THE SEDIMENTARY BRECCIAS OF THE SORJUSVANN REGION ON THE NORWEGIAN-SWEDISH BORDER NORTH OF SULITJELMA

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Nicholson R.: The sedimentary breccias of the Sorjusvann region on the Norwegian-Swedish border north of Sulitjelma. *Norsk Geologisk Tidsskrift,* Vol. 51, pp. 149–160. Oslo 1971.

The unit of granitic-gneiss-rich breccias and associated masses of coherent gneiss of basement aspect described by Kautsky (1953) as inverted but underlying a right-way-up sequence has been re-examined and is shown to be in stratigraphic relation with rocks above and probably right-way-up. It forms part of a sequence known to extend over some 700 km². The lithological character of the gneiss-breccia unit does not suggest long synsedimentary transport of its ingredients from source to accumulation area and its position high in the regional structure sequence must be the result of later movements, presumably on Kautsky's Gasak thrust.

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Introduction

The granitic-gneiss-containing breccia sequence of the Swedish Sorjusvann region was first described by Kautsky in 1953 as a part of a wide-ranging investigation into the structural geology of a tract on the Norwegian-Swedish border between latitudes 67° and 68°N. The sequence was described by Kautsky (1953, 97, 98) as two-fold, firstly a pale-coloured and coherent granitic-gneiss and secondly derived breccias, the pair being judged to be upside down now because coherent gneiss overlay breccias obviously derived from it. He suggested that the gneissic material was of Pre-Cambrian basement origin, its position high in the regional structural sequence being the result of movement on a thrust at the base of the breccias.

Re-examination of the Swedish occurrences and work on the Norwegian side of the border by the writer has convinced him that Kautsky was right in suggesting that the gneissic material is Pre-Cambrian. No evidence has been found, however, of Kautsky's supposed angular discordance between the breccia group and the rocks above; rather the two belong together forming part of a stratigraphic sequence which can be recognized widely over some 700 km². Although stratigraphic order is difficult to decide there is no certain evidence that the granitic-gneiss unit is upside-down and some indication of an indirect kind that it is right-way up (see p. 159).

The structural character of the base of the breccia unit is impossible to certainly decide on Sorjusvann evidence alone but it might well be a major slide since so many indications of various kinds throughout the region at this level suggest a thrust character for it (Nicholson & Rutland 1969, 63).

RELATION BETWEEN GRANITIC-GNEISS-CONTAINING ROCKS AND THOSE NEXT TO THEM

(a) Rocks above

Wherever exposed north of Sorjusvann the breccia unit has a black and slaty graphitic schist at its upper limit. Sometimes the black schist is itself finely conglomeratic. Generally it is a well-bedded rock with its fine-scale

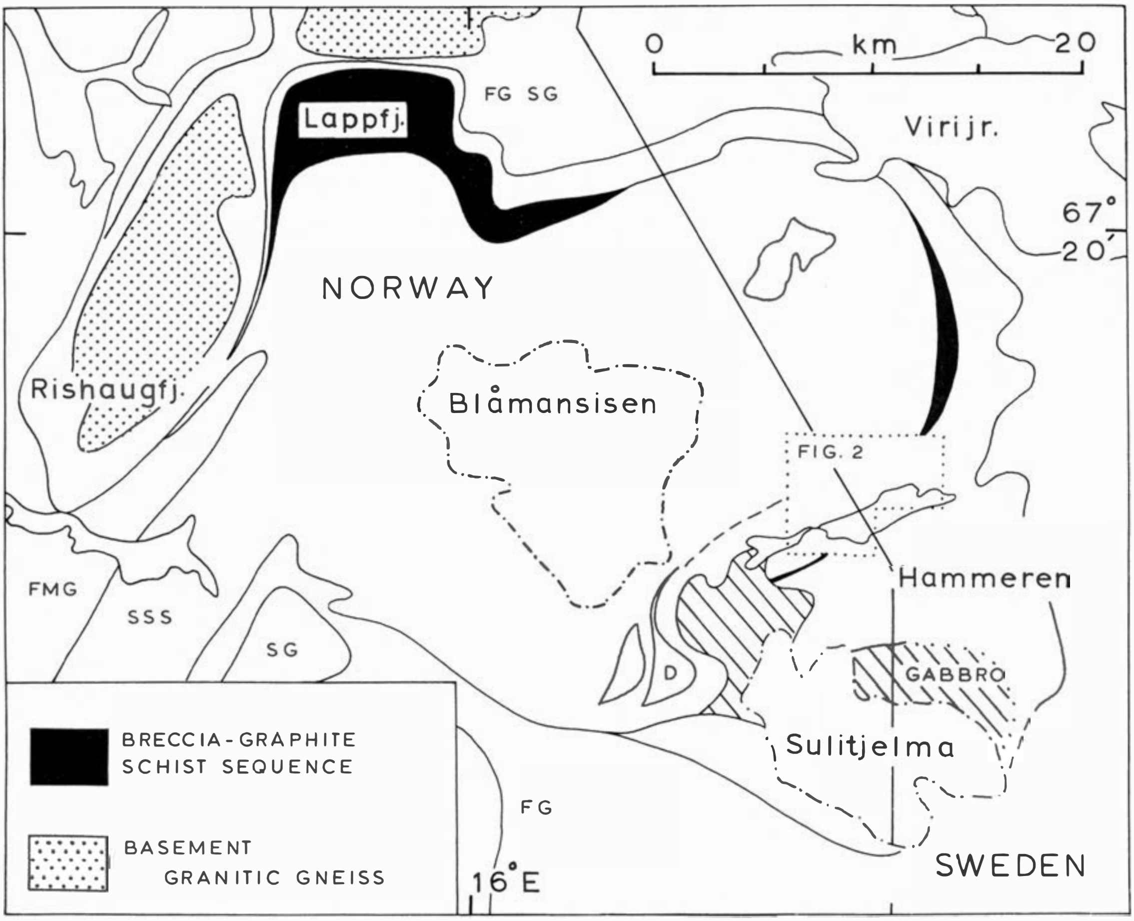

Fig. 1. Sketch map of some elements of the regional geology of the Sulitjelma region. Position of Fig. 2 indicated.

FMG Fauske Marble Group.
SSS Sulitjelma Schist Sequence.
FG Furulund Group.
SG Sjontså Group.
D Duoldagop.

bedding parallel to its contact with the breccia unit. Thus Kautsky's view that the gneiss-rich unit is separated by a strong angular discordance from the rocks above (Kautsky 1953, 97) does not seem to be correct. Furthermore, bodies of sedimentary breccia, rich in granitic-gneiss fragments, lie within the black schist itself, suggesting that there is a straightforward stratigraphic relation between this unit and the rocks below.

Kautsky (1953, 98) has suggested that the granitic-gneiss unit is inverted since a little east of the region described here he discovered coherent gneiss overlying gneiss-rich breccias. In a similar way a traverse along Sorjusvann eastwards from the west end of the lake (Nicholson & Rutland 1969, 47) takes one from the westward dipping top of a body of coherent granitic gneiss down into breccias. The precise junction, if one can be said to exist

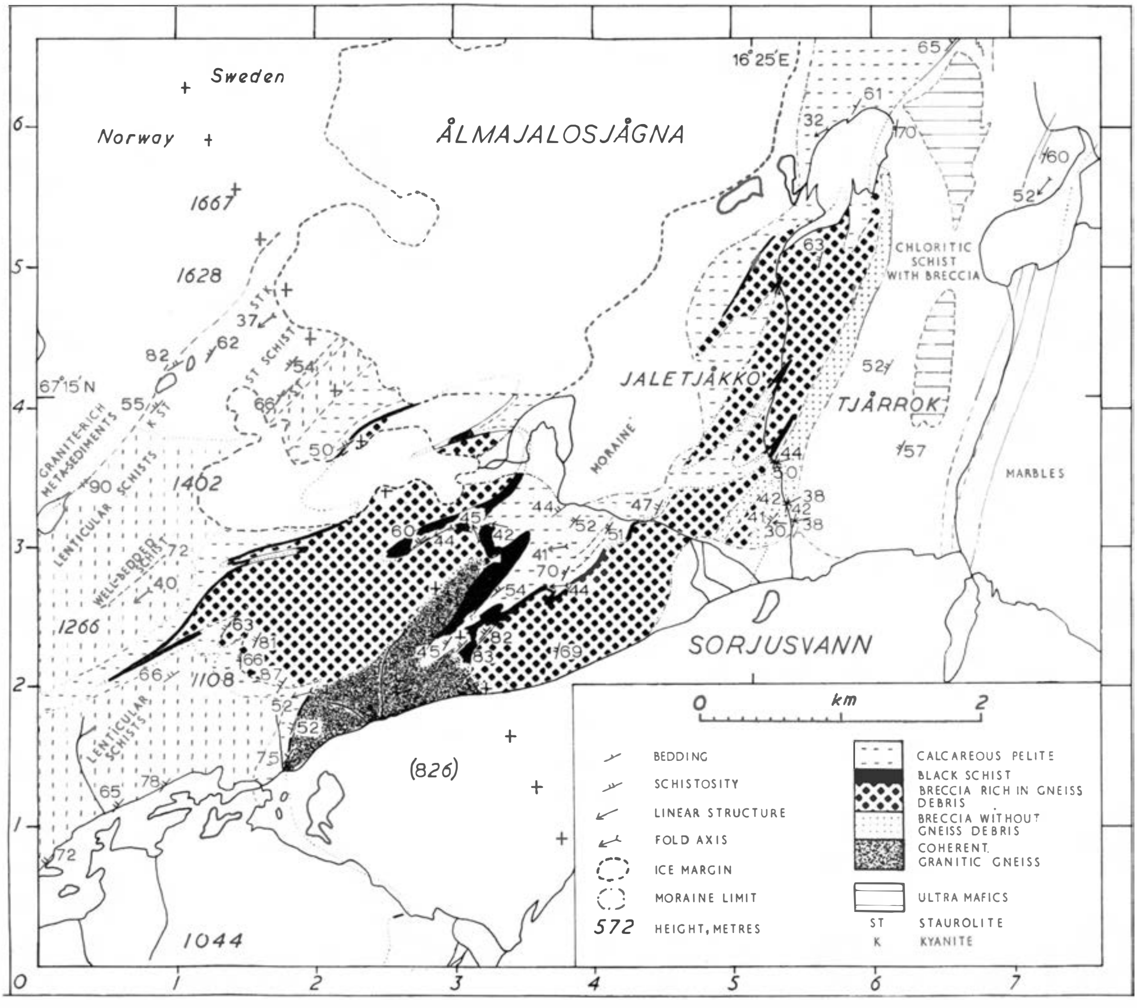

Fig. 2. Geology of the breccia region between Sorjusvann and Ålmajalosjågna on the Norwegian-Swedish border north of Sulitjelma.

between the gneiss and breccias, is not known (Fig. 2). For most of their extent in this region, however, coherent gneiss does not overlie breccia and it is more accurate to describe the coherent material as passing sideways into breccia rather than downwards. In addition both are contained below the generally thin black schist development (Fig. 2).

In the region described here the black schist in turn is always succeeded upwards in an apparently perfectly normal stratigraphic way by a generally muscovite-rich and calcareous pale-grey schist and then a semi-pelitic unit largely made up of lenticular decimeter and metre long bodies, all now ellipses with their long axes about along schistiosity, and possibly themselves once fragments of some kind. This lithology is also thinly developed at lower structural levels where it contains granitic-gneiss debris. Thus the granitic-gneiss-rich rocks seem to form a clear stratigraphic unit with the rocks above.

(b) Rocks below

Kautsky (1953, 96) has described the base of the fragmental unit in which the granitic gneiss lies as the site of a major structure, the Gasak thrust. North of Sorjusvann the rocks below this supposed thrust belong to Kautsky's Vasten Nappe and are green chloritic schists, apparently largely of sedimentary origin, with marbles beneath; ultramafic bodies and granitic lenses occur in the green rocks and granite in the marbles (Kautsky 1953, 78). In places, the contact between the granitic-gneiss unit and the green chloritic rocks can be fairly clearly seen (for example north of Tjårrok, Fig. 2) and is there sharp and apparently concordant with structures above and below.

According to Kautsky there are large-scale discordances where rocks above the Gasak thrust cut out at it, for example where the granitic-gneiss unit reaches towards Virijaure (Kautsky 1953, Tafel V). It is argued in Nicholson & Rutland (1969, 48), however, that there is a fair degree of lithological continuity north from Sorjusvann and west into Norway and that this supposed Virijaure discontinuity does not exist. There is no doubt, of course, that at the very least there are major variations in the thickness of the rock units of Kautsky's Gasak Nappe and that some units are absent around most of the Sulitjelma region, although other members of the sequence to which they belong are represented everywhere. These variations, however, are at a level above the supposed thrust.

(c) Summary

It seems certain as developed above, that the gneissic unit belongs in a stratigraphic sequence that in present-day order is as follows from the top downwards:

4. Semi-pelitic rocks of lenticular character locally including the development of the porphyroblastic staurolite and kyanite schists noted by Kautsky (1953, 101).

3. Calcareous muscovite schist often with discrete calcareous lenses and layers.
2. Black graphitic schists sometimes containing granitic-gneiss debris and other fragmentary material, and often well-bedded on a fine scale, lying just above the level of Kautsky's supposed angular discordance (above which upright rocks were supposed to occur with inverted ones below).
1. Breccia unit in part rich in granitic-gneiss debris; to the west the gneiss-rich rock grades into coherent gneiss (base not seen) but to the east is underlain by a development of breccia containing no granitic gneiss itself but including some of the other rock types of debris found in the gneiss-rich breccias. All lie on chloritic rocks and marbles.

Character of individual rock units

(a) The coherent gneiss

Where the coherent granitic gneiss shows minimum deformation there is a pronounced difference between the appearance of the sedimentary breccias derived from it and the coherent gneiss itself. Such rock is best seen at the west end of the coherent body (Fig. 2). There the coherent gneiss is a white rock flecked with dark micaeous aggregates of lenticular shape and parallel orientation. Its mineral components are quartz, sodic plagioclase, biotite and muscovite. As more easterly rocks are examined and as higher levels of the coherent gneiss are concerned (for instance along the stream over the series immediately west of the Norwegian-Swedish border) the rocks become more affected by the development of a flaser structure and the whole may begin to look fragmental like the sedimentary breccias. The flaser structure has been found only in the parent coherent gneiss and not in gneiss fragments derived from it. There seems little doubt that it is a Caledonian feature of the coherent rock, the sedimentary breccias deforming differently.

Usually the absence of anything but granitic gneiss in well-exposed and extensive outcrop-surfaces suggests deformed coherent material rather than sedimentary breccia (see p. 155). The difficulty of separation is most acute in the region of granitic-gneiss breccias of grid reference (3030) (Fig. 2). There, reasonably-sized areas of either sedimentary breccias or flaser rocks are easy to distinguish but it is not easy to draw a precise junction between them.

In spite of the general field distinctiveness of the so-called *coherent gneiss* all specimens collected from it proved to be finely crystalline when examined under the microscope. For the most part the rock is composed of large frayed and partly polycrystalline plagioclase surrounded by fine-grained quartz and mica. Although the granitic gneiss must be older than the sediments that cover it, this itself does not of course directly define it as Pre-Cambrian, for all that can be said at present of the sediments is that at least they seem very likely to be lower Palaeozoic. However, a Pre-Cambrian origin seems very likely as the rock has a distinct resemblance to the region-wide granitic basement.

(b) The breccias

Breccia description will be divided thus:

(1) main developments just north of Sorjusvann;
(2) the western area immediately north of the coherent gneiss near spot height 1108 m (grid reference 2025);
(3) the smaller north-western region also north of the coherent gneiss (3030).

Other developments shown in Fig. 2 are less well known.

(1) In the breccia unit in the region directly north of Sorjusvann there are two types of breccia, one rich in granitic gneiss and the other without it. As Fig. 2 shows, the breccia without granitic-gneiss fragments structurally underlies the other type in the eastern part of the unit and in fact a thin development of sediment without breccia lies between the two. The sharp junctions of the breccias with these sediments can be seen from the good exposures of a stream valley to provide no channel or other evidence of way-up (5335).

The lower series of breccias contains many bedded rock fragments some

Table 1. Fragment character.

Rock type	Debris present	Sources
Black schist	(1) granitic gneiss	Local, gneiss unit just beneath.
	(2) trachytic rock	Unknown.
	(3) graphitic 'pebbles'	Probably local, elsewhere get graphite schist layers at this level.
Breccia series	(1) granitic gneiss	Partly mantle gneiss of same kind, ultimate source possibly basement.
	(2) porphyry	Probably from the region of occurrence of the gneiss.
	(3) bedded calc-silicate	No known source even in main breccia.
	(4) bedded pebbly breccias	Source not known.
	(5) black garnet muscovite schist	Has some resemblance to black schist above the breccias but more massive and not fragmental.

of which themselves are breccias; conspicuous also are well-bedded dark schists, both types of rock being unknown elsewhere in the region. Generally the lower breccias have a greenish chloritic character absent above; fragments are moderately elongate in schistosity and sometimes define a fairly clear lineation in it. Fragments are usually rectangular in cross-section and, where bedded, usually elongate along their bedding. Since their original shape presumably also was rectangular it is difficult to estimate the amount of deformation they have undergone although its general flattening character about in bedding is evident.

In the granitic-gneiss-rich breccias only one rock type other than the granitic gneiss is common; a quartz feldspar porphyry. In some outcrops care has to be taken not to confuse this white-weathering porphyry with the gneiss. The former is dark when fresh, however, and porphyry fragments never seem to be as large as the granitic ones, rarely exceeding 2 cm across, while pieces of the gneiss commonly reach 5 cm or more in maximum diameter. More rarely pieces of greenish calc-silicate rock and biotite-rich schist occur with the granitic-gneiss debris.

In the development of the granitic-gneiss breccias west of the main glacial stream and nearer the exposed coherent gneiss (4328) the breccias are very rich indeed in the gneissic material. Here it is not easy to detect schistosity for the granitic fragments are not noticeably flattened and usually it is the rare much elongate biotite schist fragments that seem to betray the effects of deformation. Fragments of gneiss of distinctly oblong shape and a length of 10 to 20 cm and a width of 5 cm or so can be seen in section with their long axes at about right angles to the local schistosity attitude indicating either that the rock had undergone relatively little strain (as Kautsky has suggested, 1953, 138), or that in spite of being fragmentary it is physically homogeneous. On occasion bedding can be seen in the gneiss-rich breccias and in one case in the exposures west of the western glacial stream it seemed that bedding was parallel to the long axes of fragments. No sign of grading in the massive breccia was discovered.

(2) Like much of the more northerly developments of the granitic-gneiss breccias the 1108 region is lithologically more complex than those in the east. There occur breccias of hornblendic gneiss resembling the coherent hornblendic gneiss on the Norwegian-Swedish border just north of Sorjusvann, bedded psammitic rocks with large garnet segregations and also the common type of granitic gneiss. Similar rock types are developed south-west of the glacial lake which itself lies south-west of Jaletjåkko (3131) but not in the region around grid reference (3030) where only very granitic-gneiss-rich breccias are found.

(3) The smaller north-western region best illustrates the difficulty of separating coherent gneiss from breccias for there occur in its northern lobe both coherent gneiss with well-developed flaser structure and granitic-gneiss breccia very rich in the gneiss. Bedding is distinguishable in the breccias of the lobe itself where fragment elongation seems to be at an angle to bedding.

However, the evidence of the black schists just beyond the breccia limits seems to show that there schistosity follows bedding.

At grid reference (3129) there occurs the only area known that includes what might be regarded as fair evidence of the strongly diachronous development of a breccia margin. Bedding in both the schist beyond the breccias and even in the breccias themselves suggests that layering runs into the outer edge of the breccia.

(c) The black schist

The black schist marginal to the granitic-gneiss unit varies in thickness from one metre or so to outcrop widths of 200 m (in the latter case the sequence is much folded). As noted on p. 150 it is often clearly fragmental in part although usually finely well-bedded also. Fragments predominantly are rounded ones of graphite-rich material although occasionally scattered granitic-gneiss debris lies within the black schists. In one of these occurrences graded bedding was observed in schistose breccias indicating that the rocks there faced up toward the south-west (bedding-schistosity intersection 58/226, rocks right-way-up). As discussed on p. 158 interpretation of this facing evidence is not straightforward.

To the south of Sorjusvann the black schist of the upper margin of the breccia unit of Fig. 2 may be followed with interruptions into a substantial body that broadly strikes westward into the gabbro which it contaminates (Mason 1967, Fig. 2); note that the rocks in the Hammeren region marked there as possible amphibolite are the coherent hornblendic but pale-coloured gneisses of the granitic-gneiss unit as defined here.

As discussed above (p.151) the fine-scale bedding of the black schist seems to lie along the unit of schist and thus on the whole the contact schist/breccia probably is a time plane rather than a facies limit between rocks developed at the same time. As has been described, granitic-gneiss debris frequently occurs within the black schist but usually only on a minor scale; in contrast no graphitic schist has been found in the granitic-gneiss breccias which remain white and massive right up to their contact with black schist. From this relation and the absence of channelling or other signs of erosion of the black schists next to the breccias it seems reasonable to suggest that the main breccia may well be older than the black schists. Thus the structural sequence of the breccias and the rocks immediately above them may be right-way-up; the black schist defining the upper limit of the varied breccia unit here rich in granitic-gneiss material.

The black schist contains in addition to granitic-gneiss debris also pebbles of a relatively fine-grained acid-plagioclase-rich rock of volcanic appearance (an even-grained aggregate of lath-like plagioclase and nothing else). The porphyry which is so common in some of the granitic-gneiss breccias (p. 154) has not been found in it. If the interpretation of stratigraphic order made here is correct then one would expect that if there were a local source for porphyry debris it would lie at the breccia level and below the black schist.

No source is known north of Sorjusvann but one of the rocks illustrated by Kautsky (1953, Abb. 49) from his Gasak nappe on the south-east side of the Sulitjelma gabbro and south of Sorjusvann looks very like the porphyry from the granitic-gneiss breccias. Unfortunately, according to Kautsky (1953, 104) east of Staddajaure the porphyry overlies a development of the granitic-gneiss breccias.

(d) Calcareous muscovite schist and the lenticular semi-pelites

Neither of these types of rock will be described at any length as neither seems to contribute much to the understanding of the underlying breccias although it is clear that the muscovite schist is bedded parallel to its junction with the black schist structurally below. The lenticular semi-pelites are interesting in themselves primarily because of their odd structure. They appear to occur in the area described by Kautsky as formed of acid effusives (1953, 102). However, they seem to be sedimentary rather than volcanic; there are evenly bedded layers in them which often contain the conspicuous rounded graphitic 'pebbles' (first noted in Nicholson & Rutland 1969, p. 47), and have the same mineralogy as the lenticular material, viz. biotite, quartz, clinozoisite and acidic plagioclase.

Neither of these two schist types occurs on the north side of Blåmansisen (Fig. 1) although the lenticular rocks can be seen to fit into the Duoldagop sequence to the south-west along with a much reduced version of the breccias (no granitic-gneiss material). More detail of regional relations is given in Nicholson & Rutland (1969, 46–50).

SIGNIFICANCE OF THE SHAPE AND STRUCTURE OF THE GRANITIC-GNEISS-BRECCIA UNIT

As can be seen from Fig. 2 the granitic-gneiss-breccia unit has an odd shape. Clearly there are two possible sources of such complexity, firstly original shape (controlled by breccia accumulation) and secondly deformation effects. It is clear in the field (p. 156) that there is no direct evidence that one must accept that black schist is not the same age as adjacent breccia; bedding in the schist is parallel to its boundary with the gneiss and breccia. Such doubts seem to apply also to this explanation of the shape of the tongues of granitic-gneiss breccia on Jaletjåkko to the east. There black schist is known not only above and below the breccia 'tongues' but apparently also in folds of bedding between them (immediately on the east side of the glacial stream between Jaletjåkko and Tjårrok). Thus it is difficult to avoid concluding that the top of the breccia deposit is more or less a time plane through the region.

South of Sorjusvann more granitic gneiss is known west of Hammeren (marked as amphibolite by Mason 1967, Fig. 2). All of this material seems to be coherent but more hornblendic than most of the gneiss series further north.

The sedimentary evidence of stratigraphic order has already been discussed (p. 156). Unfortunately the one piece of graded bedding evidence available is difficult to use for although it indicates that the first folds face upwards to the south-west it does not give regional stratigraphic order as the shape of the minor fold in which it occurs is not known (schistosity is regionally parallel to bedding).

At least the long and narrow fold core of the north-west corner of the granitic-gneiss-breccia unit (1022, Fig. 2) seems likely to be an early fold while of the other two reasonably exposed broad bends of the upper limit of the unit at the west end of the body, the first (the north-eastern-closing lobe on the Norwegian-Swedish border, 3020) is clearly followed by schistosity while the second (the south-west directed closure just east of spot height 1108 m at the west end of Sorjusvann 1320) appears to trend across it. Thus beyond the western limit of the breccia unit in the 1108 m region occur lenticular schists in which bedding is very difficult to find and in which the dominant structure is parallel to schistosity, the structure running directly into the lithological junctions of 1108 m.

The detailed evidence is not available on which to decide fully the tectonic influences on the shape and structure of the gneiss body although if the stratigraphic conclusions suggested above are accepted in simplest fashion then some early hinge should lie within the northern breccia developments where they lie across the regional trend of schistosity and bedding. The weak internal deformation of the granitic-gneiss series, however, does not encourage the view that there is a major early structure there.

Origin of the breccia-gneiss unit

The major characteristics of the breccia unit may be summarized thus: –

(1) Forms the structural base of a stratigraphic assemblage of which some members are found widely over the north Sulitjelma region.
(2) Granitic-gneiss breccias contain only a few rock types other than the gneiss. The most common other type is a feldspar porphyry. Breccias are not well-bedded or sorted.
(3) Both the coherent granitic gneiss and granitic-gneiss-rich breccias have abrupt junctions with the black schists which lie structurally above them. The junction seems to be a time plane rather than a facies division.
(4) None of the rock types known from the sequence even just above the gneiss is known to occur in the gneiss breccias but granitic-gneiss debris does occur in small volume in the rocks structurally above the gneisses and gneiss breccias.
(5) If the black schist is accepted as simply lying stratigraphically as well as structurally above gneiss and breccia, then coherent granitic-gneiss both

overlies or passes sideways into gneiss-rich breccia as well as sometimes lying beneath breccia.

(6) To the east of the Sorjusvann region the lower part of the breccia unit is made up of gneiss-free breccias in which the porphyry known in the granitic-gneiss breccias is also found. In addition metamorphic grade falls from above the breccia unit to the chloritic rocks beneath and eastwards in the same fashion as described from the north side of Lomivann on the south side of the Sulitjelma gabbro (Nicholson & Rutland 1969).

The sedimentary characters listed above suggest that the breccia unit is not inverted. Because of this and because coherent gneiss at least sometimes *overlies* breccias rich in gneiss fragments, the coherent gneiss cannot be described properly as an inverted slice of basement with a debris cover (Kautsky 1953, 98).

However, the gneissic material clearly is not in its place of origin and as Kautsky first recognized, must have been transported to its present level in the regional sequence. Furthermore, and conveniently, there seems to be regional evidence of a tectonic junction between the sequence to which the gneiss, etc. belong and the rocks below (summary of evidence in Nicholson & Rutland 1969, 58–63). The presence of the break eliminates the rocks below the gneisses, etc. as sources of evidence concerning their early history and accordingly they have been noted only here.

The relation between the gneisses, etc. and rocks above suggest the two belong stratigraphically together. However, the presence of large bodies of gneiss more or less surrounded by debris raises the question as to whether or not the early movement of the gneissic material to its place in the sequence could have been during sedimentation processes rather than later. However, the unsorted character of the breccias as well as the presence of the large gneiss bodies suggest little transport during the formation of the rock although they do suggest some sedimentary slide character. Accumulation may well have been more or less in the parent basement area. Thus, although the gneiss and breccias may well lie immediately above an important thrust the lithological character of the assemblage has nothing to do with thrusting. As a penultimate sentence it may be added that a fragmental rock rich in granitic rock of basement type like that at Sorjusvann was discovered in the summer of 1970 on the east side of the Nasafjäll basement massif there forming a part of the massif. Although no detail is yet known of the Nasafjäll occurrence its discovery adds weight to proposals that the Sorjusvann assemblage also is of basement origin and isotope studies on the latter by Dr. M. R. Wilson but as yet unpublished also suggest a Pre-Cambrian age for the gneissic rocks (personal communication).

ACKNOWLEDGEMENTS. I am grateful for help received from Dr. G. Kautsky and Dr. D. G. Gee of the S.G.U. I also wish to thank Mr. M. Morey of

University College, London, who as an undergraduate mapped part of the region described here, and whose map I consulted, and also Dr. J. M. Anketell with whom I had some instructive discussion on the sedimentary character of the breccia deposit.

I am grateful to the University of Manchester for a grant to undertake work in North Norway of which that reported here is a part.

REFERENCES

Kautsky, G. 1953: Der geologische Bau des Sulitjelma-Salojauregebietes in den nord-scandinavischen Kaledoniden, *Sveriges geol. undersökning, Ser. C, No. 528.*

Mason, R. 1967: The field relations of the Sulitjelma gabbro, Nordland. *Norsk geol. tidsskr. 47,* 237–248.

Nicholson, R. & Rutland, R. W. R. 1969: A section across the Norwegian Caledonides, Bodö to Sulitjelma, *Norges geol. undersökelse, No. 260.*