjäll Calcareous Phyllite are met with in a deviating facies. The difference is due both to volcanic intercalations and to facies changes of the sediments.

4a. CALCAREOUS PHYLLITE

The sequence starts with a calcareous phyllite of the same type as the one in the eastern limb. It can be followed from the bridge over Ransarån, east of the Bie-Ransaren lake, through point 1005 up to the point 1069 north-east of Frem-sjön (Fig. 8).

4b. STEKENJOKK QUARTZ-KERATOPHYRE

The most conspicuous beds of the sequence are formed by thick layers of volcanics, mainly quartz-keratophyres, which apparently attain their maximum thickness in the Stekenjokk-Doranjaure area immediately to the south. To the north of Ransarån this formation is built up of pure effusive rocks. The main part of these are white to slightly gray or greenish, often rather coarse grained quartz-keratophyres, sometimes with an albite-granitic texture. They frequently show a distinct bedding due to thin layers of basic material (Fig. 9). An excellent

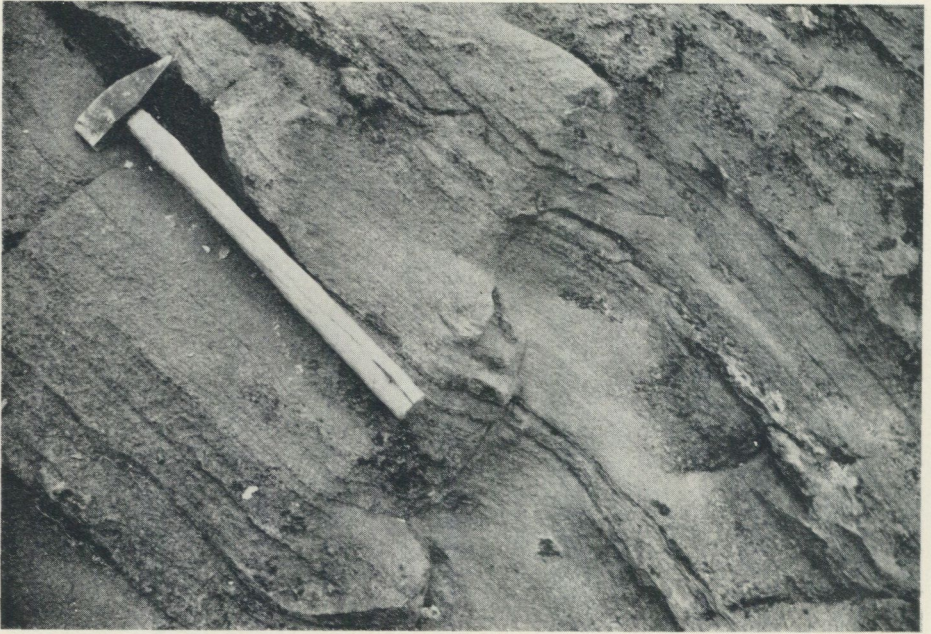


Fig. 8. Coarse, competent calcareous phyllite. Fremsjokk river, 800 m NW of Kotjärn tarn.



Fig. 9. Bedding in the Stekenjokk quartz-keratophyre, emphasized by weathering of thin, more easily eroded greenschist horizons. Locality 200 m S of Kotjärn tarn.



Fig. 10. Flat-lying, undulating Stekenjokk quartz-keratophyre. Photograph taken north-eastwards from the region 200 m S of Kotjärn tarn.

exposure to the south of Kotjärn has been studied which in 45 m contains a total of 3—4 m of greenschist material, distributed among 12 thin horizons. Both the thickness of the different layers and the proportions of greenschist to quartz-keratophyres, however, can vary very much. At a few localities in the broad valley west and south-west of Kosaåive a dark, grayish green, somewhat calcareous greenschist with big epidote concentrations has been found. Rocks of this type are often looked upon as agglomerates.

In spite of detailed field work it has not been possible to trace the Stekenjokk Quartz-Keratophyre further northwards than to the northern side of the Fremjokk valley, where its disappearance is considered to be due to a combination of primary decrease and tectonic disturbances.

In the area south of Ransarån tuffitic layers, grading into sedimentary, sometimes graphitic, beds are included in the Stekenjokk Quartz-Keratophyre. In the western part of Doranåje they occur immediately below the greenschist which forms the topmost volcanic layer of the formation. North-east of Saxån the lower part of the formation is strongly tuffitic and mixed with sedimentary material and shows an irregular alternation of white quartz-keratophyres, finegrained greenschists, sometimes agglomeratic, tuffites, lustrous phyllites and graphitic phyllites. The agglomeratic greenschist is the most persistent member and can be followed north-eastwards to Lasterfjället.

4c. KOSAÅIVE PHYLLITES

In the western limb the sedimentary sequence on top of the quartz-keratophyre is built up over long distances in quite a regular way, most clearly demonstrated in the Kosaåive mountain.

The lowest member of the Kosaåive Phyllites is a black, graphitic phyllite, 5—20 m thick. At the bottom a thin zone with some greenish horizons are met with — the last products of the Stekenjokk volcanism — and at approximately the same level thin layers of a light-coloured quartzite (not shown on the map), sometimes with a pseudo-conglomeratic appearance, have been observed. A more calcareous, gray, lustrous phyllite forms the next division, followed by a thicker (more than 50 m) graphitic phyllite with zones of a brittle, plane fracturing, graphitic shale and intercalations of glassy, yellowish quartzite. The upper part of the formation is again a gray, lustrous, calcareous phyllite.

The thickness of the formation is very much reduced to the north of the Fremsjokk river and it is not possible to distinguish the fourfold subdivision. Approximately at the same time the Stekenjokk Quartz-Keratophyre and the Kosaåive Phyllites disappear on the southern slope of Fasovardo. From the eastern part of Doranåje, on the other hand, they could be followed into the eastern limb, where northwards first the graphitic phyllites and later on also the gray, lustrous phyllites fade out into the Lasterfjäll Calcareous Phyllite.

4d. GREENSCHIST

A formation occurring only in the western limb of the syncline is formed by the greenschist which has caused the valley to the east of Kosaåive and which divides the Skaitonåje massif into two parts. The greenschist has a pronounced green colour because of its high content of epidote which is even macroscopically visible, and on weathered surfaces it shows a soft banding depending on the various proportions of calcite. No tuffitic or sedimentary layers have been observed.

Both northwards and southwards it disappears, apparently because of a primary decrease in thickness.

4e. FASOVARDO PHYLLITE

The equivalent to the upper part of the Lasterfjäll Calcareous Phyllite is the Fasovardo Phyllite. It starts with a gray, strongly calcareous phyllite containing layers approaching impure limestones in composition. The dominant rock type, however, is a lustrous, gray, slightly graphitic phyllite with a fine bedding caused by an intimate alternation of somewhat graphitic, argillaceous layers and light, finegrained, quartz rich ones. Thin greenschists or tuffitic horizons are rather common.



Fig. 11. Quartz-keratophyre with thin greenschist horizons. Stekenjokk Quartz-Keratophyre, near the small lakes S of the middle part of Doranåje mountain.

5. LASTERFJÄLL GREENSCHIST

A greenschist which has been known for a long time is best developed in the western parts of the Lasterfjäll region. This area was the subject of a detailed mapping in the summer of 1958 but in spite of this it has not been possible to establish a more detailed stratigraphy within the formation. The overall impression is an almost chaotic mixture of in part dissimilar rock members. The main part is made up of relatively finegrained greenschists, which becomes completely dominating south of Ransarån. In the western (upper) parts (at the Beitsetsnjonje mountain) coarse, phenocryst-bearing members occur which could be interpreted as original lavas. Many of the macroscopically massive greenschists have by microscopical studies also shown diffuse remnants of a porphyritic structure. Thin zones of lustrous phyllites represent originally argillaceous layers. In the highest parts of Beitsetsnjonje certain calcareous, relatively light-coloured members can possibly be interpreted as tuffites. A thin limestone horizon occurs in the lower part of the formation.

The Lasterfjäll Greenschist fades out more and more to the south. At Ransarån, immediately south of Tjåkkolastugan, outcrops show the greenschist striking across the river. In the western limb it is always thinner, although south-east of Fasovardo, due to folding and to the fact that the Fremsjokk river partly follows

the strike direction, it gives the impression of having a relatively great thickness. It has been very difficult to trace the formation further northwards in the moraine covered slope. Probably a northerly representative of the same horizon reappears in Luktjomtjuolta in the western limb of the syncline, where the light-coloured, somewhat calcareous, tuffitic rocks greatly resemble those in the crestal part of Beitsetsnjuonje.

6. LASTERFJÄLL QUARTZ-KERATOPHYRE-BEARING FORMATION

Once again quartz-keratophyres interstratified with lustrous or graphitic phyllites occur in the ridges on both sides of Remdalen. These rock members are combined into a formation with the above name. It is thickest in the eastern limb of the syncline where the formation begins with a somewhat calcareous, lustrous phyllite, upwards becoming more and more graphitic and as a sooty graphite phyllite underlying a lower quartz-keratophyre horizon. The latter may be followed continuously from the brook immediately west of the reindeer yard (rengårde) east of the Raurovardo mountain southwards to the area just north of Ransarån. Higher up another strongly graphitic phyllite is met with, followed by a somewhat thicker horizon of quartz-keratophyres and greenschists overlain by lustrous or graphitic phyllites.

No quartz-keratophyres have been found in the area from Ransarån southwards past Tjåkkolastugan, and here probably only the lower lustrous to graphitic phyllite of the formation is represented. 1 km west of Tjåkkolastugan the light-coloured quartz-keratophyre reappears in the western limb of the syncline interstratified with graphitic phyllites, and north-west of the bridge over Fremsjokk it is again beautifully exposed, as well as in the Luktjombäcken area, a couple of kilometres further to the north. Generally the content of greenschists is about 50 %.

Du Rietz' map (1941) indicates that two quartz-keratophyre horizons should reappear in the synclinal fold east of Luktjomtjuolta. As this should point to an agreement with the conditions in the eastern limb the area was revisited in the summer of 1961. The elucidation of the stratigraphy, however, is difficult without more detailed field work due to the complicated folding and possibly to minor dislocations. The most likely solution is given in the map with only one horizon of quartz-keratophyre.

In the western limb the lower parts of the formation are made up of varying alternations of calcareous, lustrous and graphitic phyllites. It is difficult to give the lower limit exactly as the Lasterfjäll Greenschists are partly missing and the phyllites adjoin directly the very similar Fasovardo Phyllites. However, the occurrence of graphitic phyllites may be taken as a proof that the rocks belong to the Quartz-Keratophyre-bearing Formation of the Lasterfjäll Group.

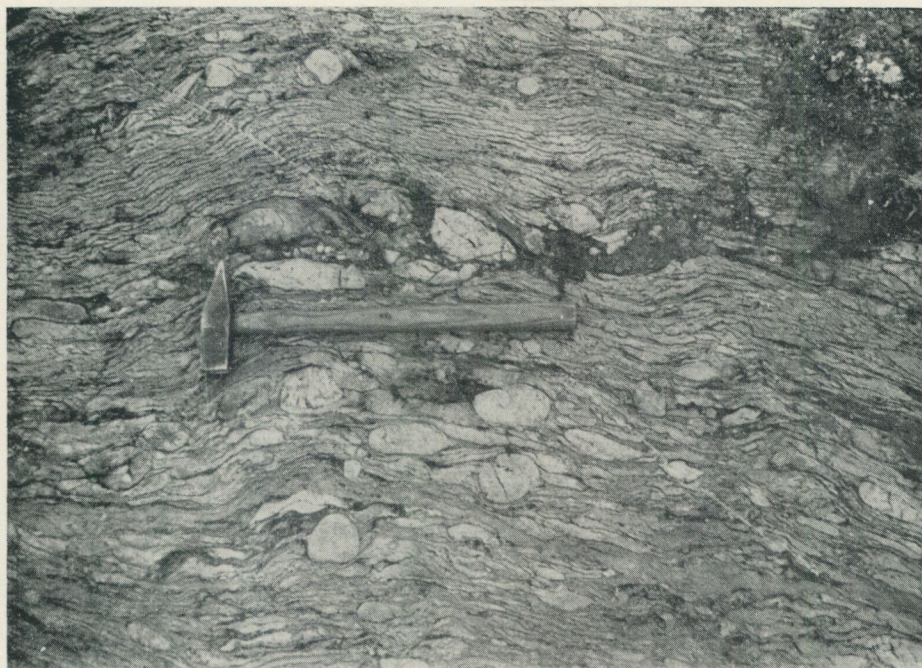


Fig. 12. Remdalen quartzite conglomerate with scattered pebbles in a quartz-phyllitic matrix. S of Raurovardo. Photo by G. Kautsky, 1949.

7. REMDALEN QUARTZITE-CONGLOMERATE-BEARING FORMATION

Approximately where the path going eastwards from Remdalens lappläger crosses the Raurovardo ridge, we have on and next to the path good exposures of a little deformed quartzite conglomerate (Fig. 12). Somewhat further to the north limestone horizons are found and also these are interstratified with graphitic phyllite. These rock members, which can be followed more or less continuously in the ridges around Remdalen, are grouped together under the name of Remdalen Quartzite-Conglomerate-bearing Formation.

The pebbles have a maximum size of one dm and seem to consist exclusively of quartzites and vein quartz. Those fragments, when examined with the microscope, are seen to be strongly recrystallized feldspar quartzites, very rich in albite and with some calcite. The latter is looked upon as a remnant of an original cement, as the matrix generally is completely devoid of carbonate. Quartzites of this type, from which the boulders could have been derived, have not been found in any formation of the Remdalen syncline. As a rule the pebbles are sparsely scattered in a matrix, which at Raurovardo consists of a banded quartzite, sometimes with a pseudo-conglomeratic appearance. This strongly quartzitic matrix seems to be typical for regions with surrounding graphitic rocks, whereas a more

calcareous and less graphitic environment, as in the western limb, generally shows a quartzite conglomerate with a calcareous, phyllitic matrix. Well exposed quartzite conglomerates of this type could be seen on the path a few hundred metres south-south-east of Enokssons stuga. In other places they are substituted by quartzites or quartzitic members, in part pseudo-conglomeratic.

Immediately above the conglomerate there occur some strongly calcareous members, which in the crestal part of Raurovardo contain pure, white to bluish grey limestone horizons about a metre in width. This part of the formation may be followed as a distinctive rock member around the larger part of Remdalen and can be identified even where the pure limestones are missing, since the characteristic, coarse textured calcareous phyllite forms a key horizon. By weathering it yields a brownish, rusty decomposition skin but on a fresh surface it is revealed as a greenish chlorite-rich, strongly calcareous rock, which sometimes approaches an impure limestone in composition. About 1.5 km south-west of Tjåkkolastugan a limestone horizon occurs in the graphitic phyllites, and its association with hard glassy quartzites suggests that these rock members belong to the Remdalen Quartzite-Conglomerate-bearing Formation.

For technical reasons it has been necessary to represent the formation as a lower quartzite with quartzite conglomerates, an intermediate graphitic phyllite and an upper calcareous phyllite with limestone horizons. Actually it is considerably more varied and interstratifications of graphitic phyllites also occur in the upper calcareous phyllite, and in the quartzitic and conglomeratic members.

The geological map (Plate I) gives an indication of a weak angular unconformity. In the extreme north-east a graphitic phyllite and two quartz-keratophyre horizons are met with below the conglomerate. Going southwards, first the graphitic phyllite, then the upper quartz-keratophyre and later on also the graphitic phyllite below wedge out. In Beitsetsnuonje the rocks of the Conglomerate-bearing Formation seem to rest directly upon the lower quartz-keratophyre, and further south the latter also seems to be missing. In the western limb the sequence is markedly thin, possibly reduced by erosion. This is presumably one of the few cases where it has been possible to show that a conglomerate in the Köli rests on the underlying formations with an angular unconformity. This is also the main reason for placing the base of the Remdalen Group at this point in the stratigraphy.

8. REMDALEN GRAPHITIC PHYLLITE

The electro-magnetic anomalies which on the geophysical maps appear as a "frame" around Remdalen owe their occurrence to strongly graphitic rocks which may conveniently be set up as a separate formation with the above name. The main part of the formation is made up of dark to black, graphitic phyllites (Fig.



Fig. 13. Intensely folded graphitic quartz phyllite of the Remdalen Graphitic Phyllite. At the bridge over Ransarån, 600 m N of Tjäckolastugan.

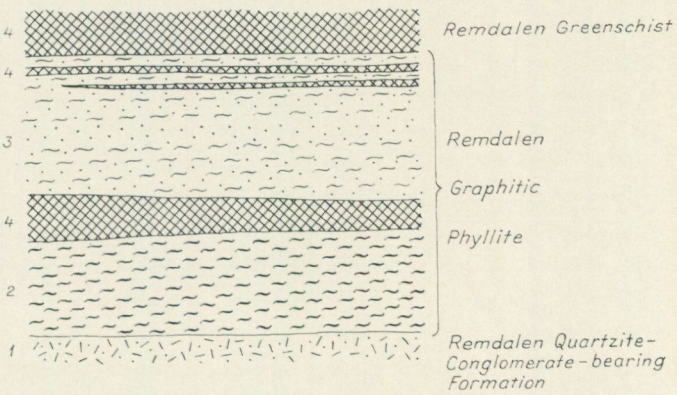


Fig. 14. Stratigraphy of the Remdalen Graphitic Phyllite. 1. Calcareous phyllite. 2. Graphitic phyllite. 3. Graphitic quartz phyllite, partly pseudo-conglomeratic. 4. Greenschist.



Fig. 15. Pure quartz phyllite with a pseudo-conglomeratic or phyllonitic appearance. Remdalen Graphitic Phyllite, 1600 m SSE of Remdalens lappläger.

13). Interstratifications of greenschist occur at several levels, but it has been difficult to decide definitely their stratigraphic position in each case. It seems, however, as if the thicker of the greenschists is situated about midway in the formation while the upper part of the formation contains one or possibly two considerably thinner greenschist horizons (Fig. 14). Between these and the lower greenschist the phyllites are strongly quartzitic and properly ought to be called graphitic quartz phyllites. Through tectonic action these quartzitic layers often have a pseudo-conglomeratic appearance (Fig. 15) but it has never been possible to prove the existence of true conglomerates.

Many of the diamond drillholes which were put down for ore prospecting in Remdalen in 1947—1952 have crossed the boundary zone between the Remdalen Graphitic Phyllites and the overlying Remdalen Greenschist. A diagram of these drillholes is given as Fig. 16, and their locations have also been marked on the geological map (Plate I). In Fig. 16 the drillholes have been adjusted to their approximate stratigraphic position. The boundary between the two formations has been placed at the top of the last thick (more than 2 m) horizon of graphitic phyllite. The upper, thin greenschist zones appear in several of the drillholes, and in Bh 15 presumable the somewhat thicker, lower greenschist was pierced. Bh 35, 4 and 2 are entirely within the Remdalen Greenschist.

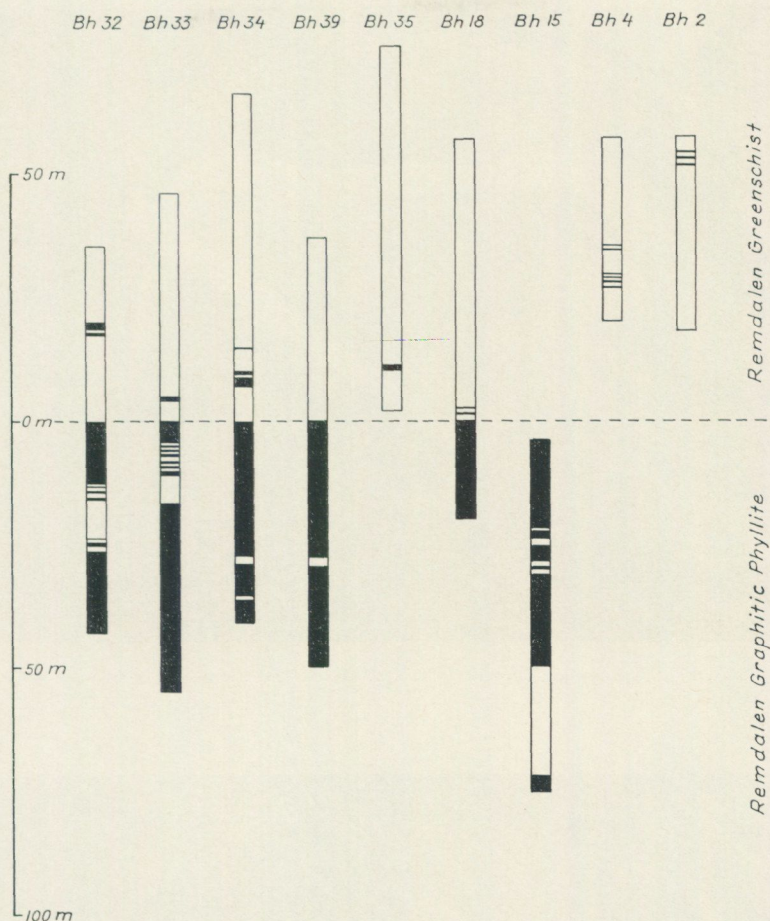


Fig. 16. Drillholes crossing the contact zone between the Remdalen Graphitic Phyllite and the Remdalen Greenschist. White = greenschist, black = graphitic phyllite.

9. REMDALEN GREENSCHIST

The Remdalen Greenschist is a formation practically free from sediments and tuffites. Its weak resistance to erosion has resulted in the valley at Remdalen, from which this greenschist has been named. Usually it is a rather dark green, fine grained rock with a calcite content that varies from one layer to another and, on weathering, often produces a marked banding (Fig. 17).

The microcline-bearing quartz-porphry was observed by Du Rietz (1941) in the Fremsjokk and Rembäcken rivers. It has been possible to follow it around Fremshöjden, and because of its association with the overlying limestone, it is a good key horizon. This relatively resistant porphyry is generally the only rock which outcrops in the poorly exposed area.

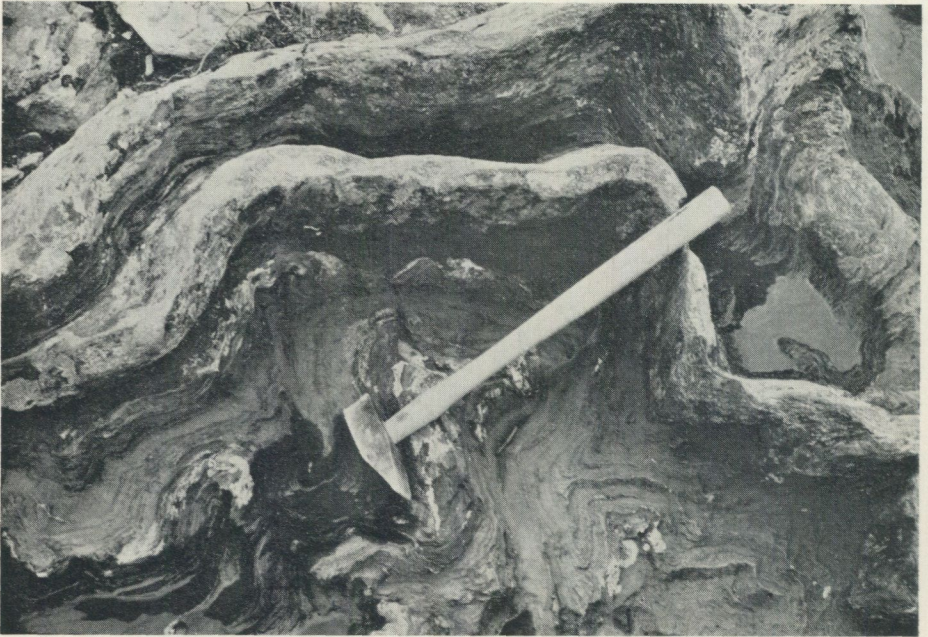


Fig. 17. Folded Remdalen greenschist. Locality NW of the bridge over Fremsjokk.



Fig. 18. Graphitic, quartz rich Fremshyllite. North-western part of Fremshöjden.

10. FREMS PHYLLITE

Through the detailed mapping and elucidation of the tectonic conditions it has been possible to demonstrate that the phyllites occurring in Fremshöjden are the highest stratigraphic members of the Remdalen syncline. They have been given the name of the Frem's Phyllite.

The good continuous sections necessary for the establishment of a detailed stratigraphy are lacking. The main part of the formation is made up of dark or graphitic phyllites which have given distinct anomalies on the electro-magnetic maps. The upper parts become more and more quartzitic and to a large extent they take the form of very light-coloured quartz phyllites. A relatively thick inter-stratification of greenschist is found in the lower part of the formation.

D. Summary of the Stratigraphy

The main results are summarized in a stratigraphic diagram of corresponding rocks in the western and the eastern limbs (Fig. 19), and a short description of the rock members of the different formations is given. Data of thicknesses have not been included since each formation shows large primary variations which may have undergone further changes in connection with the folding. However, a study of the map and the cross sections (Plates I—V) gives an idea of the approximate orders of magnitude. The entire stratigraphic sequence of the Remdalen syncline probably amounts to more than 4000 metres.

E. Intrusives

Two different types of intrusive rocks occur within the area.

The first group is composed of serpentines, hornblendites and generally garnet-bearing amphibolites. They are concentrated to a certain stratigraphic position at the top of the Fjällfjäll Arkose and in the Tjopasi Phyllite, known since long ago as the "peridotite level". Both to the north and to the south of the map area they are associated with well developed serpentine conglomerates. Minor bodies, however, occur much higher in the stratigraphy, as for example in the northern central part of Remdalen and immediately to the south-west of the bridge over Saxån. Serpentines of high stratigraphic position have also been described by Kautsky (1953). Apparently they are not associated with serpentine conglomerates.

The main group of intrusives is formed by rather light-coloured, saussuritic hornblende gabbros. In the central parts of the larger bodies at least they are medium to coarse grained, but their contacts are generally strongly schistose and

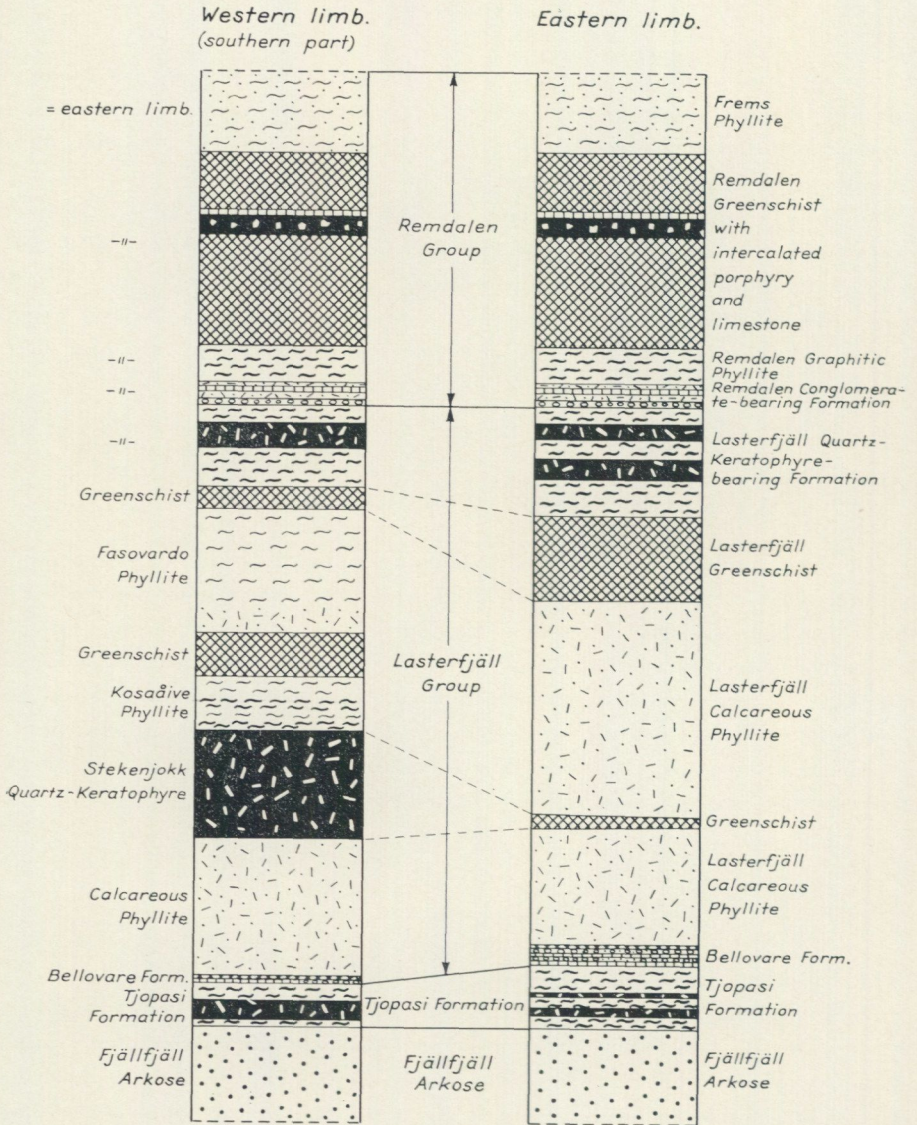


Fig. 19. Stratigraphy of the Remdalen syncline. Comparison between western and eastern limbs.

then often difficult to distinguish from finegrained, effusive greenschists. The gabbro lenses are a very characteristic feature for the calcareous phyllite, although the whole sequence up to the Frems Phyllite has been intruded. The intrusions are pre- or synkinematic, since they have been folded and sheared in the same way as the surrounding rocks.

REMDALEN GROUP

10. *Frens Phyllite*

Dark, graphitic quartz phyllites, increasingly light-coloured upwards, with an interstratification of greenschist in the lower part.

9. *Remdalen Greenschist*

Relatively dark, fine grained, banded, somewhat calcareous greenschists with an interbedded porphyry-limestone horizon.

8. *Remdalen Graphitic Phyllite*

Dark or graphitic phyllite with quartzitic phyllites and thin greenschist horizons.

7. *Remdalen Quartzite-Conglomerate-bearing Formation*

Quartz phyllite, quartzite or quartzite conglomerate, overlain by a strongly calcareous phyllite with limestone layers. The whole formation is interstratified with graphitic phyllites.

× × × ×

Minor unconformity

× × × ×

LASTERFJÄLL GROUP

6. *Lasterfjäll Quartz-Keratophyre-bearing Formation*

Graphitic phyllites with interstratifications of quartz-keratophyres, underlain by lustrous, calcareous phyllites.

5. *Lasterfjäll Greenschist*

Western limb: Pure greenschist or light-coloured, tuffitic rocks

Eastern limb: Greenschists with interpersions of phenocryst-bearing greenstones (lavas?) and minor interstratifications of lustrous phyllite.

4e. *Fasovardo Phyllite*

Calcareous phyllite, overlain by thick, lustrous, quartzitic phyllites with interpersions of greenschist and tuffites, in part also calcareous phyllite.

4. *Lasterfjäll Calcareous Phyllite*

Homogeneous, calcareous phyllite with gabbro lenses

4d. *Greenschist*

Strongly green, in part banded greenschist

(Missing)

4c. *Kosaåive Phyllites*

Graphitic, lustrous and calcareous phyllite with interstratifications of quartzites

Lustrous phyllite (missing to the north)

4b. *Stekenjokk Quartz-Keratophyre*

Light-coloured quartz-keratophyres with interstratifications of greenschists, southwards also tuffites.

Agglomeratic greenschist horizon, which fades out to the north.

4a. *Calcareous Phyllite*

Calcareous phyllite with gabbro lenses

Calcareous phyllite with gabbro lenses

3. *Bellovare Formation*

Greenschist, sometimes associated with a thin limestone horizon.

Alternating beds of limestone and quartzite conglomerate, interbedded in graphitic phyllites and overlain by greenschist. To the north the quartzite and conglomerate seem to be missing.

2. *Tjöpasi Formation*

Dark quartz phyllite or graphitic phyllite with interstratifications of quartz-keratophyres in the lower part.

1. *Fjällfjäll Arkose*

Somewhat greenish, light-coloured, banded arkose (only the upper parts of the formation have been investigated).

PART II

Tectonics

A detailed tectonic mapping combined with the tracing of good key horizons at a relatively early stage revealed the whole area of investigation between Fjällfjällen in the east and Rainesfjället in the west as a complex syncline. A. Högbom (1925) and T. Du Rietz (1941) have already given tectonic interpretations of the area but both of them thought, however, that the graphitic phyllites of Remdalen stratigraphically correspond to the dark phyllites of the Tjopasi Formation. Thus Högbom places the Lasterfjäll Calcareous Phyllite in the centre of the syncline and assigns to the western limb all graphitic rocks westwards from (and including) Remdalen, while Du Rietz interprets the Remdalen region as an anticlinorial up-folding.

The present investigation demonstrates the synclinal character of the area, and the main tectonic feature is named the Remdalen syncline.

A. Folding

1. BEDDING AND SCHISTOSITY

Within the region described in this report, one may from a structural point of view distinguish the incompetent rock members, consisting of calcareous, lustrous or graphitic phyllites and the major part of the tuffites and greenschists (Figs 13, 18, 20, 21), from the more competent ones, which besides the lowermost arkoses include light-coloured quartz-keratophyres and minor quartzite interstratifications (Figs 9, 10, 11). Occasionally the more massive members of the calcareous phyllites may show structures resembling those of the competent beds (Figs 6, 8). The incompetent rocks predominate within the investigated area. Structures caused by differences in competence can be demonstrated from the Stekenjokk Quartz-Keratophyre, where massive quartz-keratophyres alternate with greenschists. In Fig. 22 the original bedding is still apparent, while Fig. 23 shows a later stage of deformation.

Some of the competent members show a concentric folding, but generally it is a typical cleavage folding (Fig. 20). The relationship between bedding and schistosity is most clearly demonstrated in the synclinal and anticlinal hinges, where the schistosity is nearly transverse to the bedding. In the limbs, however, the strike direction of the schistosity approaches more and more that of the bedding and often it may cut across at a very small angle (5° — 10°). The dips of the two, however, may be quite different, the dip of the schistosity usually being relatively steep (petrofabric *ab* plane), while the dip of the bedding is considerably less inclined, but also here the angular difference may become insignificant with bedding surfaces and schistosity apparently coinciding. Sufficiently large outcrops

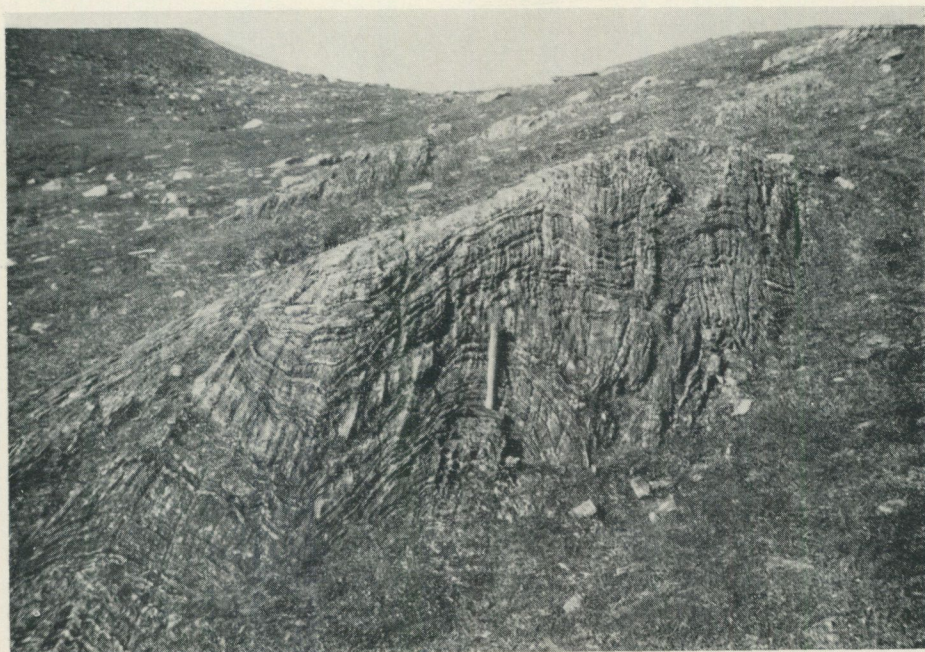


Fig. 20. Fan-shaped slaty cleavage in flatlying, banded, somewhat tuffitic, calcareous phyllite. Lasterfjäll Calcareous Phyllite at the Tjalingen mountain, 5 km S of the map area.

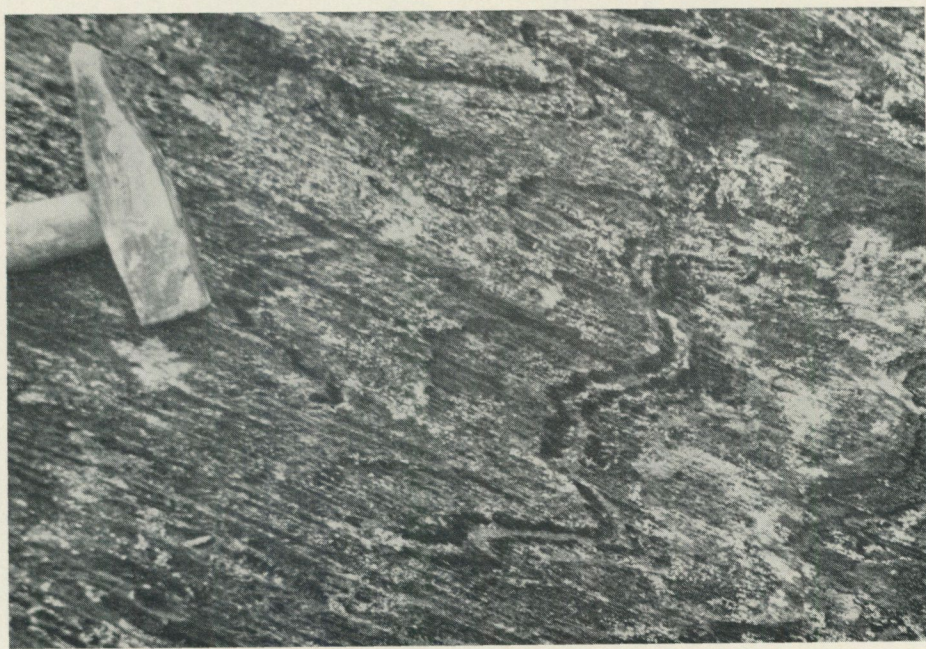


Fig. 21. Remnants of bedding in strongly sheared calcareous phyllite. Western part of the Preunttjäcko mountain, 3 km S of the map area.



Fig. 22. Dark layers of greenschist beginning to intrude the more competent quartz-keratophyre. Stekenjokk formation, 600 m NNE of Kotjärn tarn.



Fig. 23. Boudins of quartz-keratophyre, floating in plastically deformed greenschist. Locality 700 m S of Ransarån river (NE of Doranjaure lake).

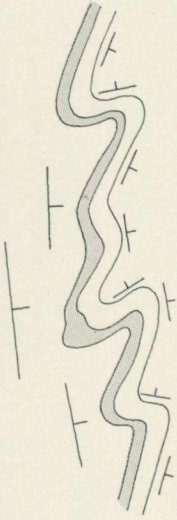


Fig. 24. Typical appearance of a folded layer. The small symbols indicate directly measured strike and dip, which may be misleading and may not always give the actual strike as shown by the large symbols.

almost always show a certain discordance between the two. These problems demand special attention in the field and different marks for bedding and schistosity must be used in the maps (cf. Högbom [1925, p. 29] and Du Rietz [1941, pp. 12—20] and their maps).

Du Rietz (1941, pp. 12—14) has pointed out the divergence between the field strike of a certain horizon (its trend in the map) and the directly measured strike. The explanation is apparently simple; single observations of bedding may be uncertain or misleading if they are made over too short distances (see Fig. 24). Consequently an effort has been made to make the measurements in as extensive exposures as possible in order to have the observations more closely approximate the true trend of the horizon (the topography is relatively weak over the whole region and only locally affects the trend of a horizon on the map).

2. DIRECTLY OBSERVED AND DEDUCED FOLD AXES

A detailed study of the fold axes has been made over the whole region (Plate VII). As shown by Fig. 24 the horizons, by their folding, define fold axes, and these fold axes can be directly observed in the field (Figs 7, 13, 17, 18). Empirically it is found that they deviate somewhat from the regional fold axis direction. On the map they have such a distribution and orientation as to converge slightly towards the central part of the syncline (Fig. 25).

To study these conditions more closely within the map area the observations (about 1400 bedding planes and 550 fold axes) have been plotted on a stereographic net. The sub-areas have been chosen to represent structurally homogeneous parts, that is to say with apparently similar directions and plunges of

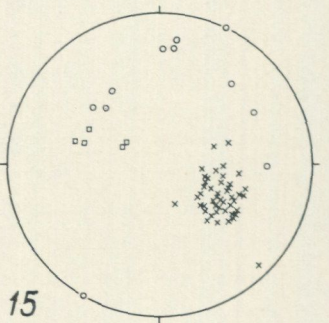
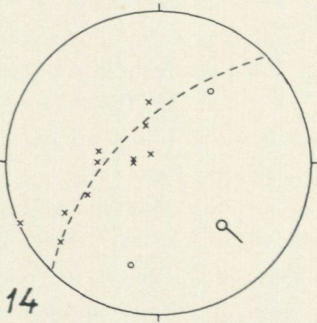
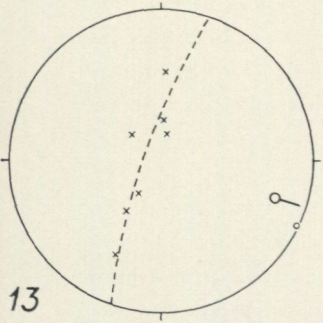
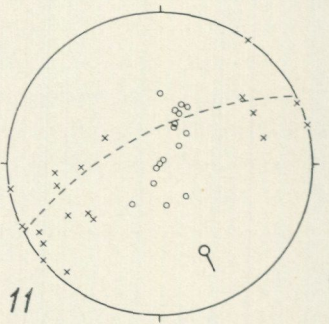
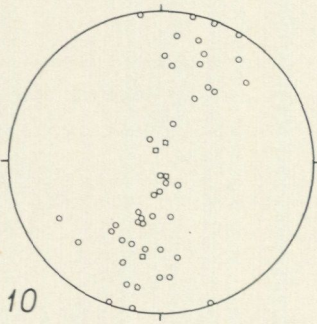
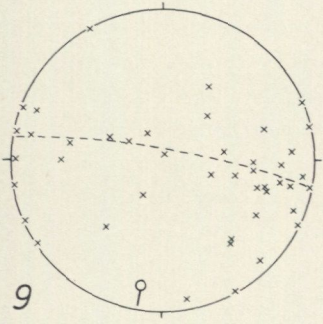
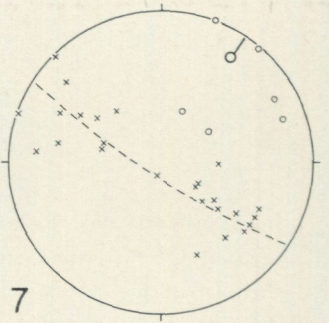
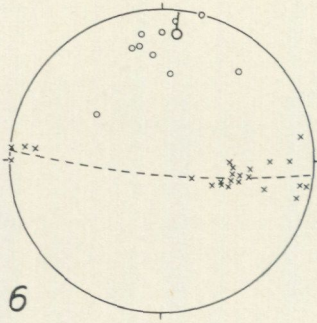
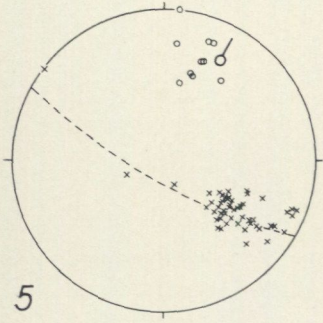
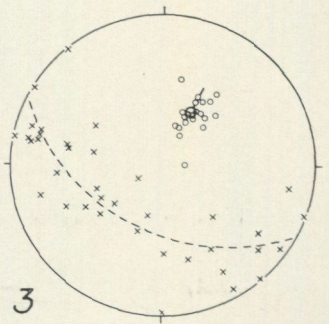
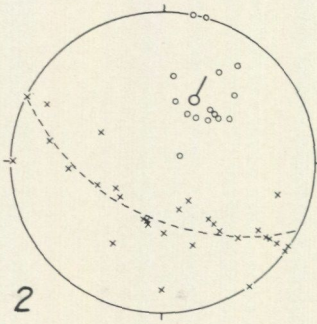
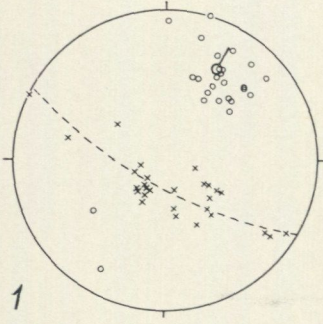
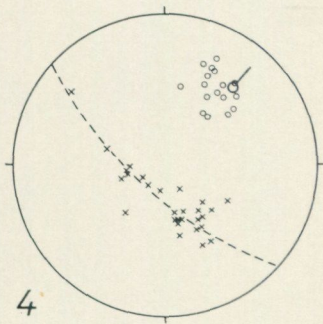
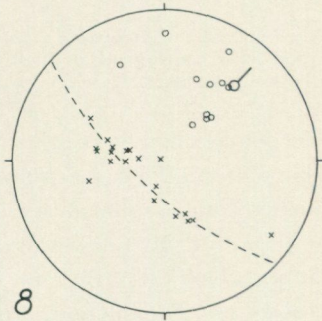


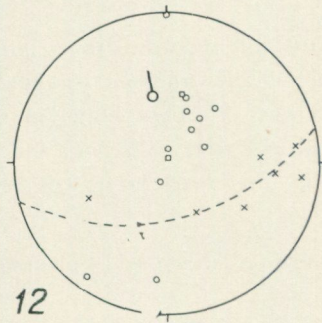
Fig. 26. Bedding and observed fold axes, plotted on a stereographic net, lower hemisphere. The deduced fold axes have been indicated on Plate VII, where the small figures in a square refer to the numbers of the diagrams.



4



8



12

Diagram no.	Subarea	Deduced fold axis (direction and plunge)
1	Stekenjokk Quartz-Keratophyre, S of Doranåje	N 29°E / 20° NE
2	Remdalen Greenschist and Porphyry. Lower part of Fremshjokk	N 26°E / 40° NE
3	W of the bridge over Fremshjokk	N 27°E / 47° NE
4	SE of Doranåje	N 46°E / 22° NE
5	North-eastern part of Tjåkkola mountains	N 29°E / 15° NE
6	Ruotamavardo	N 5°E / 10° N
7	Western part of Doranåje	N 33°E / 10° NE
8	Western part of Skaitonåje	N 42°E / 22° NE
9	Northernmost Remdalen	N 9°E / 10° S
10	Observed fold axes in the north-eastern part of Remdalen valley down to Luktjombäcken-Rembäcken junction	
11	Northern part of Fremshöjden	N 27°W / 25° SE
12	Southern part of Fremshöjden	N 14°W / 40° N
13	Rainesfjället	N 67°W / 13° SE
14	Rainesfjället, SE of Freamsjön	N 45°W / 30° SE
15	Fjällfjäll Arkose E of Tjopasi	

LEGEND

Stereographic projection, lower hemisphere

× Pole of bedding plane (primary s-plane)

○ Fold axis (field mapped)

◻ Lineation (field mapped)

○ Deduced fold axis

--- π-circle (zone of s-plane normals)

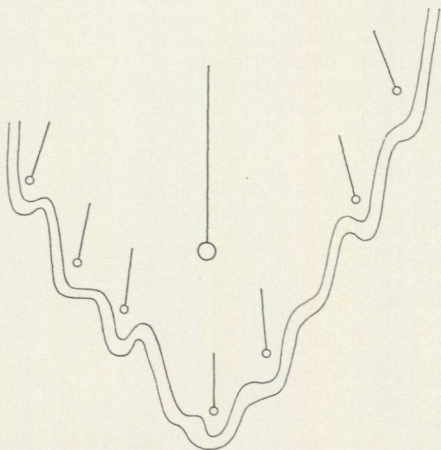


Fig. 25. Syncline with slightly plunging regional fold axis and weak convergence of the directly measured local fold axes.

the fold axes. To start with the subdivisions have been made small, successively being combined with adjoining areas showing a similar pattern. Thus the number of diagrams has been reduced to about 50; a further combination of areas gives a more diffuse picture. The most regular pattern we find in the southern parts of the map area, south of Fremssjokk-Ransarån, where also the most intensive work has been done to form the basis of a cross section. For the northern parts of the map area observations made by Kautsky between 1947 and 1954 and by Sarap in 1953 have also been used.

The most conspicuous feature is an interference of two fold axes directions, one directed NE-NNE, in the following called the main fold axis and one directed W-NNW, called the cross fold axis. In areas with elements of cross folding there seem to occur successive transitions between cross fold axes and main fold axes.

Concerning the deduced fold axes (π -poles) some interesting facts will be mentioned:

1. The directions and plunges of the deduced fold axes could be determined by plotting the poles of the bedding planes on a stereogram.
2. The deduced fold axes show a continuous variation from one subarea to the next, both in direction and plunge.
3. The deduced fold axes are more or less parallel, as opposed to the directly observed ones, which converge slightly towards the central parts of the syncline.
4. The plunges of the deduced fold axes are generally somewhat less than those of the directly observed ones.

Some of the diagrams are reproduced in Fig. 26 (stereographic net, lower hemisphere). Of these diagrams nos 1—3 represent the conditions in the southern central part of the syncline, from Doranbaracken to Fremshöjden. They indicate the main fold axis with a direction of N 25—35°E. The directly observed fold axes lie scattered around the deduced fold axis and both direction and plunge agree quite well.

In the eastern limb of the syncline (diagrams nos 4—6) bedding planes dipping north-westwards predominate. The mean plunges of the directly observed fold axes (29° , 19° , 16°) are somewhat steeper than those of the deduced ones of corresponding sub-areas (24° , 15° , 10° resp.), and furthermore the directly observed fold axes have a somewhat more northerly strike, pointing obliquely towards the centre of the syncline.

In the western limb the conditions are somewhat more complicated. Diagram no. 7 refers to the Stekenjokk Quartz-Keratophyre and the Kosaåive Phyllites north-east of Doranjaure. The deduced fold axis plunges 10° towards N 33° E, while the mean value of the observed ones gives 20° towards N 45° E. In the Skaitonåje region (diagram no. 8) the deduced fold axis has a slightly more north-easterly trend and lies about 10° less inclined than the mean of those directly observed. As most of the observations have been made on the south-eastern side of a smaller synclinal structure between Kosaåive and Skaitonåje this is in agreement with the converging tendency of the directly observed fold axes towards the centre of a syncline.

In the northernmost part of Remdalen the scattering of the poles of bedding planes is considerably greater (diagram no. 9), and there are areas where they do not at all define a fold axis. The directly observed fold axes often have a constant NNE-SSW orientation, but the plunge is varying (see diagram no. 10). Both the geological map and the field observations indicate shallow, flat-lying structures. This pattern of observed fold axes is also perceptible in the diagrams from Fremshöjden (nos 11—12), where the deduced fold axis is oriented according to the cross folding direction.

Some of the diagrams (nos 13—14) from the lower parts of the western limb also reflect this cross fold axis, in the first case in a structure also visible in the map, in the other without such a structure being apparent.

The diagrams from the western side of the Fjällfjällen anticline show similar features. The upper parts of the arkose often have a strong lineation which coincides with the direction of the cross fold axis (diagram no. 15). In the monocline series it is, however, impossible to construct a regional fold axis on the basis of the existing observations.

3. MAIN FOLD AXES AND CROSS FOLD AXES

Plate VII also illustrates the regional distribution of main folding and cross folding within the area of investigation.

The main Caledonian fold axis, trending NNE-NE, is generally responsible for the structures on the map. This is particularly true for the southern and eastern parts, and in the northernmost part it seems again to become the dominating fold axis. Other parts of the area show folding around north-westerly fold axes. Thus Remdalen and Fremshöjden form a structure associated with the cross

fold axis, but towards the north and the south it turns successively into the main fold axis direction. In the western limb the cross folding is also clearly visible in the lower parts of the sequence on the north-eastern side of Rainesfjället and also in the Kotjärn-Kosaåive-Skaitonåje region. In the other limb of the syncline, on the western side of Fjällfjället, a strong lineation has the same direction as the cross fold axis.

Thus, within the map area folding occurs with two different fold axes. In certain areas the main fold axis dominates, in others the cross fold axis, and in still others they occur together. Sometimes they are connected with each other by successive transitions. Some observations seem to indicate that the cross folding is later than the main folding, which, however, need not imply that they belong to different phases. Inhomogenities on a large scale may be thought to have caused deflexions in a later stage when the compression perpendicular to the main fold axis had largely finished.

4. DISTRIBUTION OF SYNCLINES AND ANTICLINES

The synclinal character of the area has previously been emphasized and the major syncline (1) may be followed as a continuous structure through the central part of the map (Plate VIII). It is, however, not a simple structure, but composed of different elements. From the south up to the junction of the Fremsjokk and Ransarån rivers its form is determined by the NNE-NE main fold axis, while the Remdalen part of the syncline fits in with the cross fold axis. Only where the synclinal line passes Luktjombäcken and Rembäcken in the middle part of Remdalen does it return to the main fold axis direction, as is also the case in the extreme north of the map area.

Minor structures occur at various places. In the western part of Doranåje the Kosaåive Phyllites form a well defined syncline (12), which is separated from the major syncline by an anticlinal upfolding of the Stekenjokk Quartz-Keratophyre which is slightly overturned to the east (13). A similar structure (16) occurs in the easternmost part of Doranåje, and has also affected the greenschist members of the Stekenjokk Formation and the Calcareous Phyllite to the south-west of Jalketsåive. It is separated from the major syncline by a faint, anticlinal structure (15).

Along Fremsjokk, south-west of Fremshöjden (8, 9, 10) a set of folds occurs which might have its continuation in the Skaitonåje region (8, 11) and in the westernmost part of Lasterfjället (6, 7). In the north-western parts of the map area, south of Fremsjön and north-east of Luktjomjaure, there appear minor synclinal and anticlinal structures with a north-easterly trend (2, 3, 4).

The Kosaåive-Skaitonåje area needs a short description. A faint anticline (11) may be discerned running over the crest of Skaitonåje, and immediately to the north-west the greenschist forms a broad syncline with a north-easterly fold axis

(8). Directly adjoining this another pronounced syncline with a west-north-westerly axis is formed by the Kosaåive Phyllites (21). It can be traced north-westwards to Rainesfjället, where it affects the dark phyllites of the Tjopasi Formation. This is one of the most clearly visible synclines with the cross folding direction. Still further towards the north-west, in the lowest arkose-phyllite nappe, there occurs another cross syncline (23), also represented in diagram no. 13 of Plate VII. It must, however, be mentioned that the apparent curvature of the thrust boundary separating the two tectonic units is due to the topography.

The complicated configuration of the Bellovare Formation in the crestal part and eastern side of Bellovare is the result of interference of the main folding (19) by an accentuated anticlinal cross fold (20). Further to the west the rocks of the Bellovare Formation appear in an anticlinal upfolding along the main fold axis (17), while the Calcareous Phyllite in Jalketsåive-Bellovare occupies an intervening syncline (18). ———

5. PROFILE CONSTRUCTIONS

The fold axis analysis of Chapter 2 forms the basis of an attempt to construct cross sections through the area. In this respect the southern part of the map area is especially suitable, for here successively lower stratigraphic members swing around to the south due to the north-eastwards plunging fold axis. A number of factors, however, make the practical execution difficult.

Within this area the NNE-NE main fold axis is dominating, but both direction and plunge vary within fairly wide limits. The conditions are illustrated on the diagram of Plate VII. Based on the deduced main fold axes isolines have been drawn for axial plunges. From a pronounced maximum near the bridge over Fremsjokk they decrease successively towards the area of axial culmination to the south but they also decrease towards the limbs of the syncline. The isoline for horizontal fold axes extends from Rainesfjället down to Saxån south of Doranbaracken and from there north-eastwards over Bellovare to Västra Fjällfjället. In the Doranåje area, immediately south of Ransarån, a WNW-ESE oriented trough with steeper axial plunge occurs.

Approximately in the middle part of the area chosen for the profile construction, a main profile line has been drawn perpendicular to the direction of the deduced fold axes (Plate IX). Starting at points with 1000 m spacing along this line, lines have been drawn parallel to the axial direction. They form a bundle of lines with areas of weak convergence or divergence. It should be noticed that in these constructions only the main fold axes have been taken into consideration. Especially north-westwards, from Kosaåive to Rainesfjället, cross folding structures complicate the projection procedure.

Thus it is clear at an early stage that a completely satisfactory method of pro-

jection of a cross section extending over the whole syncline can hardly be obtained. The purpose of a general cross section through the southern part of the Remdalen syncline is above all to give a picture of the type of folding in a cut perpendicular to the axial direction, and make it possible to some extent to judge the stratigraphic thicknesses. The method must be chosen, therefore, with this aim in mind.

In a composite cross section the actual conditions can only be represented completely accurately for a small vertical extent along the main profile line. Remaining parts of the cross section can be filled up only by projection of data from more distant parts, thus replacing inaccessible information about the conditions in the plane of profile itself. In the "coulisse profile" method, described by Wegmann (1929), a number of subprofiles are combined, each of them representing a relatively superficial cut in areas with tectonically different elevations. Each subprofile is constructed according to the direction and plunge of the fold axis for the area under consideration and thus reproduces with good accuracy the conditions along the subprofile line. The final compilation of the coulisse profile is made by an adjustment, so that the displacement in vertical direction of each subprofile corresponds to the axial plunge over the distance between adjoining subprofiles. By this procedure no consideration of the divergence or convergence of the fold axes nor of variations of the axial plunges for different parts of the profile can be taken. The result is that the first projection to the subprofile is made in accordance with the direction and plunge of the fold axis, while the final projection to the coulisse profile is made postulating parallel fold axes. Seen in the horizontal plane the method of projection moves the points as shown in Fig. 27. The subprofiles are fitted into the coulisse profile with unchanged widths and this may lead to considerable and undesirable changes of shape.

In areas with flat-lying or relatively slightly inclined fold axes ($< 45^\circ$) and without significant overfoldings or internal glidings one may assume that the fold axis direction (and also the plunge) shows quite a high degree of constancy at different depths in a profile plane perpendicular to the axial direction. The direction and plunge of the fold axis at the surface may be assumed to prevail also at deeper levels.

A method which takes into account the variation both in direction and in plunge of the fold axes and which has proved useful for the Remdalen syncline, has been worked out by J. Eklund and was described by M. Saksela (1932). The construction of the cross section is made with the aid of a grid, each unit of which, by projection along the fold axis direction, gives a rectangle of $1000 \text{ m} \times 300 \text{ m}$, i.e. the irregular net shown in Plate IX corresponds in the profile plane to a rectangular one. The method implies that each point is brought to the profile plane along the deduced fold axis, successively following the variations of direction and plunge during the whole projection procedure.

The result of this profile construction is reproduced as Plate II. Four schematic

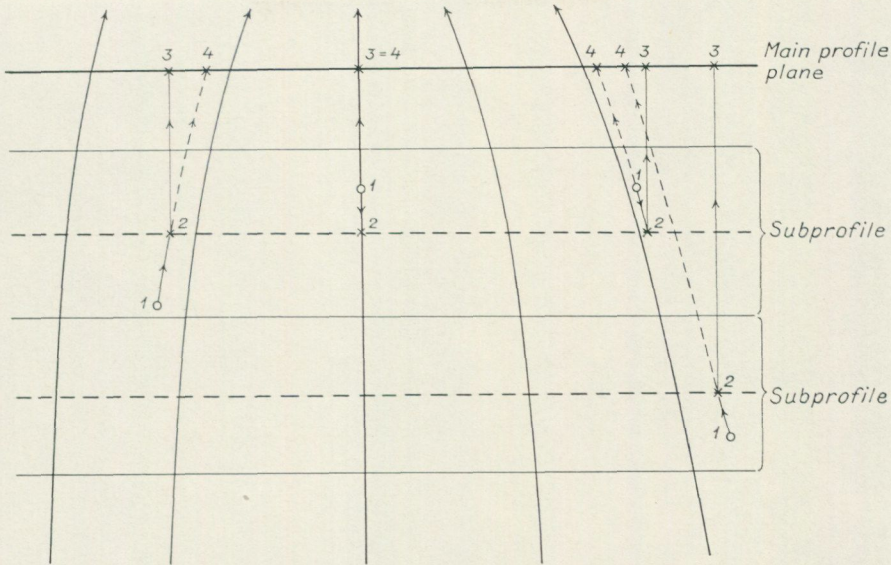


Fig. 27. Diagram illustrating projection procedures in the horizontal plane. According to the «coulisse profile» method (thin full lines) a point (1) is projected to the subprofile (2) along the axial direction, but from there to the main profile plane (3) along parallel lines perpendicular to the profile. In the method of Ek'und-Saksela the same points (1) will give the position (4), projected along dashed lines.

cross sections (Plates III—IV) and a longitudinal section (Plate V) have also been drawn to give a better understanding of the structures shown on the map.

B. Thrusts and Faults

1. THE THRUST OF THE SEVE-KÖLI NAPPE

On the map the thrust of the Seve-köli nappe has been given a thicker designation to distinguish it from minor, second order thrust planes. The Seve rocks of the overthrust unit are here completely missing and low metamorphic Köli rocks border directly the Børgefjell massif. The successive wedging out of several formations on the eastern side of Rainesfjället gives a clear picture of a tectonic discordance.

The thrust zone is usually characterized by mylonites or ultramylonites, which are sometimes strongly recrystallized and occur as feldspar porphyroblastic, dark greenish rocks or as more light-coloured, massive mylonite gneisses. The outcrop of the thrust is topographically clearly visible and plainly distinguishable on aerial photographs over long distances. Some of the topographically best marked crush zones, however, seem to be caused by minor dislocations bounding tectonic lenses in the substratum. Possibly they are due to relatively late movements, since



Fig. 28. Fjällfjäll arkose with dragfolds overturned eastwards along almost horizontal fold axes. Photo taken northwards in E-W exposure at the southern slope of the Rapestinden mountain (Norway), 1700 m W of Fremsjön.

the crushed and cataclastic rocks have not been so strongly recrystallized as those of the major thrust. A few of these smaller thrusts within the Børgefjell area have been marked on the map.

At a few places it has been possible to observe or estimate the dip of the thrust plane. 700 m east of Bie Ransaren, at and immediately to the north of the bridge over Ransarån, the slickensided ultramytonites seem to dip about 45° towards the east. The extensive mylonite gneisses in the brook running from Rapestinden to Fremsjön, immediately to the west of the map area suggest, however, a much more flat-lying position of the thrust in this region.

2. MINOR THRUSTS AT RAINESEFJÄLLET IN THE LOWER PARTS OF THE NAPPE

In the western limb of the syncline between Kotjärn and Fremsjön, the lower part of the Seve-köli nappe shows an imbricate structure, so that the Fjällfjäll Arkose and the rocks of the overlying Tjopasi Formation are repeated three times. The boundary between the two lower units is particularly well shown by beautiful mylonites and ultramytonites, dipping slightly towards the east. At the first glance



Fig. 29. Sharp dragfolds and repeated minor thrusts, dipping slightly westwards. Photo direction and locality as fig. 28.

it might appear as if the thrusting was directed towards the west, in a direction opposite to the transportation direction of the major nappe.

Good exposures on the eastern side of Rapestinden (on the Norwegian side, immediately to the west of the map area, see Fig. 33) demonstrate the type of folding typical of the Fjällfjäll arkoses. The banded rocks generally show dragfolds, overturned eastwards, with horizontal or slightly northwards plunging, N-S fold axes (Fig. 28). By accentuation of the folds, smaller breaks occur which localize the movements to certain planes and sometimes develop into minor thrusts with a relatively flatlying position (Fig. 29). Larger exposures and regional cross sections suggest that these phenomena are also repeated on a larger scale, constituting a feature characteristic for the competent arkoses. The overlying phyllites, however, behave in a slightly different way, as shown in Fig. 30. A break which is developed in the lower parts as a thrust seems to fade out relatively quickly in the intensively folded, incompetent phyllites which have undergone a more plastic deformation.

On the northern side of the Børgefjell massif, where it has been possible to study the above described structures, the thrust plane of the Seve-köli nappe is still quite flat-lying. Its relatively steep easterly dip on the eastern side of Rainesfjället-Saxfjället must be due to a later deformation. One may expect that at the same time also the minor thrusts have been overturned to the east. Consequently

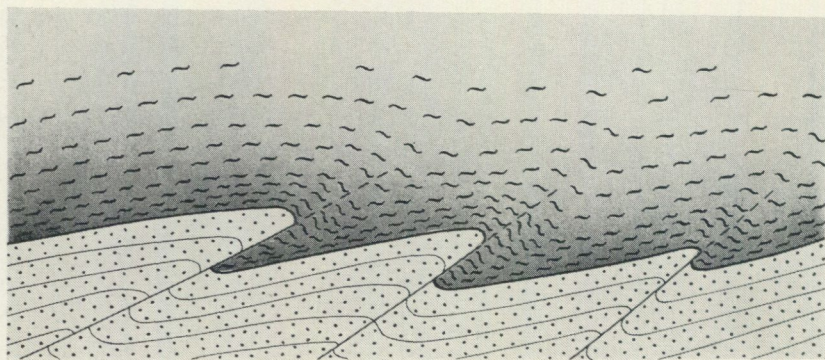


Fig. 30. Dragfolds in the arkose break and generate minor upthrusts which die away in the incompetent phyllites above.

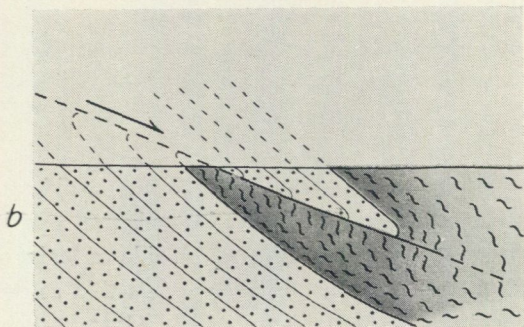
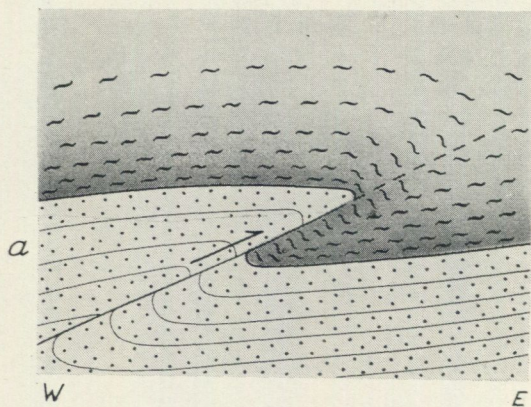


Fig. 31. — (a) Minor thrust. Compare Fig. 30. (b) Later deformation has turned the thrust plane over to the east and erosion attacks the lower part of the structure. In both (a) and (b) the direction of thrusting is indicated by the arrows.

erosion could start to remove the originally deeper lying back parts of the thrusts before their fronts, as illustrated in Fig. 31. Thus the imbricate structures on the north-eastern side of Rainesfjället may be explained as normal towards the east directed minor thrusts. Apparently they develop from dragfolds caused by the friction of the nappe against the substratum, or possibly they were formed at an even earlier stage during the folding. The occurrence of steep contacts between arkose and overlying dark phyllites, slightly overturned towards the east, further supports this interpretation.

3. MINOR THRUSTS IN THE EASTERN LIMB OF THE SYNCLINE

Minor thrusts occur in the eastern, lower parts of the syncline at stratigraphic and probably also tectonic positions corresponding approximately to those at Rainesfjället.

Farthest to the north in the north-eastern part of Lasterfjället a pronounced feature is formed by a strongly marked escarpment, which can be traced further northwards on the eastern side of Avafjället, where it clearly appears on aerial photographs. Apparently it is to be connected with the thrust, which according to Du Rietz (1941) has affected Västra Vardofjäll, 7—12 km to the north of the map area. In Lasterfjället a zone of strong mylonitization and phyllonitization is located in the lower part of the Calcareous Phyllite. The amount of thrusting, however, is insignificant.

The structures associated with the minor thrusting on the western side of Jalketsåive-Bellovare are somewhat more difficult to explain. The rocks may, however, be stratigraphically correlated with the Tjopasi-Bellovare Formations, and this implies an anticlinal upfolding of the lower-lying parts of the sequence. Genetically it may possibly be caused by a pressed up wedge of the Fjällfjäll arkose, as illustrated schematically in Fig. 32 (cf. also cross section I on Plate III).

4. THE FAULTS AT REMDALEN

The detailed geological mapping has revealed a fault in the region to the west of Fremshöjden. Generally it is only the occurrence and distribution of rock types which provide evidence of the existence of the fault, but due to easily recognized stratigraphic horizons the amount of displacement in vertical and horizontal directions can, to a certain extent, be estimated. Only in Fremsjökk and at some localities 400—500 m further to the north is the zone of dislocation itself exposed. In Fremsjökk the massive, grey porphyry changes from an unaffected appearance, becoming more and more crushed in an upstream direction and in part passes over into a bluish green, fractured mylonite with ultramylonitic veins, brought into contact with Remdalen Graphitic Phyllite. The boundary seems to be relatively steep as is also the case in the localities further to the north. The fault

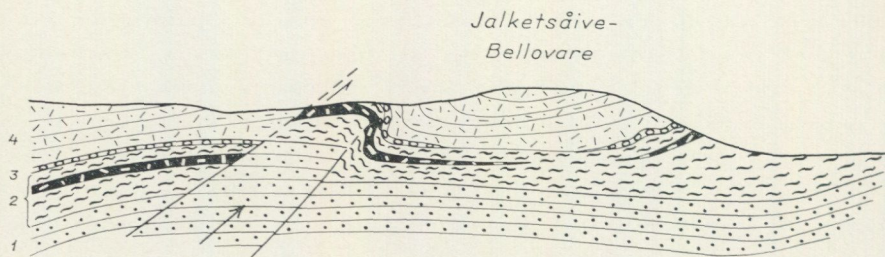


Fig. 32. E-W cross section, illustrating the structural interpretation of the Jalketsäive-Bellovare area. 1. Fjällfjäll arkose. 2. Tjopasi phyllite with quartz-keratophytic horizon. 3. Bellovare Formation. 4. Calcareous phyllite.

dies out in the strike directions: towards the south it becomes more and more difficult to trace when it enters the more uniform phyllites; towards the north, on the western side of Remdalen, the moraine cover is thicker and it is nowhere possible to demonstrate directly in an outcrop the zone of movement. A northerly extension is probably met with in the little brook which runs down to Luktjombäcken, where the more easterly of two limestone horizons is strongly brecciated.

The movement has resulted in a lowering of the eastern block. With regard to its southern part, the fault may be conceived as a dislocation along a vertical plane of schistosity (*ab*-plane of main folding) and, for the part to the north-east of Fremssjokk, as a dislocation along an *ab*-plane related to the cross folding direction. On this assumption the movement implies a fault of appreciable displacement in the central parts, but the combined effect of wrench faulting may decrease this amount considerably.

It is very difficult to come to an understanding of the badly exposed areas south-east of Fremshöjden, around and to the south of the Remdalen ore. The repetition of the Fremss Phyllite indicated by the geophysical map and the drillings can be explained by a minor thrust, but the problems demand a detailed analysis which has not yet been carried out. The most likely explanation, given on the map, is a relatively steep, minor thrust directed towards the south-east at a place where the cross folding direction in Remdalen joins the main folding direction, dominating further to the south.

PART III

Comparisons and Conclusions

A. Stratigraphic Correlation with Adjoining Areas

The stratigraphic results obtained by the detailed mapping of the Remdalen syncline suggests possible correlations and comparisons with nearby areas. At the same time care is needed for. Often the correlations are uncertain until they have been followed up in the field.

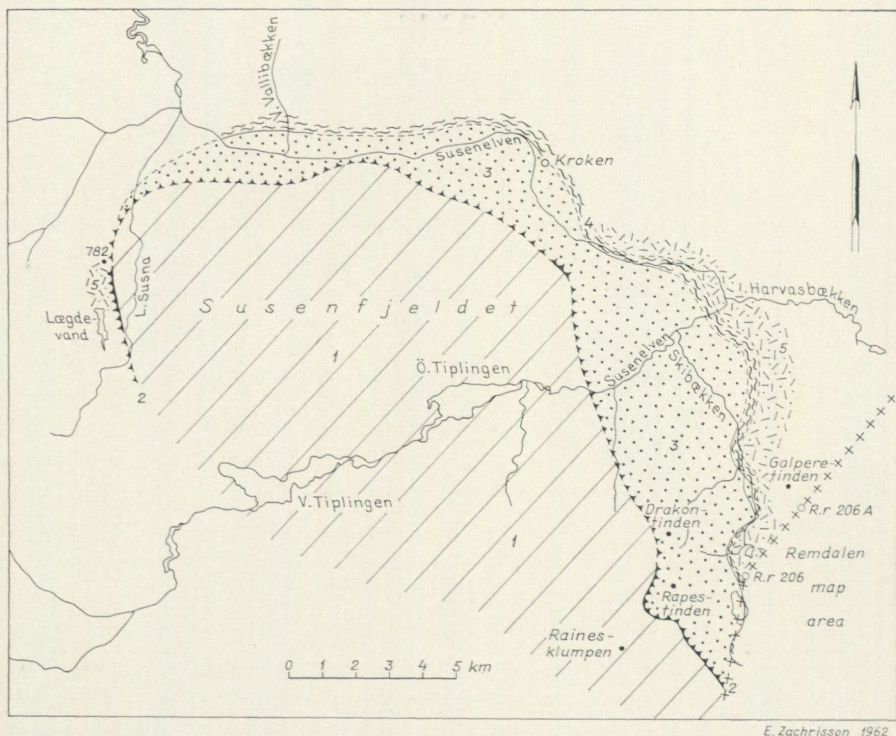
1. ADJOINING NORWEGIAN AREAS

The most recent works dealing with the bedrock of adjacent areas are T. Strand's accounts (1953, 1955) of the geology of the south-eastern-most Helgeland, on the northern side of the Børgefjell massif. During short excursions in the summers of 1960 and 1961 the author has tried to relate the stratigraphy and tectonics of the lower, western parts of the Remdalen syncline with corresponding elements on the Norwegian side.

The major thrust of the Seve-köli nappe may be followed further north-westwards from the map limit (Fig. 33) through the pass between the Rainesklumpen and Rapestinden mountains and along the western side of Drakontinden to the region immediately east of Ö. Tiplingen. Over this distance it seems to be rather flat-lying. On the western side of Susenfjeldet it appears again in the heights to the east of Laegdevand and northwards to point 782. The thrust zone is here recognized by a thick, bluish green mylonite to ultramylonite, in part with intrusions of a strongly schistose gabbro. Upwards it passes into a low metamorphic, strongly calcareous phyllite of the Köli type. Below the mylonite, exposed on the west side of Susenfjeldet and in the small brooks which run down to L. Susna, the sedimentary sequence of the Børgefjell massif consists of light coloured, rusty-looking, sometimes strongly glassy quartzites with interstratifications of graphitic phyllites and mica-schists. Upwards they become more calcareous and in L. Susna, east of Laegdevand, relatively calcareous strongly tectonized, quartz-nodule-rich phyllites or mica-schists occur. These sedimentary rocks are considered as belonging to the Børgefjell massif, as is also the case with the phyllites which, according to Strand's map (1955, p. 58), occur in the area east of Ö. Tiplingen.

Lowermost in the nappe comes the microcline-bearing Fjällfjäll Arkose with extensive exposures at Rapestinden, parts of Skibaekken and Susenelven. The roofing-slate quarries at Kroken and in V. Vallibaekken are located in the upper parts of the arkose. Towards the west the arkose wedges out and has completely disappeared in the area east of Laegdevand.

The dark phyllites — with interstratifications of quartz-keratophyres — of the



E. Zachrisson 1962

Fig. 33. Stratigraphic and tectonic conditions in the north-eastern part of the Børgfjell massif. 1. Børgfjell window. 2. Main thrust plane. 3. Fjällfjäll Arkose. 4. Tjopasi-Bellovare Formations. 5. Calcareous phyllite.

Tjopasi Formation have a relatively insignificant thickness in the vicinity of Fremssjön. In spite of this, it has been possible to identify these members at a number of localities towards the west. An interstratification of quartz-keratophyre, a few metres thick, appears in the upper part of Skibaekken at a couple of places. At Susenelven, 3 km south-east of Kroken, immediately on top of the Fjällfjäll Arkose a strongly calcareous keratophyric tuffite has been found, and in V. Vallibaekken a rusty, 1/2 m thick quartz-keratophyre appears.

An insignificant quartzite conglomerate overlain by a thin greenschist in Ski-baekken south-west of Galperetinden is identified as belonging to the Bellovare Formation. 2 km further down the brook this greenschist has a thickness of 3—4 m. Just as on the Swedish side these rocks in the region from Rr. 206 to Kroken are overlain by a calcareous phyllite.

Providing Strand's correlations with the regions within the Namsvatnet map sheet are correct, the Fjällfjäll Arkose should correspond to the so-called Daergafjell Quartzite on the southern side of the Børgfjell massif. However, they do not have any direct connection in the field, since the Fjällfjäll Arkose seems to

wedge out with a tectonic discordance on the north-western part of Susenfjeldet in the same way as it does north-east of Bie Ransan. On the Swedish side stratigraphically higher and higher members are southwards brought into contact with the thrust. Those quartzites which occur in the Sipmeken-cokka mountain and which have been described by Strand as Daergafjell quartzites belong to the Børgefjell window. However, the author has not yet had the opportunity of studying the type locality in Daergafjell.

The Tjopasi-Bellovare Formations, which to the north of Børgefjell have a relatively insignificant thickness, have not been distinguished by Strand on his map. The higher members of his phyllite-greenschist series (fyllitt-grønnskifer-serien) can not be directly correlated with the Remdalen area, but it seems as if the dark, graphitic phyllites with interstratifications of greenschist (fyllitt med grønnskiferlag, Rörvikavdelningen) might be an equivalent to the lustrous and graphitic phyllites of the upper part of the Lasterfjäll Group, where also basic effusives are characteristic. On the Swedish side they are separated from the Tjopasi Formation by thick, mainly calcareous phyllites.

2. ADJACENT SWEDISH AREAS

In his description to the map of Västerbotten Kulling leaves the question open, as to whether the Fjällfjäll Arkose is separated from the overlying sequence by a stratigraphic or a tectonic break (1955, p. 168). As it has been possible to study the contact between the Fjällfjäll Arkose and the Tjopasi Formation at a number of localities both in the eastern and the western limbs it can be established that a normal, primary contact is present.

The homogeneous, thick Calcareous Phyllite of the Lasterfjäll region undergoes through facies changes and interstratifications of volcanics large variations in composition towards the south and west. The lower part of the Calcareous Phyllite, situated between the Bellovare Formation and the Stekenjokk Quartz-Keratophyre, may, however, be followed southwards across the Jämtland boundary and has been described by G. Nilsson (1964) under the name of Blåsjö Phyllite. Within the Blåsjö region the phyllite is overlain to the west by a quartz-keratophyre-bearing formation, presumably the counterpart of the Stekenjokk Quartz-Keratophyre. Upwards the latter is terminated by a quartzite conglomerate, which G. Nilsson correlates with the Portfjäll Conglomerate. Hence this conglomerate should, in the succession of the Remdalen syncline, be placed stratigraphically in the lower part of the Kosaåive Phyllites. This assumption is supported by the presence of interstratifications of quartzites, sometimes with boudinage structures, as for example in Kosaåive and in the Stekenjokk region immediately to the south of the map area.

More detailed comparisons southwards are better deferred until further mapping has been made in the area between Saxån and Leipikvattnet and results

from this region will also give a better basis for correlations northwards and eastwards.

3. THE QUARTZITE CONGLOMERATES

The conglomerates of the Kõli sequence, which are generally quartzite conglomerates, have been subjected to much discussion and have, more than any other horizon, been used for stratigraphic correlations. They have often been designated as "Vojtja Conglomerate" without any proof. Du Rietz (1941, p. 9) assumes further that within these parts of the Caledonides all limestones belong to the same stratigraphic level, the so-called "Slätdal Limestone». The present investigation, however, shows that in the succession of the Remdalen syncline there occur quartzite conglomerates, more or less closely associated with limestones, at two quite separate stratigraphic levels. Correlations with the Blåsjö region suggest the presence of yet another quartzite conglomerate in the sequence. Thus at least three quartzite conglomerates are present (from the bottom) :

a) The quartzite conglomerates and limestones of the Bellovare Formation are best developed in the south-eastern part of the map area and can be followed from there towards the south with somewhat increasing thicknesses of both the conglomerate beds and the limestones. Northwards, as well in the eastern as the western limbs of the Remdalen syncline, these members are poorly developed or completely missing. The same stratigraphical position is very probably represented by the conglomerate and limestone localities on the eastern side of Fjällfjällen (e. g. at Rapstensjöarna). Their correlation with Kulling's Björkvattnet-Virisen area is not, however, considered as definitely settled.

b) The Portfjäll Conglomerate occurs in the Blåsjö region on top of the Quartz-Keratophyre-bearing Formation. Towards the north its thickness decreases or quartzite members take its place. Within the Remdalen syncline the stratigraphic equivalent seems to be the graphitic members of the lower part of the Kosaåive Phyllites overlying the Stekenjokk Quartz-Keratophyre. No conglomerates are met with, however, and the facies changes in the Remdalen area suggest that we northwards get a continuous sedimentation.

c) The Remdalen Quartzite Conglomerate. The rocks of the Remdalen Group rest upon those of the Lasterfjäll Group with a slight erosional discordance. The Remdalen Group starts with a quartzite conglomerate which, especially in the northern parts of the map area, is well developed. It is overlain by a very calcareous phyllite with thin limestone horizons. At present it is not possible to give a counterpart to this quartzite conglomerate outside the Remdalen area. Kulling's assumption (1955, p. 191, 1958, p. 231) that it should correspond to the Ro Conglomerate, certainly has to be rejected.

B. Areal Distribution of Effusives

Kulling (1955, p. 171) has, for the Kõli stratigraphy of the Västerbotten mountains, emphasized that "it has proved more valuable to compare the breaks in the succession, generally accompanied by coarse, clastic deposits, than to base the correlation upon the presence of effusives" (author's transl.). The correctness of this assertion is proved by the capriciousness of the extension of the effusives within the Remdalen area. A study of their thicknesses and their areal distribution gives certain clues to a better understanding of the development of the supracrustal sequence of adjacent areas.

The quartz-keratophyres of the Tjopasi Formation show an amazingly even and wide spreading. They have been found within the whole area of investigation, in spite of the fact that the thickness generally amounts only to a few metres and rarely exceeds 10—20 m. On to the Norwegian side they have been traced westwards with decreasing thicknesses on the northern side of Børgefjellet to V. Vallibaekken. On the western side of the Fjällfjäll anticline, according to Du Rietz' map (1941), they could be followed further northwards over long distances. These quartz-keratophyres very probably represent acid tuffs, originating from strongly explosive volcanic eruptions.

The Stekenjokk Quartz-Keratophyre is characterized by great thicknesses and a considerable proportion of basic material and the interstratifications of tuffites and sediment suggest a much more varied volcanic activity continuing over a considerable time. These volcanics quickly disappear towards the north in both the eastern and the western limbs of the syncline. The centre of the activity most likely is located somewhat to the south of the map area.

Those greenschists overlying the Kosaåive Phyllites occur only in the southern parts of the western limb. The absence of this formation everywhere else in the area may indicate that these basic tuffs were spread from a south-westerly eruption centre. The activity might have been intensive and of short duration as the formation consists only of pure greenschists without sedimentary or tuffitic members.

The Lasterfjäll Greenschist shows a maximum thickness in the western parts of Lasterfjället (Beitsetsnjuonje), where in spite of intensive field work it has not been possible to make clear the detailed stratigraphic relationships. This is the only area where massive, phenocryst-bearing greenstones are found which may possibly be interpreted as original lavas. Towards the south and the west they quickly decrease in thickness or are replaced by finegrained greenschists. Beitsetsnjuonje might be considered as the centre of eruption of these mainly basic effusives, probably both lavas and ashes. Thin interstratifications of sediments occur.

A third period of acid volcanism is represented by the quartz-keratophyres of the uppermost formation of the Lasterfjäll Group. The dimin-

ishing thicknesses towards the south and the west are presumably primary, but may be affected by erosion.

Finally, the Remdalen Greenschist is the product of a new period of strong volcanism. The activity starts and ends with more sporadic eruptions, while the most intensive period has produced considerable amounts of ashes, which are now preserved as banded greenschists. This basic volcanism has enclosed within itself a shorter phase, producing the acid porphyries, and during a subsequent pause in the eruptions the limestone has been deposited. The areal extent is far too limited to give any information valuable for localizing this activity geographically.

C. Relationship between Volcanism and Sedimentary Facies

Simultaneously with the volcanic activity which has produced the greenschists, quartz-keratophyres and porphyries of the region, there occurred a sedimentation which resulted in a sequence mainly composed of phyllites. Calcareous phyllites, lustrous or grey phyllites, graphitic phyllites and quartz phyllites represent different sedimentary facies and reflect varying conditions of sedimentation and sedimentary environment. The present investigation suggests a certain regularity of these facies variations, so that the facies of the sediment seems to be influenced by the volcanic activity. Without attempting to explain the causes, the observations are summarized in the following:

1. The acid volcanism is accompanied by a strongly graphitic facies of the phyllites (graphitic phyllite—quartz-keratophyre association). In the Tjopasi Formation and in the Quartz-Keratophyre-bearing Formation of the Lasterfjäll Group, the sedimentation of graphitic phyllites went on both before, during, and after those eruptions which have yielded the quartz-keratophyres, so that these are completely embedded in graphitic phyllites. The Stekenjokk Quartz-Keratophyre comes directly on top of the Calcareous Phyllite but graphitic phyllites occur both as interstratifications in and above the volcanics (the Kosaåive Phyllite). In both limbs the quartz-keratophyre — greenschist and the graphitic phyllite disappear simultaneously to the north, the latter gradually changing to a lustrous phyllite before finally dying out.

2. Immediately on top of the quartz-keratophyres the conglomerate-bearing horizons of the sequence occur. The graphitic phyllites with quartz-keratophyres of the Tjopasi Formation are overlain by the quartzite conglomerate and limestone of the Bellovare Formation, the Quartz-Keratophyre-bearing Formation of the Blåsjö region by the Portfjäll Conglomerate, and the Quartz-Keratophyre-bearing Formation of the Lasterfjäll Group by the Remdalen quartzite conglomerate and limestone. A possible explanation is that the strongly explosive volcanism which has yielded the quartz-keratophyres has also caused changes leading to regressions of the sea and to changed conditions of sedimentation.

D. Remarks on the Geological History

The succession of the Remdalen syncline reaches a considerable thickness. Stratigraphic correlations with other areas are made difficult by the local extension of many rock types, by facies variations of the phyllites, by the occurrence of petrographically indistinguishable members at different stratigraphic levels and by the possibility that breaks and erosional disconformities may occur. Absolutely certain correlations can be made only where the relationship has directly been demonstrated in the field for at least one horizon. Furthermore, the investigated area is too limited to allow a reconstruction of the geological history beyond what has already been done. It may be especially dangerous to try to generalize the tectonic results. When the area between Saxån and Leipikvattnet has been mapped in detail, the whole province from Blåsjön to Remdalen can be used as a basis for a more regional analysis, from which certain common features may appear. A few points, however, will be mentioned which seem to be valid for the tectonic development of the Remdalen syncline:

1. Already during the sedimentation, epeirogenetic or minor orogenic movements occurred which caused regressions of the sea and formation of conglomerates and sometimes faint unconformities.

2. A strong cleavage folding of the whole succession resulted in minor folds, larger folds, anticlines and synclines, oriented according to the NNE-SSW main fold axis or according to the NW-SE cross fold axis. The two fold systems can not be shown to belong to different folding phases, and their age relationship consequently not be decided upon.

3. The piling up of minor nappes and formation of imbricate structures preceded or was simultaneous with the major thrusting eastwards.

4. Deformation, affecting the major thrust planes, occurred both along NNE-SSW and NW-SE fold axes and gave rise to the Caledonian first order anticlines and synclines and associated domeshaped structures (e. g. the Børgefjell window).

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