Geology and structure of the Prestberget area.

By
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With 12 text-figures.

The Prestberget area is taken as a convenient name of the area treated in this paper, shown on the tectonogram, Fig. 2 its topographic and geologic situation is shown on the map, Fig. 1. Prestberget is a hillock rising to the west of Vågåmo village with the old church of Vågå, situated on the alluvial plain at the outlet of Finna river into the main Otta river. The area of the Prestberget proper is shown on the map, Fig. 3.

The Prestberget area is a part of the Sel and Vågå area previously studied by the writer (Strand, 1951). In that paper the writer described the Otta nappe as consisting of an underlying massif of high-grade crystalline rocks and an overlying cover of Eocambrian (?) to Cambro-Ordovician sediments of eugeosynclinal facies. Underlying the nappe are sediments of Eocambrian and Cambro-Ordovician age of the so-called eastern facies, totally different from the sediments of the nappe.

In his 1951 paper the writer gave the following stratigraphy of the Otta nappe:

Sel micaschist
Serpentine conglomerate
Greenstone conglomerate
Greenstones
Heidal series
Crystalline basement (the Rudihø complex)

With a revised classification and terminology the scheme now proposed is as follows:

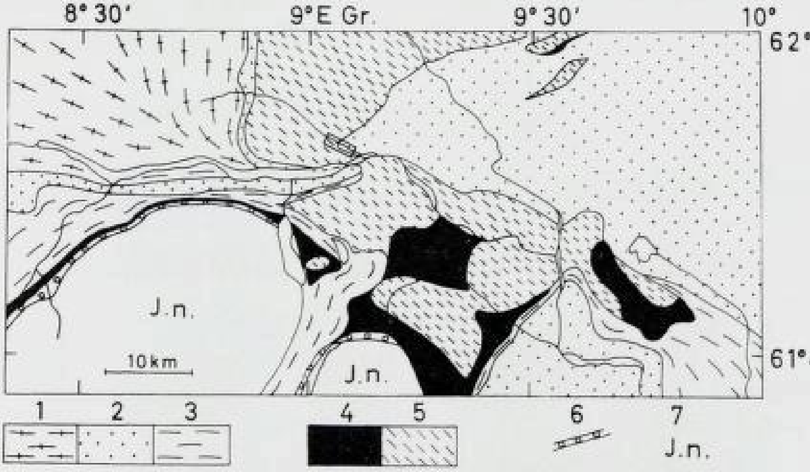


Fig. 1. Geologic map of the type area of the Otta nappe in the northern part of Gudbrandsdalen, to show the position of the Prestberget area.

1–3. Basement and sediments beneath the Otta nappe.
1. Basal gneiss. 2. Mainly feldspathic sandstones (sparagmites), Eocambrian.
3. Mainly pelitic sediments, Eocambrian to Ordovician.

4–5. Otta nappe (lower Jotun nappe). 4. Crystalline basement complex.
5. Sediments and volcanics.
6. Valdres group, greywackes with conglomerates.
7. Jotun nappe (upper Jotun nappe).

Geologisk kart over en del av nordre Gudbrandsdalen, som viser beliggenheten av Prestberg-området.

Sel micaschist	Svartkampen group
Otta serpentine conglomerate	Heidal group
To conglomerate	

The writer proposes to restrict the Heidal group (Heidal series of Gjelsvik, 1946) to the micaceous quartzites immediately above the crystalline basement and the overlying garnet micaschists. The quartzites and flagstones of the Heidal group are similar to the "light sparagmites" of the Sparagmite super-group and may be of Eocambrian age.

The Svartkampen group is a new unit and term to comprise the upper part of the Heidal series (as originally defined) and the Greenstones. The type section and area is in Heidal in the lower part of the Sjoa valley, in the north-east slope of the valley, towering to the mountain Svartkampen.

Rocks very characteristic of the Svartkampen group in the type area are "green schists", a field term for greenish micaschists more or less rich in chlorite, albite and epidote, indicating an admixture to the sediment of material from basic igneous rocks. Another type of rock characteristic of the Svartkampen group are micaschists and quartzschists with large and easily visible needles of amphibole. "Normal" sedimentary schists with quartz, micas and garnet as dominating minerals also occur in the Svartkampen group.

Interbedded with the sediments are layers of greenschist with a basaltic or andesitic composition, of thickness varying from thin seams to zones measuring several tens of metres. In an area in the Otta valley west of Otta railway station greenschists and more massive greenstones occur in a thickness of about 2000 m, representing the deposits at a volcanic center. Volcanic deposits of an acid composition, rich in quartz and albite, are much more scarce than the basic ones. It is thus clear that the Svartkampen group was deposited during a period of strong volcanic activity.

At the top of the Svartkampen group is the "Greenstone conglomerate" (Strand, 1951, p. 65–66) for which the name To conglomerate is here proposed (from To farm near Otta railway station). The writer is now inclined to suspect that the To conglomerate is equivalent to the Skardshø conglomerate (Strand 1951, p. 70), and that the former name may be superfluous.

The Otta serpentine conglomerate (name proposed by Th. Vogt (1945, p. 507)) contains a surprisingly well-preserved and rich fauna, indicating an early Middle Ordovician age (Yochelson, 1963).

The Heidal and Svartkampen groups correspond to the Røros and Støren groups in the Trondheim region, while the Sel micaschist, overlying the Otta serpentine conglomerate, must correspond to the lower part of the Hovin group in the same region.

In his 1951 paper (p. 30–31) the writer recorded some observations from the Prestberget area which seemed to indicate that older structures of slides and assumed recumbent folds with axial planes dipping gently to the north-west had been affected by a younger folding with north-west to west axial directions. The writer therefore considered the Prestberget area as worthy of a closer investigation. When Dr. Janet S. Peacy was staying at the Oslo Geological Institute in 1958, the writer suggested that she undertake a detailed investigation of the area. Dr. Peacey made a brief visit in the area, but her work elsewhere prevented her from doing any further work there. However, her painstaking work resulted in the

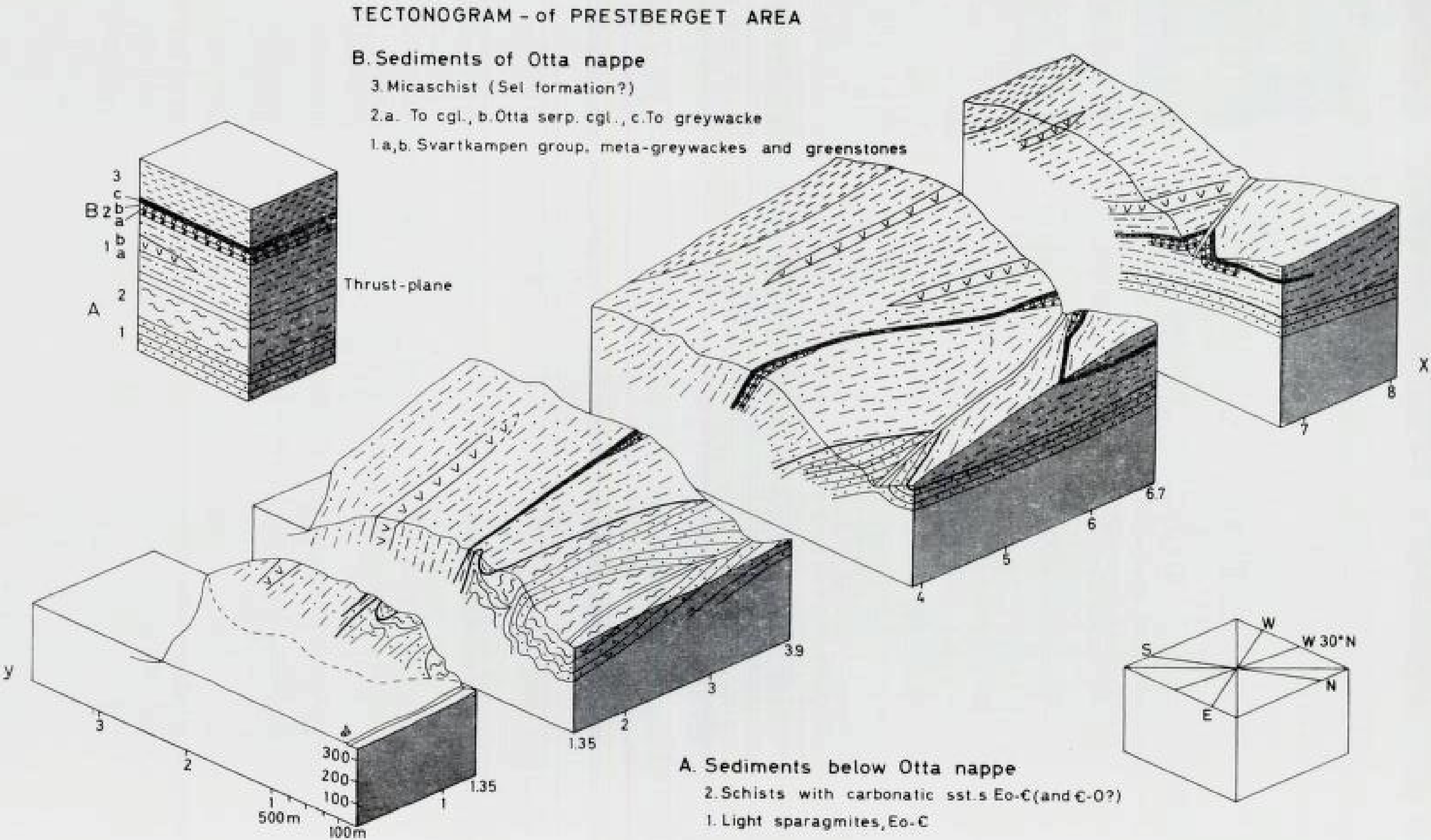


Fig. 2. Tectonogram of the Prestberget area.

Blokkdiagram av Prestberg-området.

discovery of mesoscopic[1] structures giving proof of two or three phases of folding. Dr. Peacey made a report of her work in Prestberget which she handed over to the writer and which she kindly allowed to be used in the preparation of the present paper.

The map Fig. 1 shows the Prestberget area situated at the apex of a large triangle-shaped anticlinorium of Eocambrian sparagmites with the rocks of the Otta nappe adjacent at the north-west and south-west sides of the triangle. To the south of Prestberget the eastern end of a narrow anticlinorium of sparagmites extends along the south side of the Otta valley. The structures in question have bent and folded the thrust-plane of the Otta nappe. The macroscopic structures thus indicate one or more phases of deformation later than the emplacement of the nappe.

The rocks of the Prestberget area fall in two distinct groups, the rocks of the Otta nappe and the rocks underlying the thrust-plane of the nappe. (See tectonogram, Fig. 2). The latter rocks are sandstones and schists mainly of Eocambrian age. The crystalline basement complex of the nappe is not present in the Prestberget area and from the evidence to be found in that area it is not immediately apparent that the thrust-plane beneath the nappe is a tectonic plane of a high order of magnitude. But the sediments of the nappe are radically different from those in the underlying complex.

The sequence beneath the Otta nappe consists mainly of light feldspathic sandstones in benches of about decimetre thickness. Rocks of this type termed "light sparagmites" cover large areas within the Sel and Vågå area. Above the "light sparagmites" in the Prestberget area is a sequence of pelitic schists with mostly thin intercalated layers of sandstone. The rocks are often more or less calcareous or dolomitic with rare thin layers of rather pure dolomite. Of this sequence the "light sparagmites" are certainly Eocambrian, while parts of the overlying pelitic sediments may be of Cambrian and perhaps even of Ordovician age.

The main part of the Otta nappe in the Prestberget area consists of rocks of the Svartkampen group, rocks of the Heidal group (as here defined) can not be identified with any certainty. The rocks have always a distinct schistosity, but are commonly rather tough and not too easily splitting along the planes of schistosity. The mineral composition of some examples of the rocks is given in Table I. It will be seen that most of

[1] Mesoscopic structures are structures visible in hand specimens and exposures, macroscopic structures are those that must be studied on geological maps (Turner and Weiss, 1963, p. 76, p. 144).

the rocks contain a fair amount of cafemic material, probably derived from the basic volcanic rocks formed during the deposition of the sediments.

Volcanic rocks within the area are greenschists with the minerals albite, epidote, amphibole and chlorite, indicating a basaltic or andesitic composition. They may be found as bands of about decimetre thickness alternating with the sediments, but may also form layers several tens of metres in thickness. Allthough there is some variation among the deposits of the rocks here in question, there are no characteristic marker horizons.

The To conglomerate in the present area has the same petrographic characters as in the type area near the Otta railway station, a dark rather massive greenish rock with boulders of light quartzite.

The Otta serpentine conglomerate is easy to recognize and is exposed in a fine development at Dalen farm (3.8x, 1.8y)[2] with boulders of serpentinite reaching a size of 30 cm.

In the Prestberget area the Otta serpentine conglomerate is overlain, in a normal succession according to the writer's interpretation, by a dark greenish rock visibly rich in chlorite, which will here be designated as the To greywacke. A conspicuous feature of this rock is lenses of light-coloured material rich in quartz embedded in the dark greenish matrix. If the above interpretation is correct, there is a difference in the sedimentary facies between the Prestberget and the Otta areas, as in the latter the monotonous Sel micaschist follows immediately above the Otta serpentine conglomerate.

The higher parts of Prestberget are underlain by micaschists of the same type as in the Sel micaschist formation at Otta. It is probable that the micaschists in the present area represent the Sel formation, even if the characteristic conglomerates have not been found beneath them.

Intrusives into the rocks of the Otta nappe are saussurite gabbros occurring as lenses of size about 10 m. In some cases the rocks are fine-grained and even porphyritic with the character of dolerites. The intrusives seem to be especially common in the rocks close above the slide near the To and Otta conglomerates.

As will appear from the tectonogram, Fig. 2, the thrust-plane of the Otta nappe slopes down to the north and sinks below the surface at the Finna river (4.5x, 0.5y). Roughly parallel to the thrust-plane is a slide that disappears below the surface farther north (7 x, 1 y). The dip of the two tectonic planes is between 3° and 4° to west-north-west. The lower

[2] The numbers refer to the coordinate system of the tectonogram, Fig. 2.

part of the Otta nappe, between the thrust-plane and the slide mentioned above, consists of the common Svartkampen rocks described above.

A description of the slide may commence at the Finna where the slide-plane disappears beneath the surface. Here at the west side of the river the To conglomerate with boulders of light quartzite is overlain by serpentine conglomerate (partly talcose) and further by To graywacke with the characteristic light lenses. At the east side of the river (inaccessible) the To conglomerate is seen to rest on underlying quartz-schist. Near the boundary to the quartz-schists the boulders in the overlying conglomerate are highly deformed, indicating that the boundary is a slide-plane.[3] To the south-east the slide-plane is seen to jump upwards on to a higher level in the underlying schist, which thus seems to be cut off by the slide. — The greywacke above the serpentine conglomerate can be followed upwards along the valley slope until it disappears below drift cover about (6 x, 1.5 y).

The slide is exposed again in the eastern part of the area. From a field situated about (5 x, 1.5 y) a foot-path leading towards east to the farm Dalen follows a ledge, a feature along the slide. The To greywacke is here found to rest on the underlying schists with a thin intervening serpentine conglomerate, almost wholly smeared out at the slide. At the path, about (4.5 x, 1.6 y) the following section is seen: above, to the south of, the To greywacke is a rusty weathering micaschist followed by greenstone, the whole thickness being about 20 m. In the surroundings of Dalen farm (3.8 x, 1.8 y) the section above the slide corresponds to that at the Finna river: To conglomerate with boulders of quartzite, serpentine conglomerate and To greywacke, the beds are here vertical or dip steeply to the south. The To conglomerate and the Otta serpentine conglomerate disappear to the east of Dalen, while the To greywacke can be followed further east to disappear just west of the Prestberget road (see map, Fig. 3). East of Dalen the section above the To grewacke is the same as the section at the foot-path about 500 m further west: rusty micaschist and greenstone.

The observations leave little, if any doubt, that a plane of movement, a slide, occurs below the sequence formed by the three members: To conglomerate, Otta serpentine conglomerate and To greywacke. But as was emphasized earlier the three members are assumed to form a succession "right side up" above the normally underlying Svartkampen

[3] The section here was figured by the writer (Strand 1951, Fig. 12, p. 31), but was then given a somewhat different interpretation.

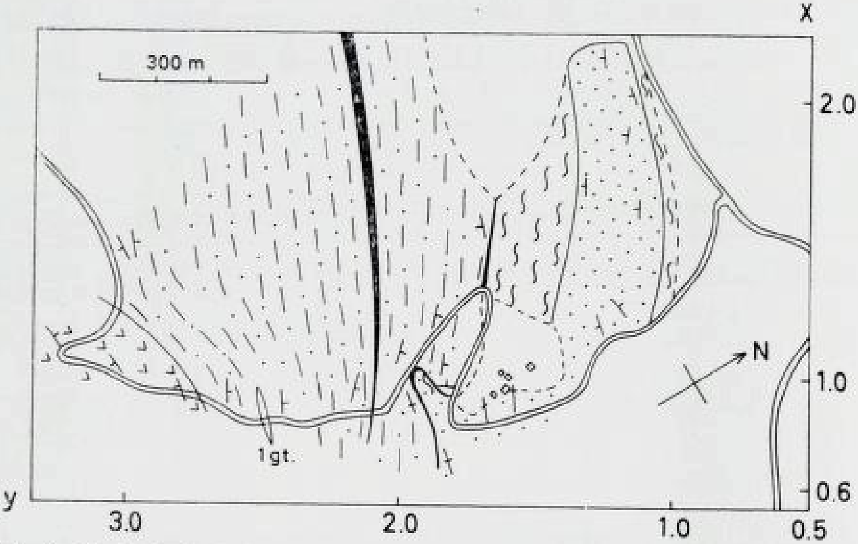


Fig. 3. Geologic sketch-map of the area along the Prestberget road, the Prestberget area proper. Symbols and grid the same as in the tectonogram, Fig. 2.

Geologisk kartskisse over området i Prestberget langs veien til Nordherad.

rocks. If we are to assume an unbroken succession between the To greywacke and the great overlying masses of meta-greywackes and greenschists, the sequence in the Prestberget area must be radically different from the sequence at Otta, where the thick Sel formation of monotonous micaschists comes directly above the Otta serpentine conglomerate. Now, at two places along the slide the To greywacke has been found to be overlain by a highly crumpled and squeezed micaschist. It is a possible interpretation that this micaschist represents the Sel micaschist formation, which was cut off and smeared out along a slide-plane. On the under side of this large slide the To greywacke, and the Otta and To conglomerates were torn loose from their substratum and dragged along. The Otta serpentine conglomerate, great parts of which became talc, formed a horizon of easy gliding and was smeared out along the slide. The slide-plane that can be mapped in the present area should thus be a secondary feature beneath a more important slide. Above the main slide horizon in the micaschist we should have rocks of the Svartkampen group in a normal stratigraphic position overlain by micaschists of the Sel formation at the top of the hill (see tectonogram, Fig. 2).

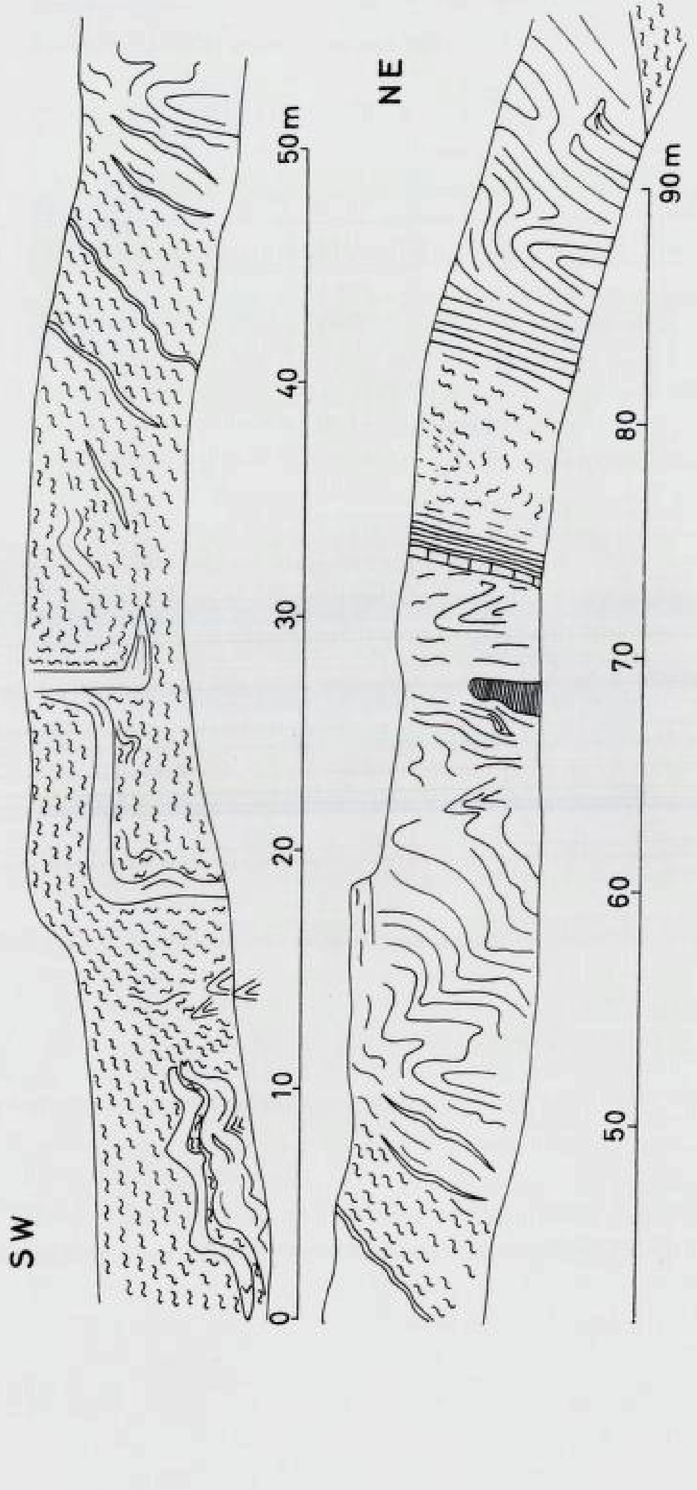
The writer suspected that the tectonics of the Otta nappe was one of large recumbent folds with axial planes dipping north or north-west and has eagerly looked for mesoscopic structures (fold closures) that might prove the presence of such folds. The results have been in the negative. A layer of greenschist, some tens of metres thick, was followed to the east and was found to dwindle out to a thickness about one metre at (6 x, 2.5 y). But the exposures near this locality gave no indication that the pinching out of the greenschist marks the apex of a fold.

The Prestberget area proper is readily accessible as a road from Vågåmo ascends up its slope. The rocks are well exposed along the road. Some of the sections are very spectacular and evidence of three phases of deformation can clearly be seen. See map and sections Figs. 3–9. As was mentioned previously Dr. Peacey has found evidence of at least two phases of folding from her study of the mesocopic structures in the area of Prestberget proper, and the following description of the structures of the first two phases, F_1 and F_2, has been drawn from her report.

The structures of the first phase, F_1, are found all over the area and are quite characteristic, the folds are acute and isoclinal with sharp crests and often intense thinning of the limbs. The axial planes strike west-north-west and dip steeply to north-north-east, while the plunge is on the average 50° in direction slightly south of west, though the plunge is rather variable. A strong lineation in the rocks is apparent as an elongation of the grains of quartz and other minerals and by a preferred orientation of amphibole porphyroblasts. The L structures trend in directions between W and WNW and most of them have a variable pitch in the same direction. See Fig. 12.

A later phase F_2, produced folds of an orientation not sensible different from that of the F_1 folds, but of an entirely different style. The folds are rather open with rounded crests and are further distinguished by a grooving and rodding as a strong b lineation. Of decisive importance is the fact that folds of F_1 type have been refolded across the axial planes of folds of F_2 type (Fig. 5).

A third phase of deformation, F_3, was more tentatively indicated by Dr. Peacey on the evidence of a group of folds younger than F_1 with a style different from that of the F_2 folds in being more brittle. A decisive indication of a phase of deformation later then F_2 is that the axes of the F_2 folds with their characteristic lineation can be seen to have been bent and to have varying orientations in places very near to each others (to be seen in the dolomitic sandstones at 50–73 m in the Prestberget section, Fig. 4). In the same section a layer of thin-bedded quartzite can be seen



SW
NE
0
10
20
30
40
50m
50
60
70
80
90 m

to have been folded on axes deviating about 20° from the strong F_2 lineation of the rock (Fig. 7). It will not in all cases be possible to distinguish between F_2 and F_3 structures, the attitude of which are shown in Fig. 12 from Dr. Peaceys observations. Some of the folds of supposed F_3 age are reclined with axial plunge and dip of axial plane practically the same.

Dr. Peacey has further observed folds that have been torn away from their surroundings on planes of heavy mylonitisation (Fig. 10), a further indication of repeated deformation. Further information on the structures in the sections at the Prestberget road can be got from Figs. 4–9 and the adjoined texts.

The orientation of quartz c axes were measured in eleven orientated specimens from the area (D 1–11, Fig. 11).

There are only two of these, D 1 and 3, that show a symmetric pattern with the L structure in the axis of the girdle. In D 2 a faint lineation (elongation of flakes of chlorite) is not in the girdle axis, but there is a very faint indication of a second girdle with the L structure as axis. According to the writer's interpretation the quartz orientation was connected with the F_1 phase. In the case of D 2 the deformation that caused the L structure (probably F_2) had very little effect on the orientation pattern. An alternative interpretation must be that a late phase (F_3?) did

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Fig. 4. Section through the Eocambrian (and younger ?) schists, sandstones, carbonatic sandstones and subordinate dolomites underlying the thrust-plane of the Otta nappe. Prestberget, south-west end of section 20 m distant from the sharp turn in the road (1.3 x, 1.7 y). The south-west parts of the section are strongly crumpled schists with quartz-stringers with embedded sandstones.

0–11 m. Folds in sandstone, see Fig. 6 for a large scale picture.

14 m. Folds of F_1 type with varying axial trend and plunge.

40–45 m. A ledge of thin-bedded quartzite shows folding (F_3) on axes diverging from the F_2 lineation (see Fig. 7).

50–73 m. Dolomitic sandstones, more or less fine-grained and rich in carbonate, with folds, made easily visible by the selective weathering (see Fig. 8). The folds with the characteristic F_2 lineation have varying axial trends and plunges. At left side of the large cave, 67 m, is a clear example of double folding (see Fig. 5).

73–81 m. A 1-m-thick layer of dolomite in dolomitic schist, followed by siltstones and schists.

80–94 m. Quartzite sandstones of "light sparagmite" type, at 90 m folds, probably of F_1 phase, with bent axial planes.

At the north-east end of the section is a thrust-plane, dipping 30° NNW, upon an underlying schist, again underlain by nearly horizontal sandstone.

Profil gjennom eokambriske (og yngre?) skifrer, sandstener, karbonatholdige sandstener og (sparsomt) dolomitter i Prestberget. Hårnålsvingen er like ved den sydvestre ende av profilet.

Fig. 5. By J. S. Peacey. Left figure: F_1 folds refolded by open folds (F_2) with characteristic lineation. In section Fig. 4, 67 m. Right figure: Characteristic F_1 folds. Prestberget (1.0 x, 1.9 y).

Til venstre: F_1 folder foldet for annen gang av åpne folder (F_2) med karakteristisk linjestruktur. Til høyre: typiske F_1-folder.

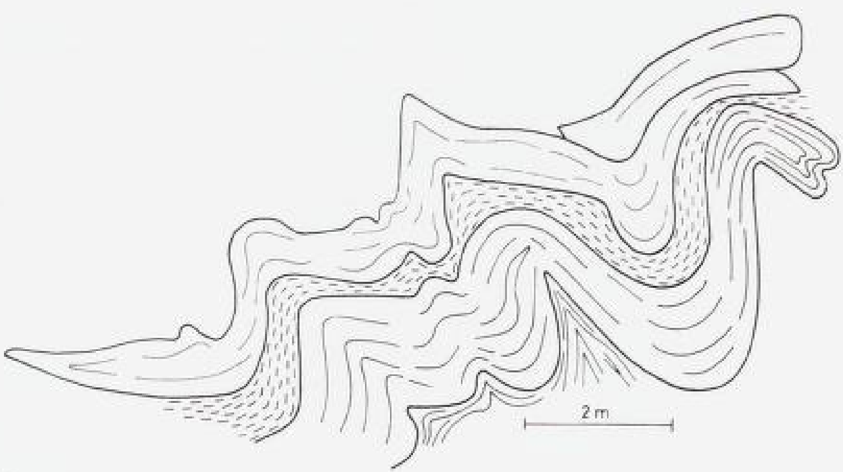


Fig. 6. Folds (F_2) in sandstone, 0–11 m in section Fig. 4. The varying thickness of the sandstone in the lowermost fold and the fold closures found within the ledges of sandstone indicate repeated folding (F_1 and F_2).

Folder i sandsten, 0–11 m i profil fig. 4, som viser gjentatt foldning.

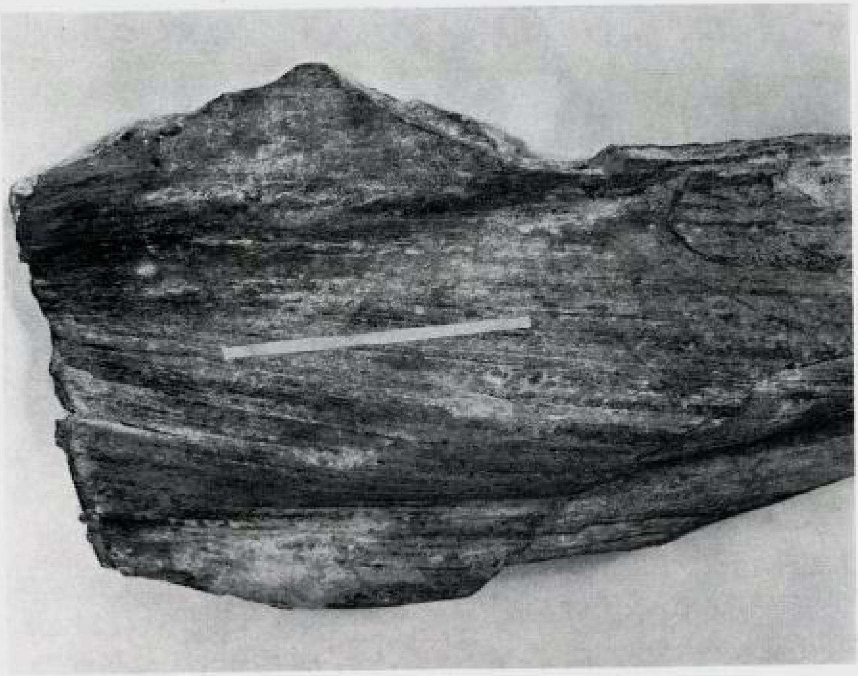


Fig. 7. Thin-bedded quartzite, Prestberget, 40–45 m in section Fig. 4. The white strip in the midst of the picture, 20 cm long, marks the crest of an anticline, diverging about 20° to the strong F^2 lineation.

Tynnbenket kvartsitt, Prestberget, 40–45 m i profil fig. 4. Den hvite stripen, 20 cm lang ligger langs ombøyningen av en fold.

completely destroy and reconstitute all older patterns, but this seems much less likely. D 4–6 are from quartzites in the sequence below the Otta nappe in the Prestberget section (Fig. 4). Two of them show girdle patterns, but the strong F_2 lineation of the rocks are not in the axis of the girdle. D 5 and 7–11 show assymmetric patterns not easy to interpret, but clearly indicating a polyphase history. In accordance with the above interpretation the orientation patterns formed during the F_1 phase could thus in many cases be effaced and modified during later phases, but not entirely re-orientated on a new plan. In the case of D 8 & 9 it is possible that the rocks were tilted by folding after the production of the earlier pattern.

D 12, inserted for comparison, is a regular type of quartz orientation

Fig. 8. Folds in dolomitic quartzites, 50–70 m in the section Fig. 4. Selective weathering made the folds easily visible and formed a number of caves, the largest of which (at right margin of picture) is 3 m high at the opening. The weathering is most probably pre-glacial, as indicated by Reusch (1921).

Folder i dolomittholdig kvartsitt, 50–70 m i profilet fig. 4. Forvitringsformer med huler, sannsynligvis av preglasial alder, se Reusch (1921).

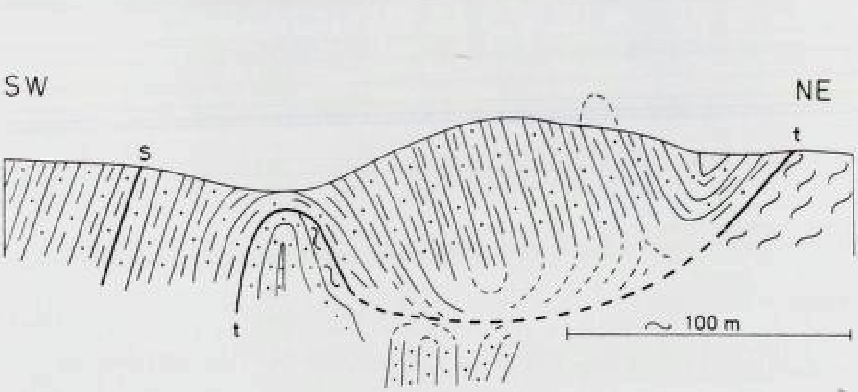


Fig. 9. Section in Prestberget, symbols as in the tectonogram, Fig. 2. The thrust-plane (t) near the north-east end of the section is at the sharp turn in the road (1.3 x, 1.8 y). The rocks in the right and middle parts of the sections are tough meta-greywackes with interlayered bands of greenstone. To the left the thrust-plane and the rocks below and above it have been folded into a sharp antiform. Further left the slide is marked by a strong tectonisation, but the To greywacke can not be found at the road (it is present a hundred metres above it).

Profil i Prestberget, skyveplanet (t) i den nordøstre del av profilet er ved hårnålsvingen.

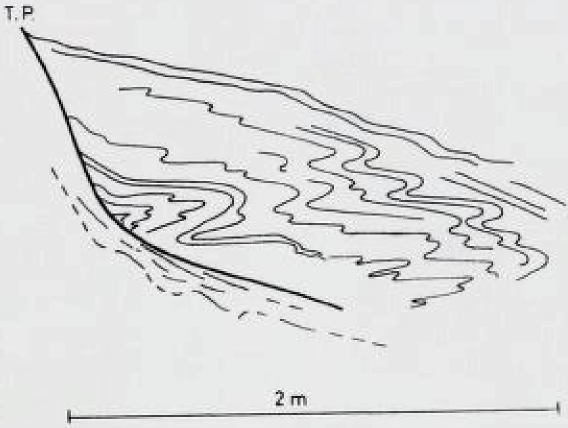


Fig. 10. By J. S. Peacey. Folds (F_1), torn away from their surroundings and resting on a mylonitised slide-plane. Prestberget (1.6 x, 1.0 y).

Folder (F_1) som er blitt slitt løs fra sine opprinnelige omgivelser ved en senere fase av bevegelse.

pattern found in rocks of the Heidal group in the Otta nappe in Heidal, 20 km south-east of the Prestberget area.

To sum up the history of the Prestberget area, it seems very natural to correlate the F_1 phase of deformation with the period that culminated in the *mise-en-place* of the Otta nappe, assuming that the deformation and mineral orientation and the nappe movement were guided by an essentially uniform plan.

As was mentioned previously the writer earlier assumed that the tectonics of the Otta nappe in the present area was one of large recumbent folds with a north-east and north axial trend. But within the area nothing has been found that could verify such a hypothesis. It seems that the main movement towards south and south-east was by partial movements within the rocks and on slides within the nappe complex, apart from the movement along the thrust-plane. The resistance to this movement was small enough that the stresses could be released by the sliding of the rocks, and bending moments to produce larger folds in the "main" Caledonian direction were not set up. But orientation of quartz on girdles with north- and north-east-trending axes (of assumed F_1 age) and by (comparatively rare) L structures in the same directions testify to movements to south and south-east. But this main movement direction of the rocks is very faintly displayed by observable mesoscopic structures. As in many other parts of the Scandinavian Caledonides the prominent structures are cross-structures. We may perhaps understand the mechanism that produced the cross-structures, when considering that the plans of stress and deformation could vary from place to place during the same phase. There could thus be components of stress, or, more correctly, of stress gradients in direction normal to that of the main movement, which resulted in cross-folds and other cross-structures. Patterns in the basement (as margins of basins of deposition) could possibly in some cases be a cause of cross-folding or they could make it especially strong. But cross-folding seems to be of such common and general occurrence in so many parts of our Caledonides (and in many other orogenic belts) that an effect of frames seems inadequate as a general explanation. –

The F_1 cross-folds observed in the present area are commonly of small dimensions, their present attitude may in many cases be influenced by

Fig. 11. Diagrams 1–12.

Equal area (Schmidt) net, lower hemisphere, in the horizontal plane. Orientation of quartz c-axes, each diagram based on the orientation of 200 grains. Contouring: 0–1–2–4–6 %.

1. Quartz-muscovite schist, sp. No E 29 ø 390 (No 1, Table 1), Råstad farm (4.7 x–0.2 y), outside of the area of the tectonogram). Maximum concentration 8 %.
L structure is a fine corrugation of micas.

2. Quartz-albite-amphibole schist, E 29 ø 400 (No 2, Table 1). At the Finna river opposite the outlet of the Måla brook (5.0 x, 0.9 y). Max. conc. 10 %.
L structure (faint) is elongation of chlorite flakes.

3. Amphibole porphyroblast schist, E 29 ø 398, south-east of Dalen farm (3.3 x, 0.4 y). Max. conc. 8 %. L structure is parallel orientation of amphibole needles, which structure seems to have been effaced by a later deformation (without a new L being produced).

4. Feldpathic quartzite, E 29 ø 380, at the sharp turn, Prestberget road (1.3 x, 1.8 y). Max. conc. 5 %. L structure is F_2 corrugation or fine rodding.

5. Same rock as preceding and from the same fold. E 29 ø 381. max. conc. 4 %.

6. Dolomitic quartzite, E. 29 ø 408, Prestberget, 65 m in section Fig. 4, Max. conc. 6 %

7. Quartz-epidote schist. E 29 ø 403, loc. as 400 & 401 (D 2 & 10). Max. conc. 5 %.
L structure is a corrugation or fine rodding of F_2 type.

8. Quartz-albite chlorite rock, E 29 ø 375 (No 3, Table 1), knoll at path south-east of Dalen farm (2.8 x, 1.7 y). Max. conc. 5 %. No visible L structure.

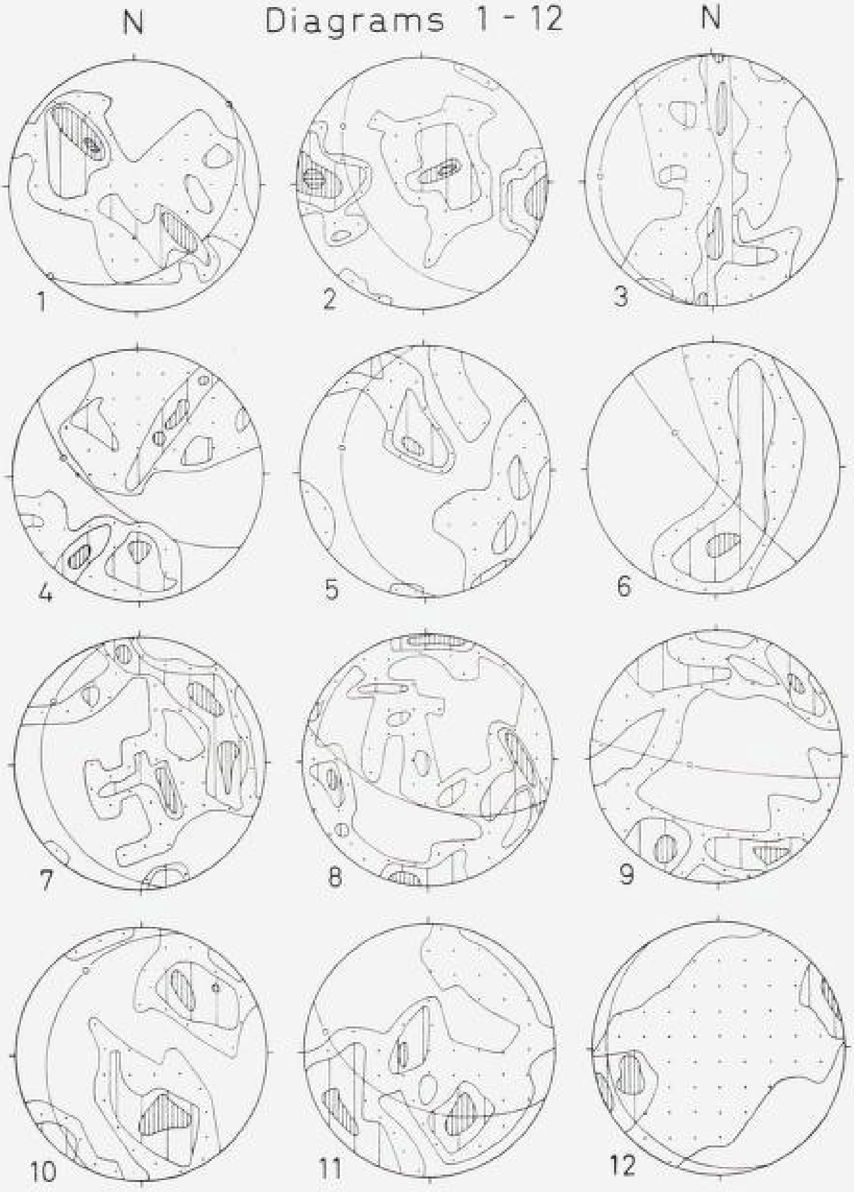
9. Amphibole porphyroblast schist, E 29 ø 395, at old road to Kvarberg farm (2.3 x, 2.1 y). Max. conc. 5 %. L structure is parallel orientation of amphibole.

10. Quartz-epidote-amphibole rock. E 29 ø 401, loc.: same as 400 (D 2). Max. conc. 5 %.
L structure is elongation of chlorite flakes.

11. Quartz-albite-chlorite rock, E 29 ø 409, Prestberget, above the hairpin turn in the road (just above the thrust-plane of the Otta nappe) (1.5 x, 1.8 y). Max. conc. 5 %.
L structure is indistinct corrugation of mica and chlorite.

12. Garnet micaschist, F 29 v 662 of the Heidal group, Heidal, 20 km south-east of the Prestberget area. Max. conc. 6 %.

Diagrams 1 - 12



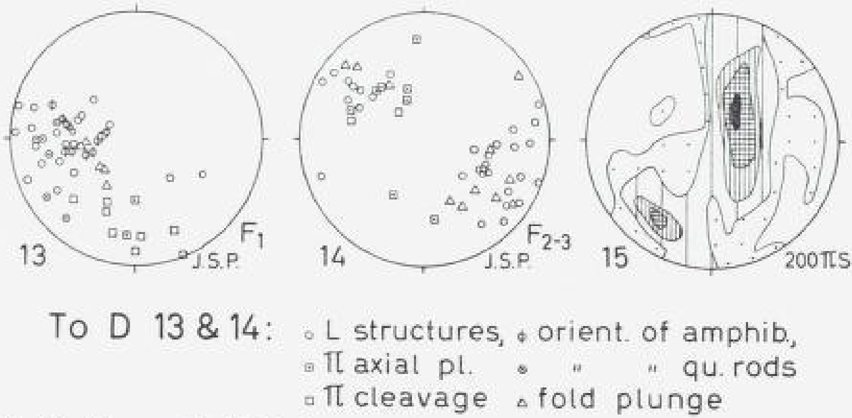


Fig. 12. Diagrams 13–15. Equal area net, lower hemisphere. D 13 and 14 give observations of F_1 and F_2–F_3 structures in Prestberget by Dr. Peacey, see adjoined text. D 15, contoured diagram of 200 poles of bedding planes from the Prestberget area. Contour intervals ½–1½–3–4 %.

F_2 and F_3 movements (see D 13). It seems no unreasonable assumption that much of them were interfolial folds (definition of term in Turner and Weiss, 1963, p. 116) formed in incompetent and easily "foldable" rocks by gliding of more competent rocks above and below them.

It now seems certain that the deposition of the Valdres group started in early Middle Ordovician time, and there are good grounds to assume that the emplacement of the Otta nappe was contemporaneous with the older parts of that group and earlier than the younger parts of it. The probable age of the F_1 phase should thus be Middle Ordovician.

The F_2 and F_3 phases must then be correlated with the folding of the Otta nappe together with the underlying rocks and the basement, thus producing the structures that determine the pattern of the present geologic map. The boundary line between the Otta nappe in south-west and the underlying mainly Eocambrian rocks in the north-east, extending more than 50 km to the ESE from the Prestberget area, is at the NE side of a synclinorium in the Otta nappe. See map, Fig. 1. The thrust-plane of the Otta nappe is bent down along the boundary line, to a vertical position over parts of the distance and locally even to inversion. The synclinorium is in a tract of especially strong cross-folding. The F_2 folds with their strong lineation must most probably be correlated with the making of the synclinorium in question. As was mentioned earlier, the Prestberget area is only a few kilometres removed to the north of the east end of an anticlinorium of light sparagmites extending at the south side of the Otta valley. This may further account for the strong compression of the rocks in Prestberget proper, shown in the sections Figs. 4–9.

The Jotun nappe was emplaced after the deposition of the sediments of the Valdres group, upon which it rests. The Bygdin conglomerate at Bygdin, 65 km south-south-west of the Prestberget area, situated near beneath the thrust-plane of the Jotun nappe, has a structure of strong cross-folding very similar to the F_2 structures of Prestberget and surroundings (Strand, 1945). John R. Hossack, Edinburgh, is at present engaged in detailed investigations in the Bygdin area. He has kindly informed the writer that he considers the strong cross-folding at Bygdin to be younger than the deformation of the conglomerate boulders parallel to the thrust-plane of the Jotun nappe, but that he is uncertain as to the question of a time break between the two phases. It is quite probable that the strong cross-folding found at Bygdin is the same phase as F_2 in Prestberget. The age of this phase is probably not older than late Ordovician and not younger than late Silurian.

It is not easy to get exactly to know what happened in the F_3 phase, perhaps the F_2 structures were further accentuated by it. Structures of local thrusting and fracturing found by Dr. Peacey in Prestberget may belong to that phase. The F_3 phase may be as late as post Middle Devonian, corresponding to the folding of the Old Red Devonian deposits of south Norway.

Detailed structural investigations have until now been undertaken in small parts only of the Scandinavian Caledonides and they have not in all cases led to the discrimination between separate tectonic phases. Mention may be made of the important work of Lindström (1961 and earlier papers), based on a large amount of measurements from a number of areas in the eastern parts of the mountain-chain. By statistical treatment of L and beta structures he has found evidence of at least three phases of deformation. But it is not possible to make any correlations with the phases in the Prestberget area, at least not in present state of knowledge.

In the Driva valley, about 100 km north-north-east of the Prestberget area, Wegmann (1959) described folds with axes trending east–west, the axes of which were bent down to a strong easterly plunge along the western boundary of the Trondheim region. The folding on east–west axes, assumed to be contemporaneous with nappe movement, can be correlated with the F_1 phase in Prestberget, while the axial flexure along the Driva probably was in the same phase as F_2 in Prestberget.

In Glomfjord region situated at the Arctic Circle in northern Norway detailed investigations carried out by a research group from University College, London has resulted in the recognition of two phases of folding (Rutland 1959, Hollingworth, Wells and Bradshaw 1960, Nicholson and Walton, 1963). To quote from the abstract in the paper of Hollingworth et al.: "Almost everywhere there is evidence of two major episodes of folding. The first folding was isoclinal and recumbent and associated with large scale sliding. – Later folding is generally of a more open type, though locally recumbent. – The later folding has largely controlled the present geometry of structural units . . . . ." Similar relations between an older phase with tight isoclinal and recumbent folds and a younger phase with open assymmetrical folds has been found in Sørøy, Finnmark, 70° 40′ N, by Ramsay and Sturt (1963, p. 414–415, Fig. 2).

The two areas are thus similar to the Prestberget area in so far that an older phase with large horizontal movements of the rocks was followed by a younger phase with a more stiff behaviour of the material. But it would be premature at present to set up any time correlations between phases of folding in regions so far apart.

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As will be apparent from previous parts of this paper, Dr. Janet S. Peacey began the detailed work in the area and placed valuable observations at the disposal of the writer. She also read the manuscript. Norges Geologiske Undersøkelse defrayed the cost of the field work. Nansenfondet gave a grant for the preparation of the quartz orientation diagrams; Sigurd Huseby, cand. mag., carried out the measurements for the diagrams. Unni Bjørlykke, cand. real., made point-countings to determine the mineral compositions in Table 1. The technical staff of the Faculty of Science at Blindern performed the photographic work and the faircopying of the drawings. Mrs. Rut Backer typed the manuscript.

Institutt for geologi, Blindern,
March 1964.

Table 1.
Mineral composition of rocks of the Svartkampen group in the Prestberget area.

	1	2	3	4	5	6
Quartz	66	66	57	56	49	35
Albite		19	19	19	17	9
Epidote		3	2	3	7	11
Muscovite	28			8	6	2
Biotite	2		4	4	1	3
Chlorite	4	1	14	4	1	16
Amphibole		11			12	19
Garnet					1	
Calcite			4	5	6	5

Sphene, ore and other accessories not included.

1. Specimen. No E 29 ø 390, Råstad farm (4.7 x, – 0.2 y) (outside the area of the tectonogram).
2. E 29 ø 400, at the Finna river opposite the outlet of the Måla brook (5.0 x, 0.9 y).
3. E 29 ø 375, knoll at path south-east of Dalen farm (2.8 x, 1.7 y).
4. E 29 ø 26, loc. as 2.
5. E 29 ø 25, loc. as 2.
6. E 29 ø 28, at the south side of Finna river opposite Holen farm (7.5 x, 0.7 y).

Sammendrag.

Geologi og struktur i området ved Prestberget, Vågå.

Prestberget er det bratte berget vest for Vågå kirke (med Jutulporten), hvor veien til Nordherad slynger seg oppover. Ved veien ved Bygdetunet er det meget gode blotninger av foldete lagdelte bergarter og det kan her påvises at lagene er blitt foldet tre ganger. Den første fase av foldning (F_1) førte til små sterkt sammenklemte folder. Bevegelsene i denne fase har særlig vært glidning av bergartene og det var i denne fase at et stort flak av bergarter (Otta-dekket) kom på sin nåværende plass efter å være blitt flyttet meget langt (100 km eller mer). Bergartene ble igjen foldet i en ny fase, F_2, dobbelt foldning av de eldre F_1-folder kan sees flere steder (se særlig fig. 8). Samtidig ble Otta-dekket og dets underliggende skyveplan foldet, se stereogrammet, fig. 2. F_2-foldene har en meget tydelig linjestruktur i akseretningen. Det er funnet folder med akser som danner en vinkel på omkring 20° med F_2-linjestrukturen, (Fig. 7), disse må derfor være dannet i en senere, tredje fase, F_3.

Foldningen F_1 og fremskyvningen av Otta-dekket har muligens foregått så tidlig som i mellomste ordovicium, mens den siste foldning, F_3, kan være foregått så sent som i devon. Noe sikkert kan vi ikke vite om disse forhold.

References.

Gjelsvik, T. 1946. Anorthosittkomplekset i Heidal. N. G. T. 26, pp. 1–58.

Hollingworth, S. E., M. K. Wells and *R. Bradshaw*, 1960. Geology and structure of the Glomfjord region, north Norway. Int. Geol. Congr. Rep. 21st session, Norden. Part 19, pp. 33–42. Copenhagen.

Lindstrøm, M. 1961. Tectonic fabric of a sequence of areas in the Scandinavian Caledonides. Geol. Fören. Förhandl. 83, pp. 15–64. Stockholm.

Nicholson, R. and *B. J. Walton*, 1963. The structural geology of the Nævervatn–Storglåmvatn area. N. G. T. 43, pp. 1–58.

Ramsay, D. M. and *B. A. Sturt*, 1963. A study of fold styles from Sørøy, north Norway. N. G. T. 43, pp. 411–430.

Reusch, H. 1921. Huler dannet ved forvitring. N. G. U. Nr. 87, VI, 15 pp.

Rutland, R. 1959. Structural geology of the Sokumvatn area. N. G. T. 39, pp. 287–337.

Strand, T. 1945. Structural petrology of the Bygdin conglomerate. N. G. T. 24, pp. 14–31.

— 1951. The Sel and Vågå map areas. N. G. U. Nr. 178, 116 pp.

Turner, F. J. and *L. E. Weiss*, 1963. Structural analysis of metamorphic tectonites. MacGraw – Hill, New York, 545 pp.

Vogt, Th. 1945. The geology of part of the Hølonda–Horg district. N. G. T. 25, pp. 449–527.

Wegmann, E. 1959. La flexure axiale de la Driva. N. G. T. 39, pp. 25–74.

Yochelson, E. L., 1963. Gastropods from the Otta conglomerate. N. G. T. 43, pp. 75–81.