THE VATNFJELL FOLD NAPPE COMPLEX OF SALTDAL, NORTH NORWAY

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The Vatnfjell post-schistosity fold nappe, southern Saltdal, Nordland, latitude 67°N, develops disharmonically westwards into the Saltdal Depression, off the anticlinal step in basement that lies between the former and the higher lying Sulitjelma Depression to the east. The complex faces down in the terms of the regional structural sequence but joins smoothly with upward facing folds to the east and north. The relative lowness of the Sulitjelma Depression probably results more from the elevation of the Tysfjord and Nasafjäll culminations to north and south than to its own changes of level. Thus the hypothesis of lateral spreading from an ascending gneiss lobe restrained by a stiff cover that may apply to more westerly Nordland fold nappes is replaced for the Vatnfjell complex by one of westward flow and shear of a relatively easily deformed marble-rich sequence (perhaps containing folds initiated by regional shortening) between stiffer rocks above and the anticlinal step and accompanying growing depression in the basement below.

The domes and fold nappes of Nordland are later than the major strain producing episode and cannot be used as evidence of the role of gravity at the earlier stage.

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The basal member of the regional structural sequence of the northern Nordland region of Norway in about latitudes 67° and 68° N is a generally granitic Pre-Cambrian gneiss revealed in two series of post-schistosity domes, one about along the Norwegian-Swedish border and the other along the Atlantic coast (Fig. 1).

Two values of nearest neighbour spacing (Fletcher 1972) may be defined from the region. Firstly there is a common 20–30 km interval between the individual members of compound culminations both in the linear assemblage between Nasafjäll and Tysfjord and in the less regular Svartisen group. Secondly there is a 70–90 km distance between major groups.

From members of each set of domes examples of post-schistosity and post-metamorphic fold nappes involving the meta-sedimentary cover to the domes are known. The most obvious western example, the Svartisen Fold Nappe, has been described already (Nicholson & Walton 1963, Rutland & Nicholson 1965); here the most easterly is described – the Vatnfjell Fold Nappe of southern Saltdal.

The Vatnfjell Fold Nappe unlike the Svartisen Nappe has no tight core of basement but develops disharmonically in cover rocks. However, both fold

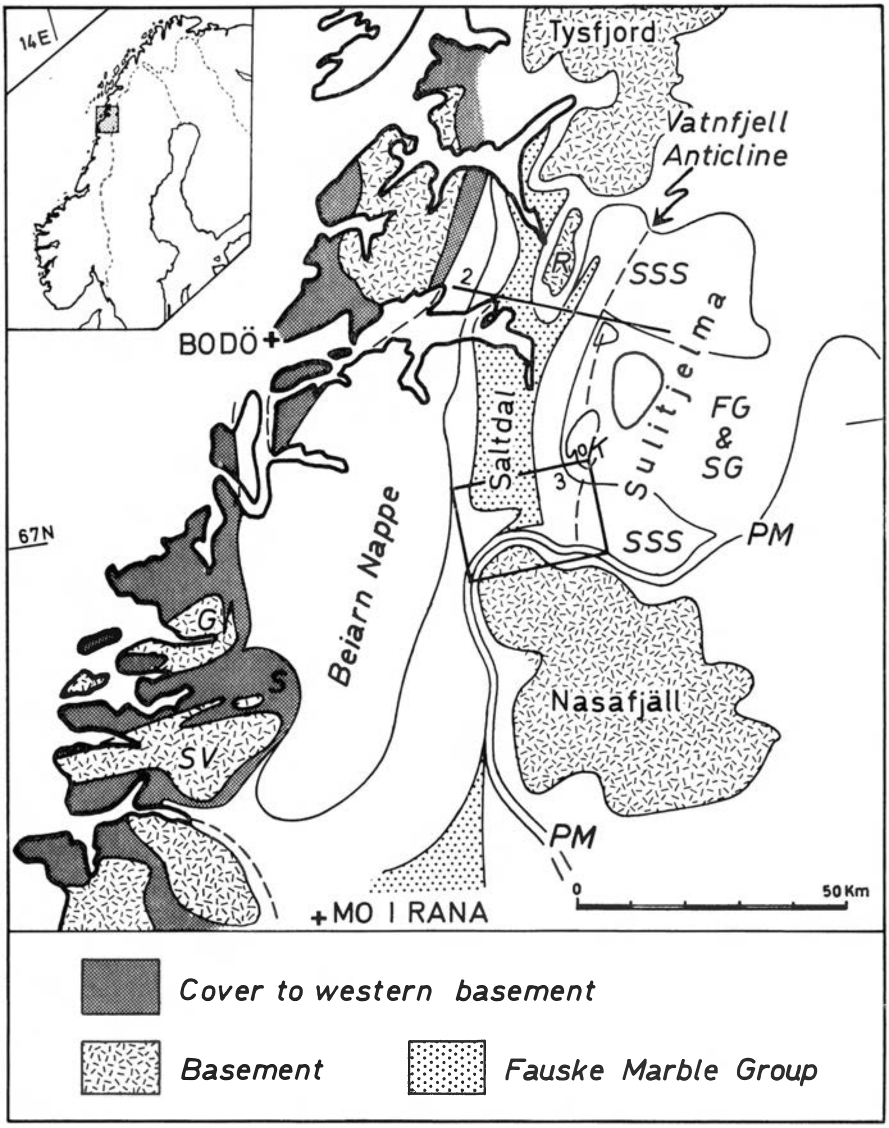

Fig. 1. The geology of a region north and south of Bodö, Central Scandinavian Caledonides. Positions of Figs. 2 and 3 shown.

SV Svartisen
S Storglomvatn
SSS Sulitjelma Schist Sequence
FG Furulund Group
SG Sjönstå Group
R Rishaugfjell
K Krågdal
PM Pieske Marble

nappes have a strongly non-cylindrical character and varied axial orientation; both deform already schistose rocks and both occur off relatively elevated basal gneisses; all suggesting that they in part at least are late gravitational features.

The Svartisen Fold Nappe with its recumbent core of granitic gneiss may represent the spreading head of a buoyant body whose further upward penetration was resisted by a stiff cover. The Vatnfjell Fold Nappe, however, lies on the western edge of what in a broad way was part of the largely inactive Baltic Shield, and it is difficult therefore to suppose it was produced by an ascending relatively light body. Instead it may have resulted from development of folds into a growing depression on the west side of the stable block and under a stiff superstructure. Under these circumstances it may be necessary, however, to invoke regional shortening to initiate folds locally highly modified by flow between basement and superstructure.

Regional geology

Fig. 1 shows the position of the Sulitjelma depression between the basal culminations of Tysfjord and Nasafjäll in the Scandinavian Caledonides. The structural sequence of the region is probably made up of several thrust nappes and as a number of fossil occurrences are known from it (Nicholson & Rutland 1969, 1970) there is a clear indication that the structural sequence itself was constructed sometime later than the upper Ordovician. Isotope studies by Wilson (1971) suggest that metamorphism associated with formation of the regional sequence was probably of Silurian age.

Since we are not concerned here with the construction of the regional sequence but with its further deformation we can use the sequence as a regional 'stratigraphy'. From this 'stratigraphy' we can define anticlines and synclines and distinguish them as downward facing when respectively synformal and antiformal, a matter of some convenience when Rusånes area is described.

No obvious division exists between the rocks of the Sulitjelma Depression and those of the broadly flat lying eastern zone of the Caledonides, here mostly in Sweden, where a Caledonian cover lies allochthonously on un-Caledonised basement. A limit may be put to it in the west, however, at a sharp downward step of basement running north-south between the basement areas of Nasafjäll and Tysfjord. This is the Vatnfjell Anticline (Nicholson & Rutland 1969); an anticline in terms of the regional sequence. On the west side of the Vatnfjell Anticline there is another depression, here named the Saltdal Depression, into which developed the late fold nappe complex that is the main subject of this account. This depression itself merges west into the much larger Beiarn Depression between the eastern and western basement elevations.

Fig. 2 shows how the highest member of the structural sequence of the Sulitjelma Depression, the Sulitjelma Schist Sequence, thins out abruptly on the west side of the depression until it cannot be separately distinguished, behaviour characteristic not only of this unit and region but apparently of the orogen as a whole (Nicholson & Rutland 1969, Zachrisson 1969, Nicholson 1971).

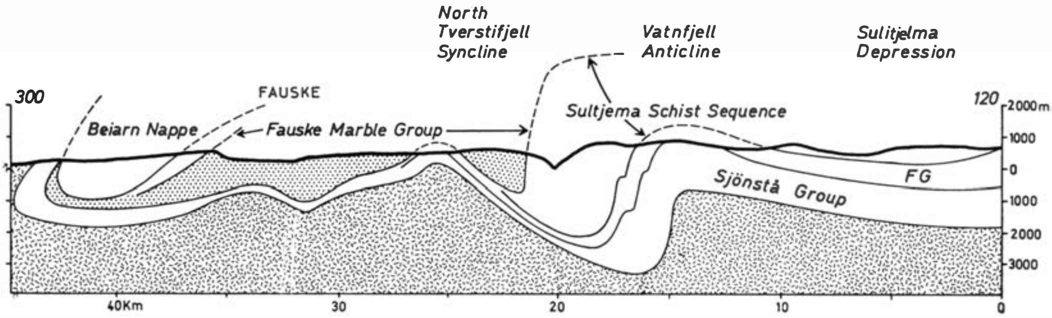

Fig. 2. Section across the Fauske Marble Group. Position shown in Fig. 1.

Structure of the Saltdal Depression

Fauske sector

Fig. 2 is a section across the northern end of the Saltdal Depression, largely as already published (Nicholson & Rutland 1969, Fig. 7). From east to west it shows the shallow Sulitjelma Depression, the Vatnfjell Anticline which limits it in the west and the adjacent Northern Tverstifjell syncline in which the Sulitjelma Schist Sequence quickly thins to nothing: all folds are upward facing (a more detailed map than provided here of this tract is available in Nicholson & Rutland 1969, Fig. 6).

The Vatnfjell Anticline runs the whole length of the Sulitjelma Depression between the northern and southern basement massifs and thus has a regional plunge of zero. On it there are two slight culminations in Sjönstådal and Krågdal, arising from the presence of two contemporary cross folds running east from it (in the latter culmination, the deeper cut, the whole sequence down to basement is revealed). To the east of the Anticline lies the basin of Baldoaivve between the two cross folds and itself a deep zone of the Sulitjelma Depression. Here, and in similar basins to the north and south of the cross folds, occur the main developments of the Sulitjelma Schist Sequence. The Vatnfjell Anticline and Northern Tverstifjell Syncline both deform schistose rocks and also have dependent minor folds deforming schistosity, some with a strong crenulation cleavage (Nicholson & Rutland 1969).

Rusånes sector

Inspection of Fig. 3, a map of the Rusånes area of southern Saltdal, provides several obvious differences of structure from the northern end of the depression (some of its western parts have been described by Steenken 1957). There is also one new rock unit, a highly schistose biotite microline gneiss, which may represent a slice of much deformed basement and perhaps too the eastern limit of the Beiarn Nappe.

Description is best started east of Saltdal where (Fig. 6) the late structures are at their simplest and consist of two upward facing folds, the Vatnfjell Anticline and the Southern Tverstifjell Syncline.

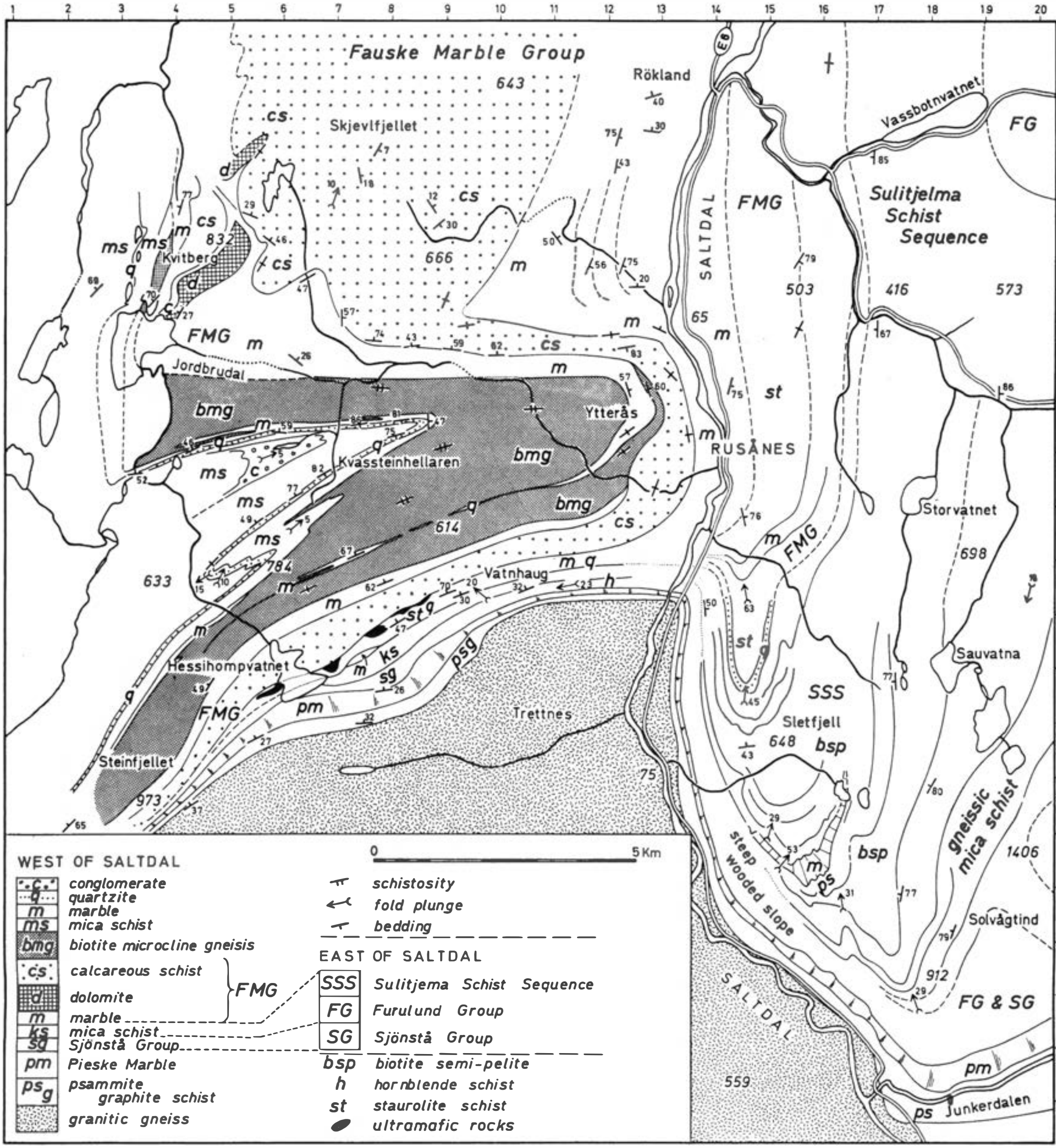

Fig. 3. Map of the Rusånes area of southern Saltdal. Position marked in Fig. 1.

The latter is the southern equivalent or continuation of the Northern Tverstifjell Syncline but was described as the Rusånes fold by Nicholson & Rutland (1969, Fig. 14) when this relation was not clear. The Vatnfjell Anticline has the Sulitjelma Schist Sequence of the southern part of the Sulitjelma Depression with a general flat dip in its eastern limb and a vertical western limb in the same rock body common to both it and the Southern Tverstifjell Syncline. This vertical limb contains a thickness of some 2 to 4 km of the schist sequence. Beneath the latter in Junkerdalen lie schists between it and the Pieske Marble which resemble the Furulund and Sjönstå Groups of the northern part of the Sulitjelma Depression and at whose structural level they lie. Below the marble are sparagmitic rocks and graphitic schists like those which occur at the basement top west of Saltdalen.

In the Southern Tverstifjell Syncline east of Saltdalen, where the fold is upward facing (1616, grid ref. Fig. 3), the Sulitjelma Schist Sequence is overlain by marbles and porphyroblastic staurolite schists of the lowest member of the Fauske Marble Group. Further south, and above the basement of Junkerdalen (1912), dips are small so that the plunge of the Syncline here must be small also. However, dips soon increase northwards or down plunge (Fig. 4) so that by the time exposures on the fold hinge in Saltdal (1423) are reached the dip of bedding round the hinge is vertical and so is the fold plunge. Further west and across Saltdal along the core of the Syncline the biotite microline gneiss is crossed (1324) and easterly plunging metasediments structurally below the gneiss are reached (0823). The Syncline here is downward facing (Fig. 3). Now the eastern plunge itself lessens so that in the schistose conglomerates of the core west of Kvasstein-

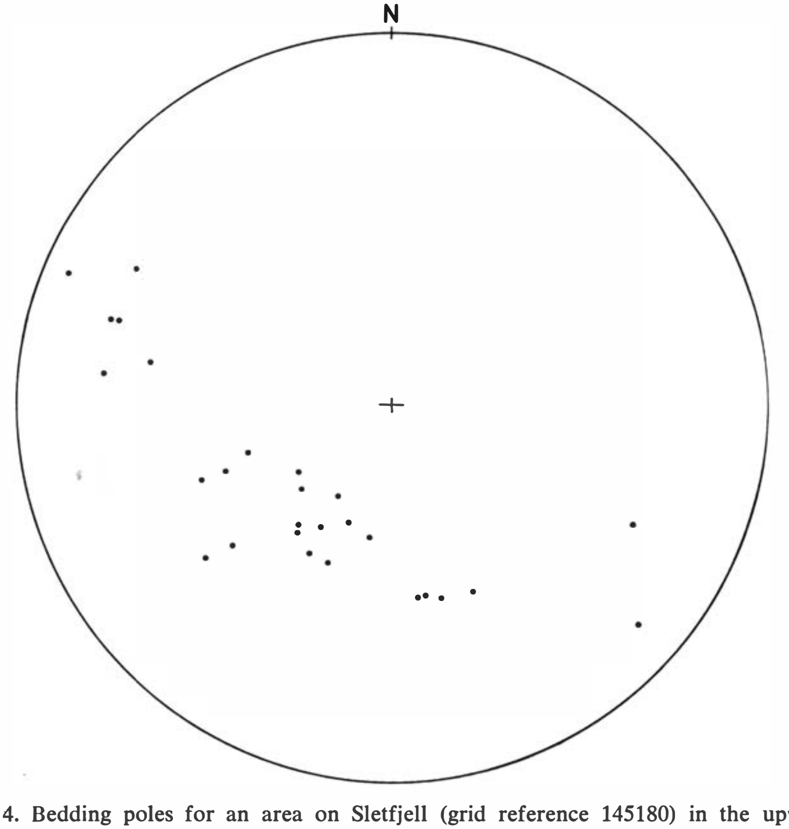

Fig. 4. Bedding poles for an area on Sletfjell (grid reference 145180) in the upward facing southern Tverstifjell Syncline to the east side of Saltdal.

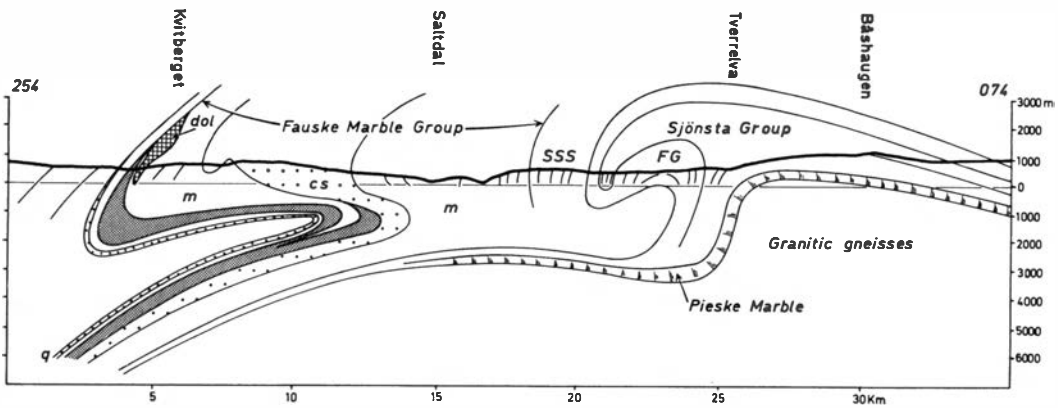

Fig. 5. Tentative section across the Vatnfjell Fold Nappe (Fig. 6). Ornament as in Fig. 3. SSS Sulitjelma Schist Sequence, FG Furulund Group.

hellaren (0623) the plunge is horizontal or even slightly westerly. The Syncline has completed a plunge change of something approaching 1800.

On the north side of Jordbrudalen (0626) and of the downward facing section of the Southern Tverstifjell Syncline there is another and complementary fold hinge closing to the west. All along its core zone this second fold is synformal, plunging easterly or north easterly and also downward facing. To the southwest the two folds merge and die out (Fig. 6).

Fig. 5 shows the relation of the pair of downward facing and westward merging folds to the upright folds of the east side of Saltdal: the downward facing western structures are shown smoothly joining with the latter over a north-south antiform as Fig. 3 shows they must do. This antiform can be equated with the Rishaugfjell Antiform of the northern sector. The southern antiform, however, has a different attitude from the Vatnfjell and Tverstifjell Structures; in the north all three folds are co-axial. In both the cases it seems inevitable that all formed together so that they are related like the Svartisen Nappe and the antiform along Storglomvatnet over which it lies.

No large scale map has yet been prepared of the west side of the Krågdal inlier to substantiate the form given to it on the section Fig. 5 and on Fig. 6. However it seems necessary to accept the downward facing anticline there even though it is probably not directly continuous with the main downward facing fold east of Saltdal.

Finally and as a prelude to later discussion it may be useful to again emphasize the difference between the basement rocks of the east and west limbs of the Vatnfjell Anticline: an eastern one more or less continuous with the eastern basement which eventually merges with the Baltic Shield and a western limb that clearly has departed largely from this regional attitude. The Caledonian cover over all is not only strongly deformed but seems to be of a uniform structural character from west to east: orogen cover and

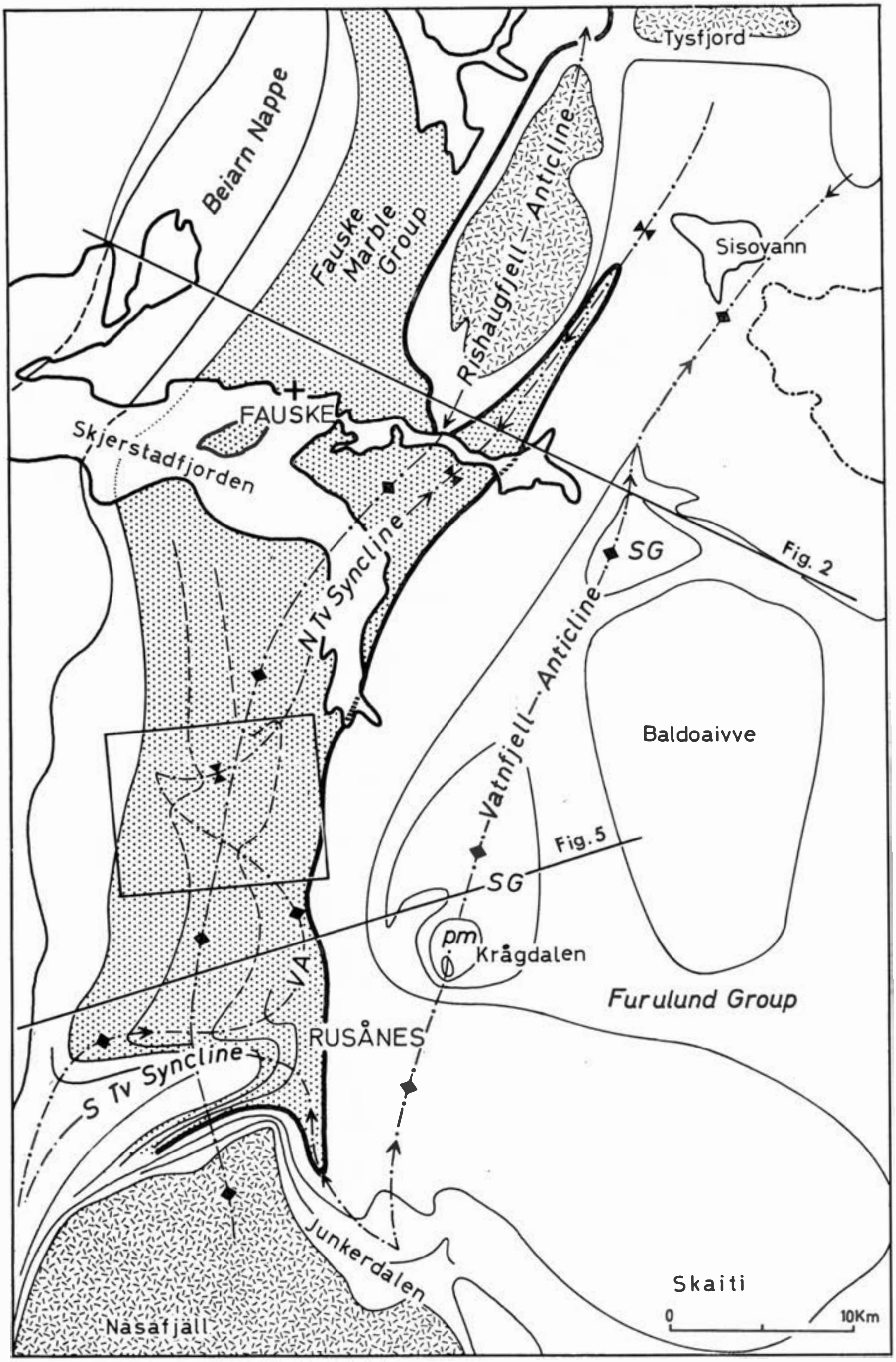

Fig. 6A. A map of the Saltdal Depression showing major rock units and the possible way in which the late structures of the Fauske and Rusånes areas may fit. In an attempt to emphasize the fact that the Marble Group is *not* repeated across its width its structural base is marked by a heavy black line.

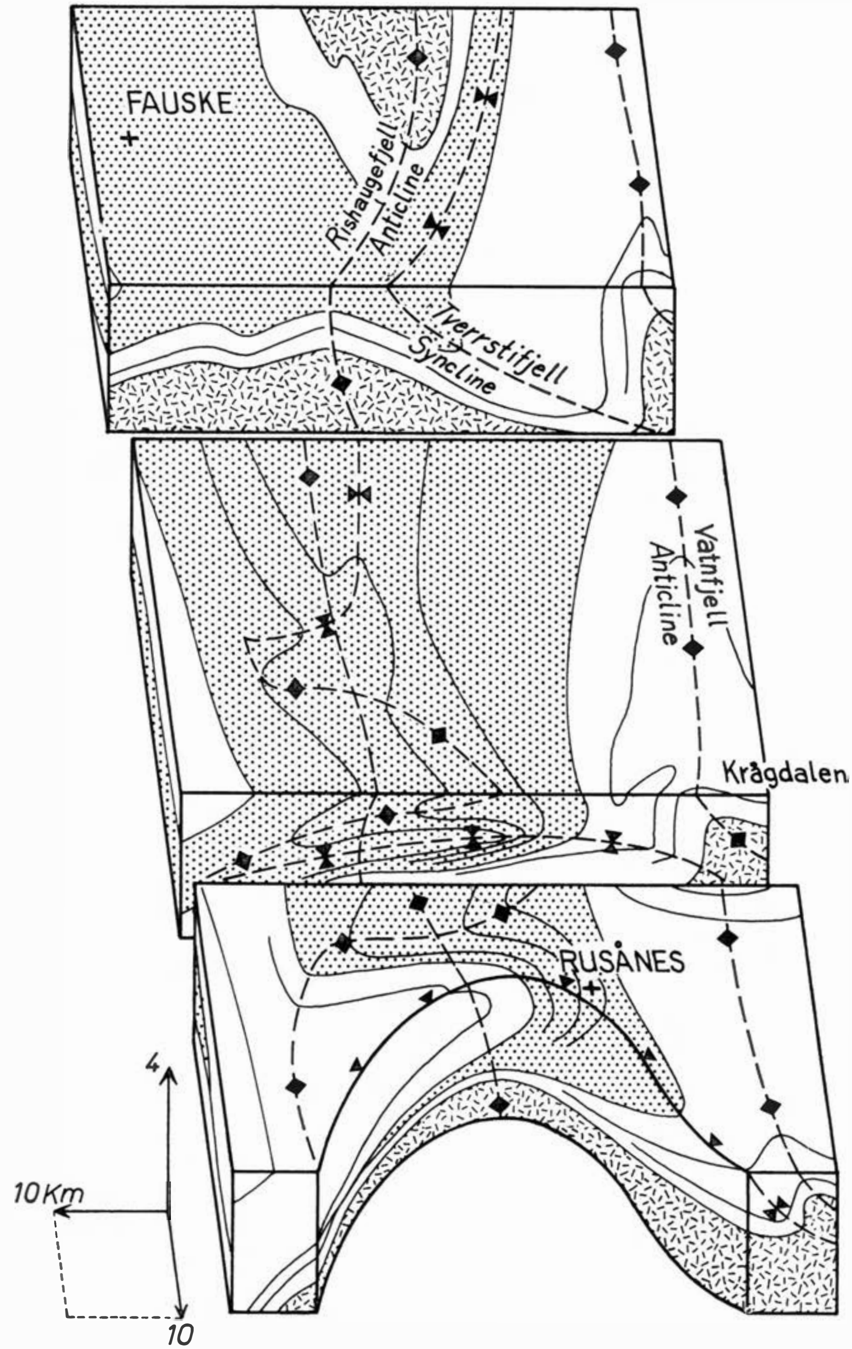

Fig. 6B. Block diagram showing the supposed structural character of the Fauske Marble Group of Fig. 6A. Figs. 6A and 6B do not cover quite the same area. An indication of the vertical and horizontal scales is given by the lower left hand corner of the block diagram.

basement in the east of the deformation belt are separated by an obvious post-metamorphic thrust but in the west as in the Rusånes area no structural break is present.

Correlation between north and south

Figs. 6A and B show how the structures of the Fauske and Rusånes sectors may be fitted together. The particular detail of their union in the inset rectangle of Fig. 6A is not known. Indeed it is possible that the two sets of structures in the west die out rather than merge in the manner suggested there and the one boundary known through the sub-area, the western edge of the Fauske Marble Group, appears to run smoothly north-south through it. Poor exposure and tree cover in the key area make it unlikely that the issue can be settled firmly one way or the other.

Minor structures of the Rusånes area

The Vatnfjell Fold Nappe west of Saltdal folds schistosity like the Vatnfjell Anticline east of Saltdal and the same Anticline in the Fauske sector (Nicholson & Rutland 1969); no new penetrative structures are produced anywhere. However, both upright and downward facing portions may contain

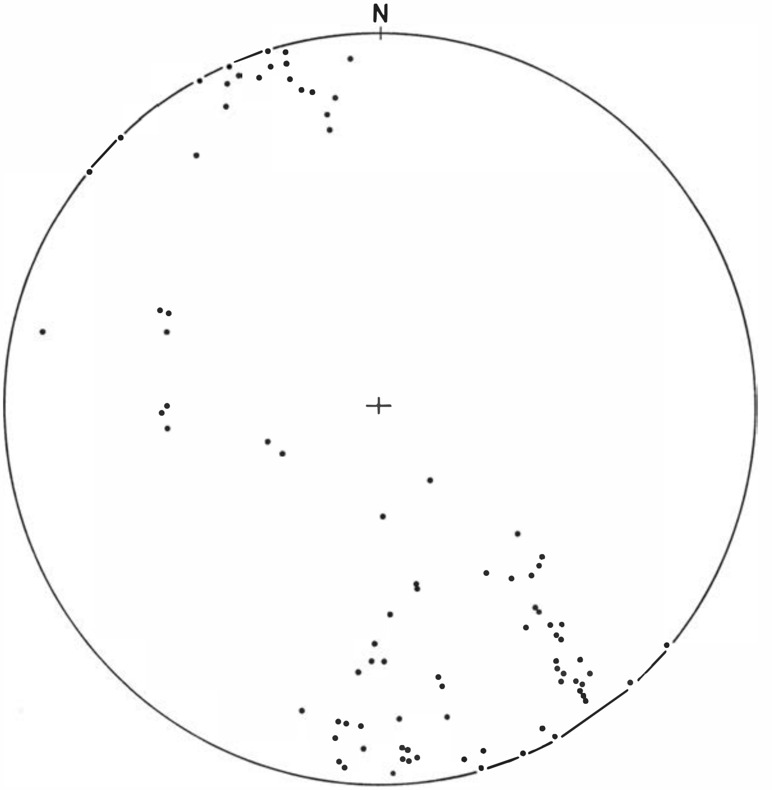

Fig. 7A. Equal area projection of bedding poles for quartzite of Kvasstein area, downward facing Southern Tverstifjell Syncline.

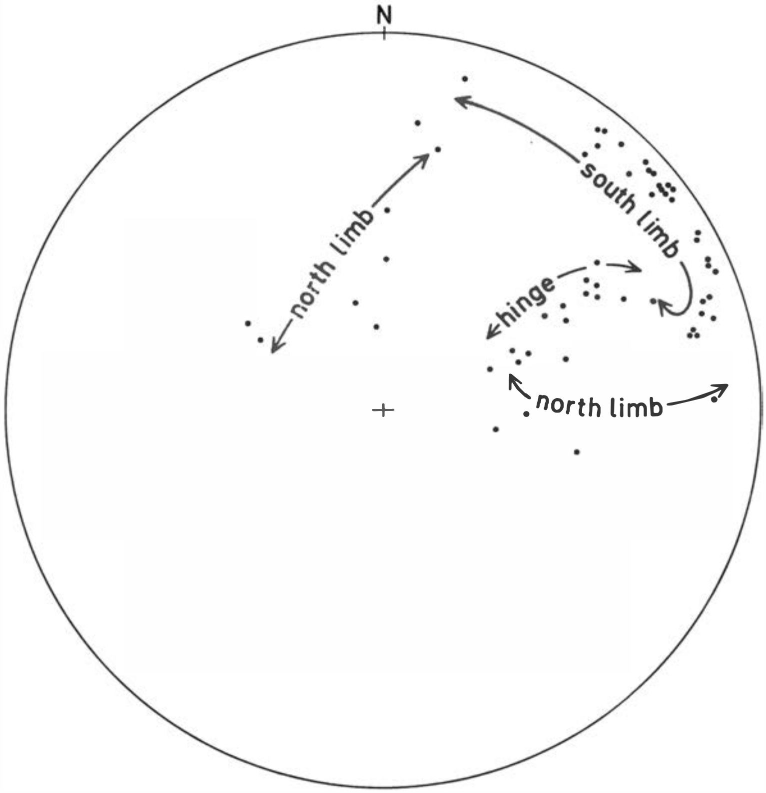

Fig. 7B. Lineation poles for same area as Fig. 7A.

a crenulation cleavage whose trace is parallel to fold traces and which is especially well developed in the downward facing Southern Tverstifjell Syncline of the Rusånes area but weak in the upward facing continuation east of Saltdal. The major folds are not modified earlier folds and their character contributes nothing to knowledge of earlier deformation. On the whole the Rusånes rocks are poor in minor folds of any generation, including post-schistosity ones fitting the major folds. There is one good example, however, of a linear structure older than the Vatnfjell Nappe reoriented during the formation of the latter: the conspicuous lineation of the quartzite of the downward facing portion of the Southern Tverstifjell Syncline (0724). The lineation is a penetrative one defined by the lengths of muscovite flakes and the blade-like quartz crystals of the slightly micaceous quartzite.

The pattern of lineation and bedding poles in the Kvassteinhellaren subregion (0723) is shown in Figs. 7A and 7B. There is a tendency towards the pattern which a flattened flexural slip fold of a previously parallel lineated sheet would produce (Ramsay 1967), viz. lineations in the hinge zone lie nearer to the later fold axis than those in the limbs. Southwards in the southern limb the lineation trends about along the strike of the quartzite, say somewhat east of north, and not in the trans-orogenic direction of the Furu-

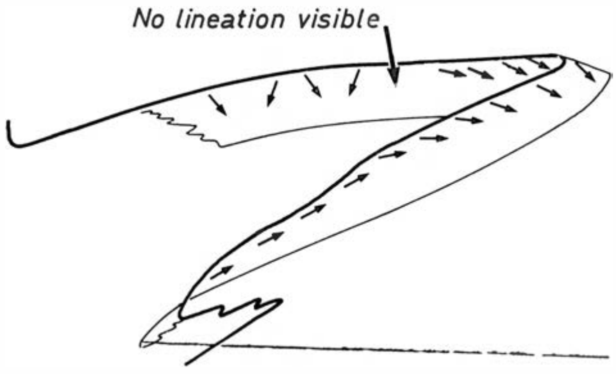

Fig. 8. Sketch of the downward facing Tverstifjell Syncline of the Kvasstein area showing general lineation pattern.

lund Group of the east side of the Baldoiavve outlier of the Sulitjelma Schist Group. This difference has regional interest as a transverse attitude is the expected one; not enough work has yet been done to explain this local relation or to use it in regional description (Nicholson & Rutland 1969, Henley 1970).

Lineation values in the southern limb of the Southern Tverstifjell Syncline change smoothly towards the hinge of the fold but in the north limb there is a section of quartzite without visible lineation (Fig. 8); over the gap there is change in attitude of the lineation from gentle easterly to steep. Since there is no known late structure in this gap it may perhaps be inferred that the variation is an early characteristic.

Although systematic thickness measurements of the bed of quartzite were not made it is known that thickness normal to the bed at the hinge is not much different from values on the south limb in general so that in this sense the fold has a character near to Ramsay's 1B class and thus one conceivably produced by flexural slip (Ramsay 1967). However, the quartzite of the north limb of the downward facing Southern Tverstifjell Syncline is everywhere thinner than the south limb; so also is the rest of the sequence stratigraphically above the biotite microline gneiss (Fig. 3).

Although the deformation episode in which the Vatnfjell complex formed has been described as post-metamorphic, that is not to be construed as implying its mineral grains show any degree of post-crystalline deformation; on the contrary quartz crystals are unstrained and polygonal and bent micas show an adjustment into separate and unbent parts filling the curve of the apparent one-time single crystal.

The problem of thinning sequences

The problems of the significance of variation in thickness of major rock units has been raised earlier by Nicholson & Rutland (1969). In a broad way westward thinning of the type shown in the Rusånes area is typical of at least the eastern half of the orogen, occurring both when the thinning sequence is involved in late folds, as here, as well as where folds do not occur as north east of Nasafjäll (Nicholson & Rutland 1969, Fig. 17), on the east side of the Rombak window further north (Kulling 1964) or around Börgefjell (Zachrisson 1969). Minor scale evidence is against the proposition that such pronounced thinning can form with the late folds described here which with their axial plane crenulation cleavage are superimposed on the already thinned and schistose sequence. The thinning has thus been ascribed to an early kind of plastic imbrication (Nicholson & Rutland 1969). This problem is complex and cannot yet be regarded as solved.

The highly schistose biotite microline gneiss of the Rusånes area may well be a deformed slice of basement; if this is so then its emplacement and the development of its complex relation with the Fauske Marble Group, and the attendant schistosity, are earlier than the Tverstifjell Syncline. Again there is no room for interpretation that would accept the Syncline, and the Vatnfjell Anticline, as contemporary with the thinning.

Finally it may be suggested as a digression that the gneiss, if basement, lies at some important break in the sequence which may prove to be the base of the Beiarn Nappe rather than the level speculatively chosen earlier (Rutland & Nicholson 1965, Fig. 8). Work now in progress by Mr. M. T. Styles in Beiardalen should help to settle the matter.

The Svartisen Fold Nappe

At the north east corner of the Svartisen Gneiss Dome (Fig. 9) there is a downward facing anticline which has a core of granitic gneiss where seen west of the ice-cap (Nicholson & Walton 1963, Fig. 4). The nappe-like fold deforms already schistose rocks; it also deforms isoclinal folds, some of large scale, to which that schistosity is axial plane.

As in Saltdal the fold nappe lies round a broader fold of the parent basal gneisses beneath; this fold was distinguished by Rutland & Nicholson (1965) as F3 of that area while the nappe was said to be F2. However, even this F3 fold was recognized as probably representing stages of uninterrupted folding from the F2 stage so that there as in Saltdal it seems that the antiform over which the fold nappe is draped grew with it.

Discussion of the formation of the fold nappes

The Vatnfjell Fold Nappe complex has been described and its similarities with the Svartisen Fold Nappe of coastal Nordland noted. Both consist of strongly non-cylindrical folds that become downward facing in terms of the earlier constructed regional sequence. The arcuate Svartisen Fold Nappe. however, lying round the north east corner of the Svartisen Dome, has a

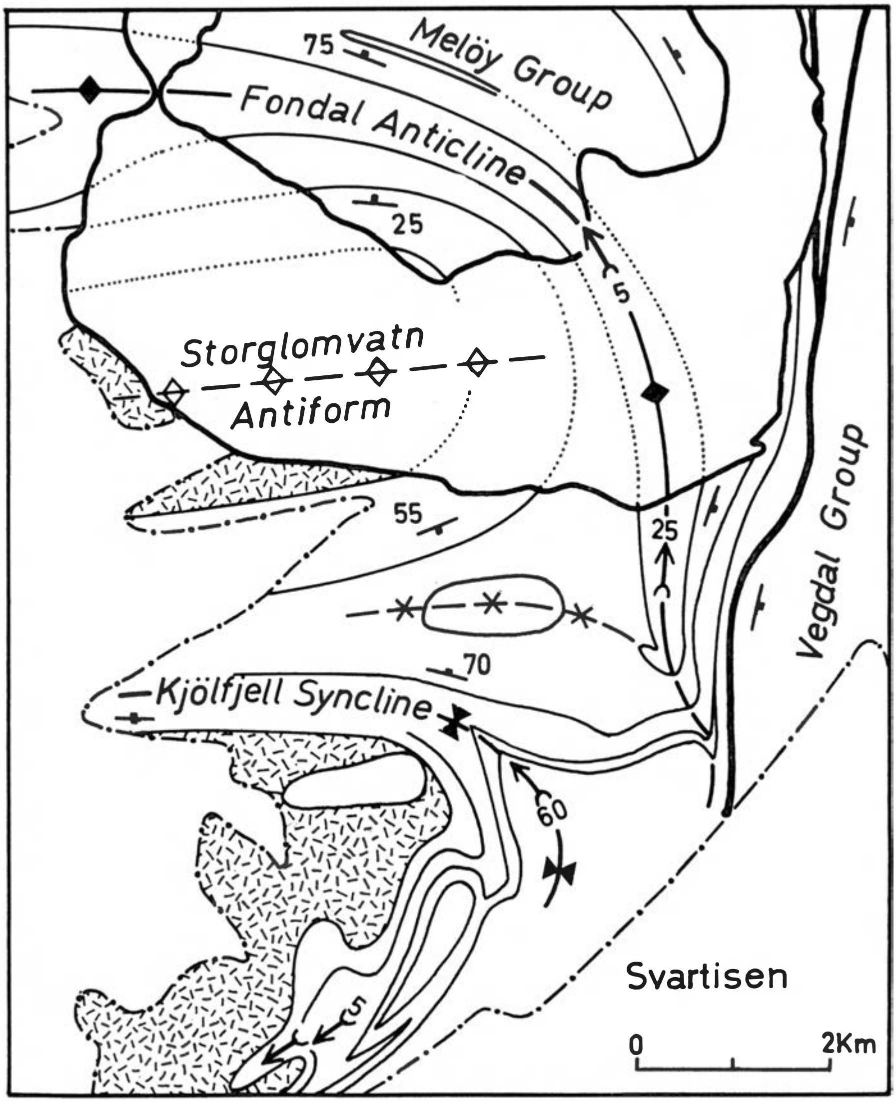

Fig. 9. Map of the north east corner of the Svartisen Dome (Fig. 1). Basal gneisses ornamented.

core of granitic gneiss even where downward heading. The Vatnfjell complex has no such core.

Structures like the Nordland domes and fold nappes are well known from regions with a granitic gneiss basement, perhaps most notably from the northern Appalachians (Cady 1969, Thompson et al. 1968). Many of the dome complexes described from outside the Scandinavian Caledonides, like those from Nordland, have been regarded as gravitational structures. Unlike those of east Greenland there is no sign of intrusion or metasomatism playing any role in the formation of those from Nordland (cf. Haller 1955).

The domes of Nordland have figured in tectonic hypotheses emphasizing the role of gravity in major orogenic tectonics (Ramberg 1967); that is, in the origin of deep-seated structures and not merely superficial ones. As we have seen the Nordland domes, etc., are post-schistosity and post-metamorphic structures. Thus they do not fit Ramberg's synthesis which requires them to be associated with the major strain producing episodes, including that which formed the schistosity.

Recognition of gravitational structures
In spite of Ramberg's attempts to provide a quantitative definition of gravitational tectonics (1967) it seems that we must still rely on geometric criteria for their definition rather than on the potentially more useful ones of kinematics and dynamics; clearly a deficiency in orogenic belts as here where it is not safe to ignore the possibility of the other sources of energy (as they may be ignored outside them, see for example Stephansson 1971). Suggestions of gravitational origin usually depend heavily also on the recognition of some light and relatively elevated rock body; so much so that structures of that type away from such situations may remain unrecognized.

In orogenic belts the configuration from which a structure grew is likely to be more or less obscure so that judgement as to whether or not Ramberg's gravitational potential (Ramberg 1967) has fallen is difficult to make. Since, also (Ramberg 1967) individual minor structures accompanying a gravitational feature cannot differ inherently from those produced in regimes of shortening or elongation produced in some other way, they cannot be used alone in distinction. The arrangement and the pattern built up by them, however, might be distinctive and contribute to the geometric argument. This has been emphasized recently by Fletcher (1972) who has suggested in addition that any concentration of deformation may indicate lesser viscosity (i.e. greater deformability) at the level concerned. However, as far as can be seen there is no concentration of deformation in the Nordland basal gneisses although the great differences of lithology and arrangment of rocks on the two sides of the gneiss/cover junction make comparisons difficult.

On the whole the level of erosion at Svartisen seems to reveal the top of the Svartisen Nappe Complex and not its flanks so that the component folds of the Complex, strongly affecting both gneiss and cover, are in this way not the flank folds of the reversed sense of vergence common to gneiss domes and anticlines. Rather the folds lie at the head of the gneiss body and seem explainable in terms of the restraint of the upward motion of similarly deformable buoyant gneiss and nearby cover against stiffer sequences above (Fletcher 1972).

In the Vatnfjell Nappe Complex the basal gneisses do not enter the recumbent part of the complex, a situation that may reflect the greater stiffness of the gneisses there, although cover/gneiss differences again cannot have been large in the neighbourhood of the junction as no concentration of deformation is visible there. On the whole, it seems as if it was the western limb of the Vatnfjell Anticline that sank while the eastern remained fixed so that the idea of upward motion and following sideways spreading of buoyant gneisses and their cover is less easily applied there than to Svartisen. An alternative of flow of the nappe into an actual depression cannot be allowed since the complex must have been deeply buried at the time of formation. Also since current ideas of the physical properties of rock do not allow turbulent flow in them the flow fold notions of Wynne-Edwards (1963) seem inapplicable.

It does seem possible that sideways flow off the Vatnfjell Anticline in a deformable cover sequence between stiff upper rocks, perhaps partly of the Beiarn Nappe which does not share the structures, and a subsiding western basement in the Saltdal depression, could have produced the flattening and western overturn apparently required for the Vatnfjell complex. This proposal has much in common with the intrastral flow of Rosenfeld (1968). Then the folds of the Fauske sector, parallel to one another, were formed in a tract of less active gravity flow where the depression between Vatnfjell Anticline and western elevations is arguably less deep than in the latitude of south Saltdalen. Thus less opportunity was provided in the Fauske area for the shear, westward overturn and amplification of folds forming near the gneiss-cover interface. Finally the general parallel trend of structures throughout the region may reflect larger scale shortening more regularly oriented than the local shortening of the fold nappes. This regional shortening in turn perhaps is the result of either similar gravitational motions on a still larger scale or perhaps more likely of regional shortening produced in some other way. Finally the presence of thick marbles may be important in concentrating deformation: explanations remain speculative.

In summary, the folds of the Vatnfjell Complex may owe their inception to regional shortening and their exaggeration beyond the shape of the contemporary folds of the Fauske region to the locally strong gravitationally driven flow. A similar birth for the Svartisen folds may also be applicable although their even more varied geometry at least suggests a more thorough modification in the gravitational movements. The complex deformation of the adjacent Sokumfjell Marble Group (Nicholson & Walton 1963) may be attributable also to the same drastic gravitational tectonics.

Gravitational tectonics in the orogen as a whole

Ramberg (1967, 1966) has already analysed the structures of the Scandinavian Caledonides in terms of gravitational tectonics and has compared the two rows of domes that the orogen seems to show, one about its centre and one in the west, with two buoyant ridges in certain of his centrifuge experiments whose position reflected the boundary of the deformation zone and the shape of the body capable of acting as source of upward flow. This is an interesting idea and would fit with the ideas developed here of post-schistosity domes.

It has already been pointed out that the east limit of domes in north Nordland about coincides with the east limit of a metasedimentary cover of high grade Caledonian character to its base, suggesting some temperature control of doming. However, it is not so easy to use the metamorphic character of the schist cover as a clue to temperature down to basement as tentatively suggested by Nicholson & Rutland (1969) since, for example, the low grade Köli region whose western edge about coincides with the dome limit is underlain itself by higher grade rocks to the east as is the Köli of Västerbotten (Zachrisson 1969). In any case the evidence of grade comes from the cover to basement and not basement itself and it is necessary before using it to judge whether or not cover was above basement at the stage of interest. Thus at the east edge of the orogen where crystalline Caledonian schists overlie rocks without Caledonian metamorphism the condition of the former is almost entirely irrelevant to discussion of basement temperature (it is relevant, of course, to the degree that a thrust cover insulates and gently heats a cold basement onto which it has been moved).

As we have seen the metamorphism of the Saltdal cover is earlier than the fold nappe formation and so not directly an indication of conditions at that time; since the metamorphism of the thrust rocks was earlier than their transport fold nappes and thrusting occur in the same time interval (no evidence is known to suggest that metamorphism across this part of the belt is not broadly coeval). That is not to say that there could not have been very large displacements at the basement/cover level at an earlier stage within the orogen but rather that the evidence for them is different and less easy to read than for the post-metamorphic transport evident at the edge.

It is possible the regional elevation of which the large central domes are witness is related in part to gravitational sliding to the east although as yet no relation between thrusting and position relative to the domes has been established. Then sliding could be a superficial equivalent to the deeper Vatnfjell flow structures. Finally it may be concluded that Ramberg's opinion (1967) that the penetrative extension fabrics, etc., of the Caledonian orogenic belt were produced by flow towards domal culminations of which the Nordland domes are examples is incorrect (cf. Ramberg, Fig. 105 with Fig. 1 of this account). It is possible that portions of the cover and basement deeper down that can at present be seen in the Bodö tract have undergone the kind of penetrative deformation that Ramberg has suggested is the general cause of such Caledonian fabrics. It does look, however, that the Nordland domes are too late and too small to be associated with the overall structuring of the orogen and that if such large scale gravitational movements as those Ramberg postulates did occur they were earlier. Then the seemingly obvious gravitational features, the domes, etc., are not relevant to any argument concerning early movements. And in any case a straightforward description of them in gravitational terms only as we have seen is not always easy.

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