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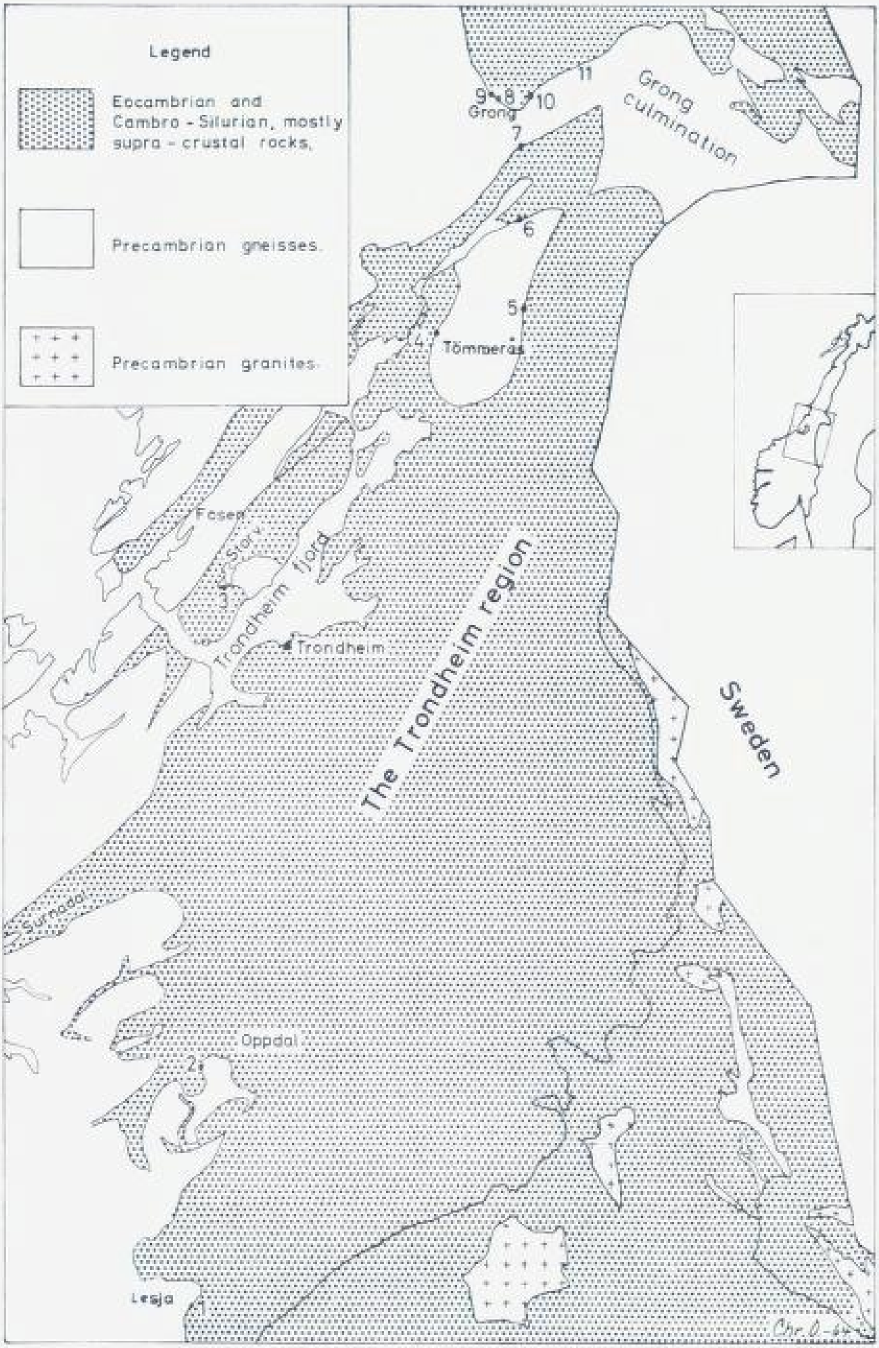
Legend
Eocambrian and Cambro - Silurian, mostly supra - crustal rocks.
Precambrian gneisses.
Precambrian granites.
Grong culmination
Grong
Tömmerås
Fosen
Trondheim fjord
Trondheim
The Trondheim region
Sweden
Surnadal
Oppdal
Lesja
Chr. O-64

Fig. 1.

THE NATURE OF THE BASEMENT CONTACT.

By *Christoffer Oftedahl.*

Abstract.

The gneisses below the Cambrian schists or Eocambrian flagstones in the central Norwegian Caledonides have been considered of Precambrian age, but the fact that the contact is always concordant has been explained as due to Caledonian tectonization. The author describes shortly a number of localities of this contact and concludes that a more likely explanation is that the rocks are really close to concordant, e.g. the Precambrian rocks within the Trondheim region were essentially flat-lying at the begin of Cambrian time.

Introduction.

In the last century the contact between the Precambrian basement and the overlying sediments of Eocambrian or Cambro-Silurian age presented no serious problem to the geologists. The Trondheim region (Fig. 1) and its continuation through Jotunheimen, Sognefjord and Hardangerfjord was considered as the main Caledonian zone. Southeast of this zone a very marked angular unconformity was known. The gneisses northwest of the zone were considered to be of Precambrian age. This situation lasted until the 1930 years, when O. Holtedahl in several papers took up the problem, see the summary by Strand (1960, p. 230—235). The most important conclusion was that the northwestern gneisses (western part of Fig. 1) represent a mixture of older Precambrian basement and highly metamorphosed (eventually granitized) Cambro-Silurian rocks, all rocks now showing Caledonian metamorphism.

The rocks overlying the Precambrian basement gneisses consist either of Cambro-Silurian sediments, mostly of some Cambrian age, and arkoses, the so-called sparagmites. The latter rocks have a lowermost Cambrian or uppermost Riphean age or both ("Eocambrian"), depending on definitions used. In the area west of Oppdal the gneisses are overlain by a flagstone belonging to the sparagmitian complex and in this area O. Holtedahl (1938) made his field observations which led to his general conclusions. Holtedahl also observed that besides being folded together with Eocambrian and Cambro-Silurian sediments, the basement gneisses had a conformable contact to the younger sediments. This presented another major problem to him, and his interpretation was that since there is no angular unconformity, the concordant gneisses necessarily have to be sparagmitic flagstones granitized or migmatized by the "caledonization" of all rocks involved. This process of caledonization produced what Holtedahl called "basal gneisses" and the importance of these basal gneisses were emphasized by Strand (1960, p. 230—245) in his summary of the Norwegian Caledonides by specifically describing "the region with basal gneiss in the northwestern part of southern Norway".

The present author has his main field experience within the Norwegian Caledonides from the Grong area, but has made more cursory observations in many other parts of the Caledonides. The contact relations were studied in a number of localities, and the obtained observations on the schistosity and layering of the Precambrian concordant with the overlying metasediments suggest clearly that the layering is a primary feature. This means that the Precambrian rocks were essentially unfolded when the Cambrian beds were deposited in the central part of the Norwegian Caledonides. It is rather surprising that this view has appeared as an alternative working hypothesis only shortly mentioned in one paper (Strand, 1949, p. 32).

In the following observations from 11 localities are shortly described, then the results are discussed.

Observations.

1. *Lesja.* 5 km SE of Lesja the contact is observed in the mountains. The best exposure has only the five meters of the very contact lacking. Here beds of flagstone steeply dipping to the west are overlying finegrained and schistous leptite. The structure is interpreted as a primary sedimentation feature. T. Strand (1949, p. 31—32) has studied this area by survey field mapping and thin section work. He is the first who has considered both possibilities for explaining the banded character of the gneisses: "The banding of the gneisses can be interpreted in more than one way, the interpretation of the banding will imply also an interpretation of the genesis of the rock. Thus the banding may be a primary feature . . . In other cases the banding may recall banding in a supracrustal rock (Figs. 2,3). In this case the banding may be

influenced by the metasomatic processes or by metamorphic diffusion within the rocks, still it may be a structure prescribed by the bedding." Later Strand (1951, p. 13) published the following statement concerning the basement contact from Lesja southwards to Otta-dalen: "The gneisses have sharp contacts to the overlying sparagmites, but there is no unconformity at the contact."

2. *West of Oppdal.* Along the main highway from Oppdal westwards granitic gneisses are beautifully exposed in long road cuts west of Lønnset (see Holtedahl, 1938, p. 34—41). The banding looks distinctly sedimentary and is parallel with the bedding of the overlying sparagmitian flagstones. Holtedahl's interpretation was that the gneisses represent metamorphosed (and granitized) Eocambrian sediments. Rosenqvist (1944, p. 123) thinks that the conformity must be a pseudo-conformity and that all structures are Caledonian in origin. The interpretation that the gneisses are Precambrian with their primary features retained, is offered as an alternative explanation.

3. *Storvatnet.* On the southwestern side of Storvatnet, 20 km NW of Trondheim, both the Precambrian gneisses and the overlying Cambrian micaschists are well exposed in long road cuts, although some hundred meters are missing in the contact zone. The strike is persistant and parallel in both complexes, so that a rough parallelism in undoubtful. The gneisses consist of a mixture of finegrained leptitic bands, mediumgrained granitic gneiss and augen-gneiss. Persistant dark schlieren and amphibolite zones with thickness up to one meter lieve little doubt that these planar features which are parallel to the general schistosity represent the primary bedding of the gneiss complex. The area around Storvatnet has not been spesificly described earlier, but the area immediately to the west has been studied by Ramberg (1944). Here gneiss cores are conformably underlying metamorphosed sediments of Cambro-Silurian age, and the cores are interpreted as zones where the migmatite front has risen much higher than in the Synclines. The author prefers a purely stratigraphic interpretation. Then the gneiss anticlines should be basement anticlines where leptites have recrystallized to granitic gneisses of various kinds during the same metamorphism that altered the overlying Cambro-Silurian rocks.

The Tømmerås anticline consists of more or less leptitic rocks. The author thinks he has observed what looks like parallel contacts at localities 4, 5 and 6. This is in a general way verified by Dr. Janet S. Peacey (see her article in this volume).

7. *Agle.* About 1 km south of Agle station a long railroad cut exposes the contact between leptitic gneisses and overlying Cambro-Silurian micaschists. The leptite beds are parallel with the overlying micaschists. The upper two meters of the leptite are schistous and contain feldspar porphyroblasts, 2—3 cm in size, while the underlying leptitic gneisses contain more scattered and smaller porphyroblasts. In a small road cut close by, however, there seems to be a clear angular unconformity between the two complexes. More extensive field investigations are necessary in order to find out if this is a strictly local phenomenon or is more regional.

8. *Grong station.* 1.0 km north of Grong railroad station the contact between Precambrian and overlying younger rocks is exposed over a flat area of elevation 275 m. Below the micaschists there is a transitional zone which is usually a few meters thick. Both in the transitional zone and the underlying regular granitic gneisses the foliation is parallel to that of the overlying micaschists. Since the gneisses are rather homogenous without clear bedding features, one might well suppose for this locality that the foliation could be of secondary origin.

9. *Medjå Bridge.* This locality is mentioned rather because of easy access. Road cuts at the main northern highway and exposures along the adjacent River Namsen show highly deformed and folded gneisses and overlying micaschists. Although there is no knifesharp contact to be inspected, there is parallelism between the micaschists and the underlying granitic gneisses, where aplitic to felsitic leptite beds are still visible.

10. *East of Formofoss station.* A very instructive section is found along the creak that runs down to river Sandøla just west of Trangen, ca. 5 km northeast of Formofoss station. The Precambrian consists of thick beds of red leptite, forming beautiful steps in the landscape with thickness 1—2 meters. Between the beds are found layers of hornblende schists to micaschists of thickness 10—100 cm. These beds, as well as the bedded appearance of the leptite, are considered indicative of primary sedimentary bedding. Only occasionally traces of Caledonian metamorphism is seen, in the form of feldspar porphyroblasts in size up to 5 cm. The beds have a constant strike and dip, and although the stratigraphically most important 20 m of the contact are lacking, it is easily seen that the regional strike and dip of the overlying micaschists is the same as in the leptite.

11. *The Grong culmination.* The Grong area and the Precambrian of the Grong culmination is well known from the geologic maps of S. Foslie. From his own field work in this area, the author finds that much larger areas than those mapped by Foslie as containing leptite or quarz porphyries may be seen to have consisted of such rocks, although Caledonian recrystallization has transferred them in part to fine-grained or medium-grained gneisses or augen-gneisses. In general the author finds that there is a marked conformity between the bedded leptites and the overlying phyllites or micaschists throughout the Grong area. This is most beautifully seen in the Sandøla River Valley (Loc. 11).

From the literature only one paper should be cited, otherwise the reader is referred to the survey by Strand (1960, p. 230—245). The Surnadal Syncline culminates a little west of the area shown by Fig. 1, and further west the so-called Molde-Tingvoll syncline is mapped and shortly described by Hernes (1955). The most striking feature is that the syncline of greenstone and micaschists of undoubtedly Cambro-Silurian age is underlain by a huge syncline of Precambrian gneisses with no unconformity anywhere. All gneisses show more or less marked sedimentary features. Although the features indicative of a primary or a secondary origin of the concordant basement schistosity are too shortly described, both modes of origin seem possible in this area.

Discussion.

Three viewpoints seem to be responsible for the fact that the previous authors have been so reluctant to discuss the concordant basement contact as possibly primary. The first is the view that a typically granitic gneiss is mostly formed by complex metamorphism and granitization of older rocks. But waterlain pyroclastic tuffs and tuffites of some granitic composition or other form a very common group of rocks in the Precambrian. This is recognized long time ago i Sweden, where they are mostly called leptites, but much less so in Norway. When such rocks are exposed to regional metamorphism, they recrystallize very easy to form granitic rocks with banded appearence.

Secondly it is assumed that the Precambrian rocks in the Norwegian Calendonides got a completely new Caledonian structure during the main Caledonian orogenic phase. But the author thinks that it is necessary to distinguish rather carefully between the secondary schistosity or foliation of a gneiss and its layering or banding. Only a minute differential movement may be necessary to produce a completely new mineral orientation within a gneiss, whereas very extensive plastic flow with differential flow gradients between 10 up towards 100 or more may be necessary to change one heterogeneous rock into another with a new and tectonic layering which looks like sedimentary bedding. There is no need to go into any detail on these problems, because they are excellently treated in a recent publication by J. A. Redden (1962), and only one sentence needs to be quoted. After interpreting sharply banded and layered gneiss rocks as meta-sedimentary, Redden states: "I believe the burden of proof must be on the geologist who contends that such structures are *not* bedding." From Norway there is only one good description of a clearly Caledonian deformation of the Precambrian. From the southwestern part (Hardangerfjord) Kvale (1945, p. 15) has described a locality where a tectonic schistosity is seen in Precambrian quarzite. This structure may be seen many hundred meters down in the Precambrian, but the origional bedding is still clearly preserved.

Third is the view that Precambrian rocks must be folded. However, considerable areas in adjacent Sweden are covered by virtually flat-lying and unfolded Precambrian, called Sub-Jotnian Dala porphyries, Jotnian Dala sandstone, and Olden porphyries.

Much more field work is necessary in order to arrive at a certain conclusion, but in view of the fact that only the basal gneiss hypothesis is mentioned in general treatises like "Norges geologi" by O. Holtedahl (1953) and "Geology of Norway" (Chapter on Caledonides by T. Strand (1960)) it seems justified to the present author to advance a tentative hypothesis as the more likely conclusion, namely that the basement contacts of the central Norwegian Caledonides are what they look like, namely concordant. More explicitly expressed, this means that the Precambrian rocks were essentially flat-lying and unfolded at the begin of Cambrian or Eocambrian sedimentation. This hypothesis covers the Caledonides from Ottadalen in the south to the Grong culmination in the north, a distance of 350 km. Even if the assumption by Holtedahl (1938) that the gneisses underlying some of the flagstones are Eocambrian in origin, they again have a basement contact which seems to be concordant.

The problems discussed have only been treated in one paper and with a result which is completely opposite to the hypothesis here presented. Birkeland (1958, p. 412) reports that "the junction between the basement complex and the overlying formations could in many cases be readily recognized as an unconformity ...". This unconformity also appears in his general map, but there are no descriptions of localities where such unconformities may be inspected. Until such descriptions have been published, the author thinks that Birkeland's conclusions are wholly unsubstantiated and can be overlooked.

If the advanved theory proves to be probable by further work, the consequences to Precambrian geology are quite important. The flat-lying Precambrian complex consists mostly of leptitic rocks with quite small admixtures of ordinary clastic sediments. The leptites may be waterlain pyroclastic sediments or in cases also rhyolitic lava flows. In the Grong area the leptites continue into the Olden porphyries. As to the southern half of the Trondheim region, it seems natural to consider the originally flat-lying Precambrian to represent a continuation of the Dala porphyries. Recently the age of the Dala porphyries as well as the Olden porphyries has been increased from the earlier 700–800 mill. years to at least 1200–1300 mill. years (Magnusson, Lundqvist, and Regnéll, 1963, post-printed addition). Possibly the Dala sandstone may have an age approaching 1600 mill. years (Geijer, 1963, p. 134). However, the suggested comparison may be erroneous, because there is no trace of the Dala sandstone in the leptitic gneisses in the southern Trondheim region. Anyhow, if the hypothesis of flat-lying Precambrian between Ottadalen and the Grong culmination is accepted, it is clear that this area was not hit by a later Precambrian orogenesis. This means that the Gothian (Dalslandian) orogenic zone in Sweden and the Gothian or "Telemarkian" orogenic zone in southern Norway trends southwest of the said area,[1]) whereas the Sveco-Fennian zone of middle and northern Sweden trends northeast of the area or below the rocks of the said area.

The problems discussed for the central Caledonides also exist for the northern part. Thus there is a clear angular unconformity between the Precambrian and overlying Cambrian in the Rombak window, 20 km east of Narvik (Th. Vogt, 1941). But the basement only 35 km west and southwest of Narvik is concordant in nature, the problems of which have been discussed by Foslie (1941). Even here a primary concordance may be assumed.

[1]) Note added in proof. — This is recently confirmed by I. McDougall and D. H. Green (Norsk Geol. Tidsskrift, vol 44, 1964, p. 183—196). They find that two classical eclogites from Sunnmøre seem to be 1800 m.y. old, with metamorphism probably at 900—1100 m.y. and certainly at 400 m.y.

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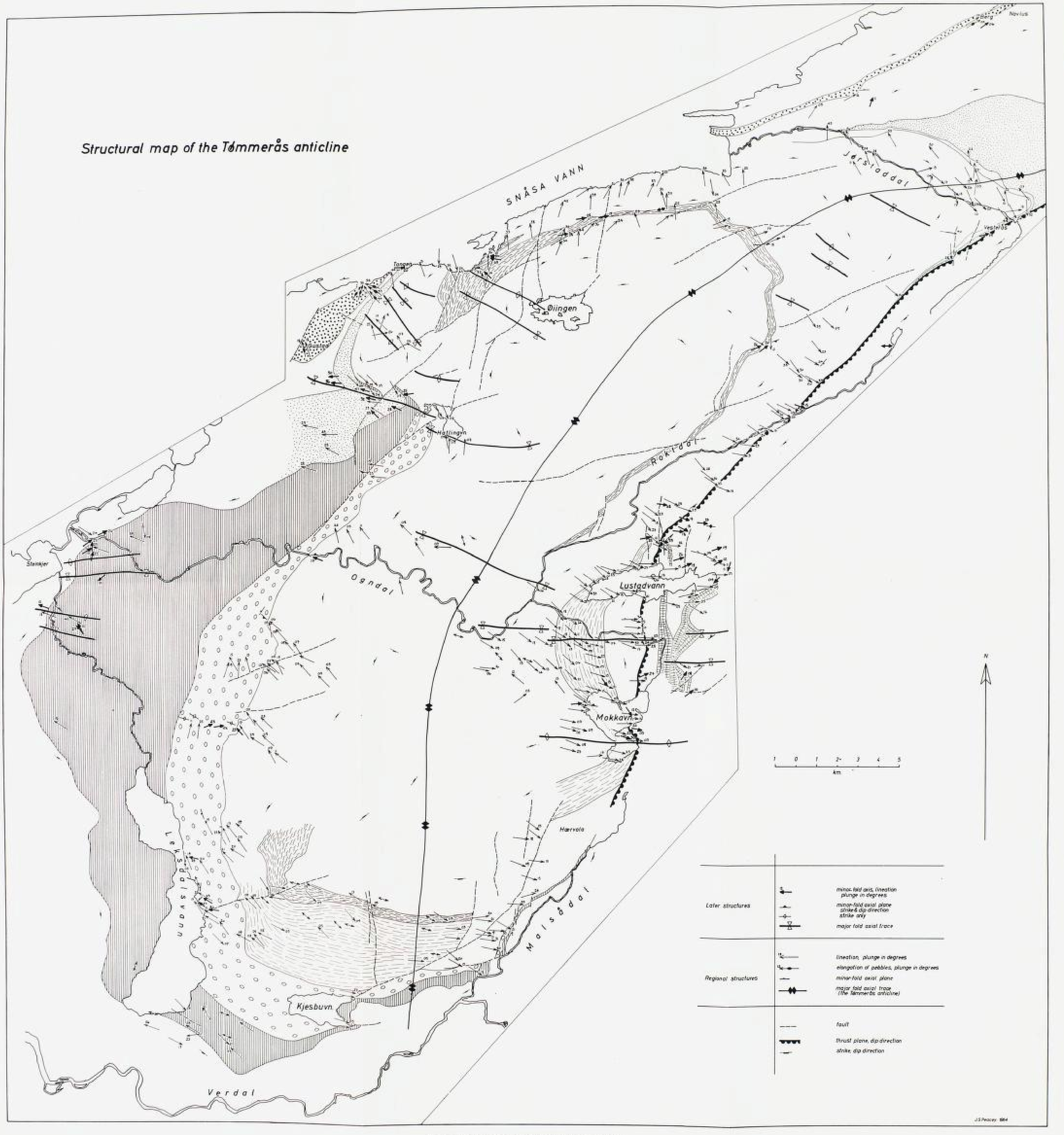


Fig. 33. Structural map of the Tømmerås anticline.

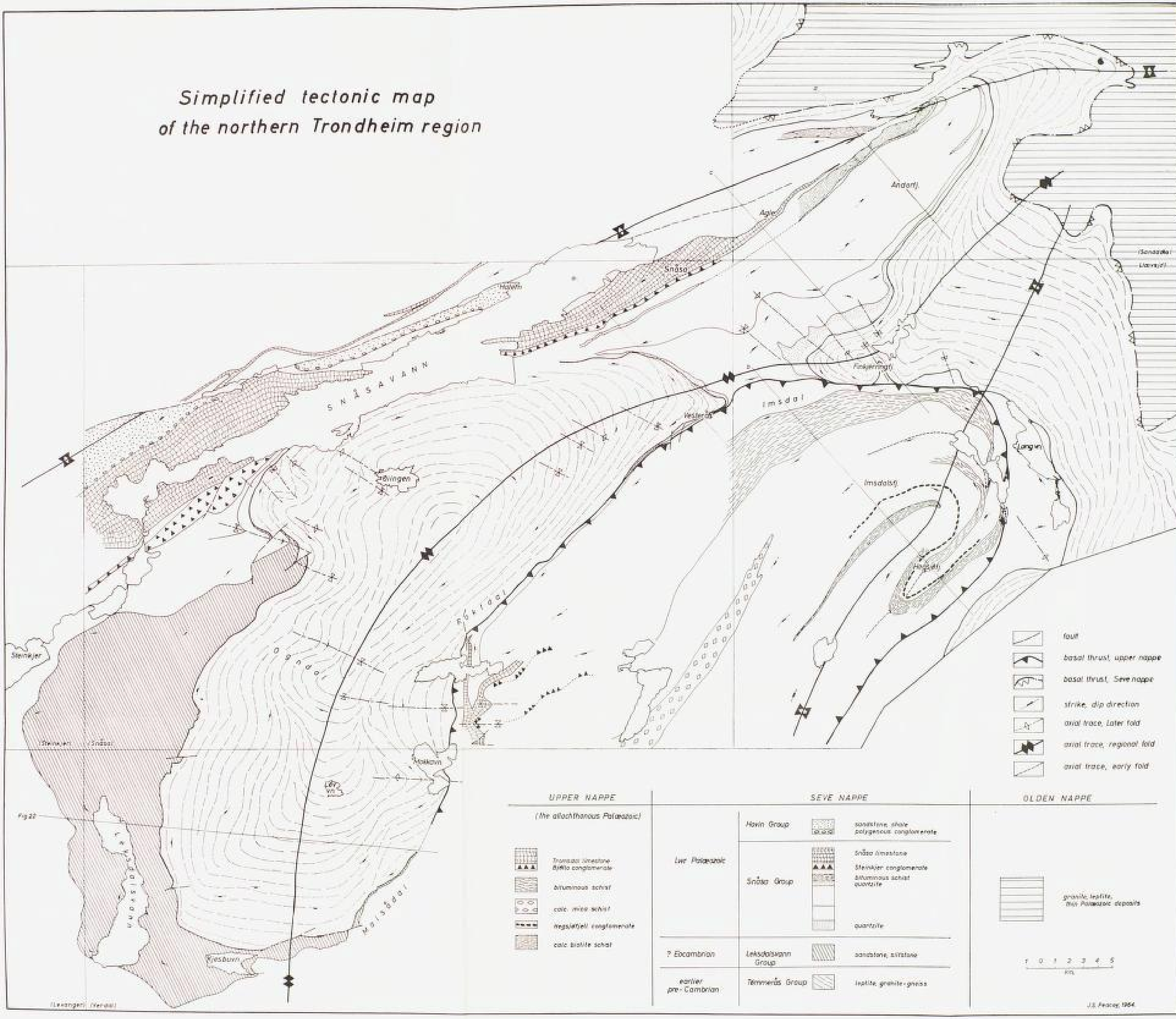


Fig. 34. Simplified tectonic map of the northern Trondheim region.

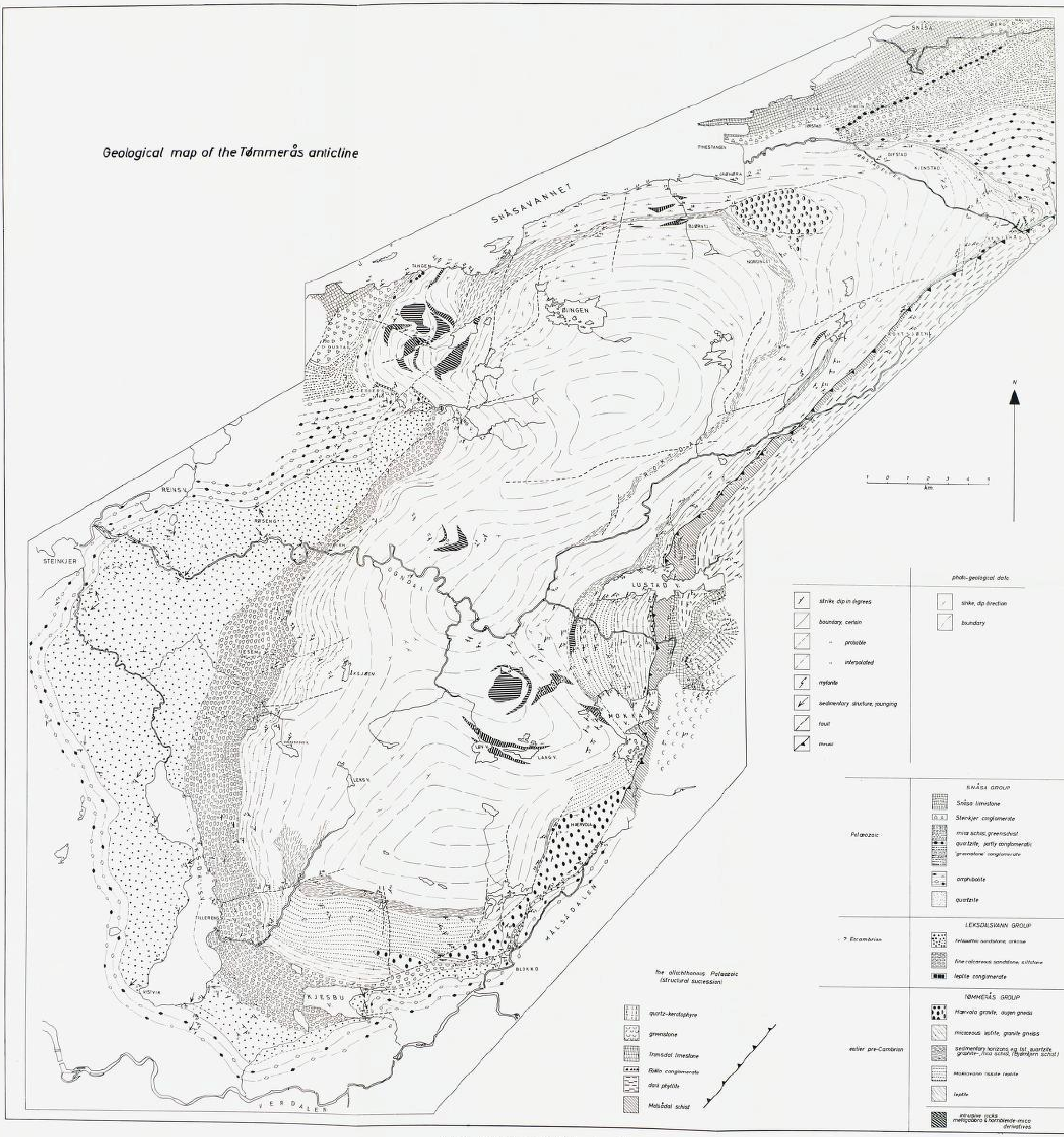
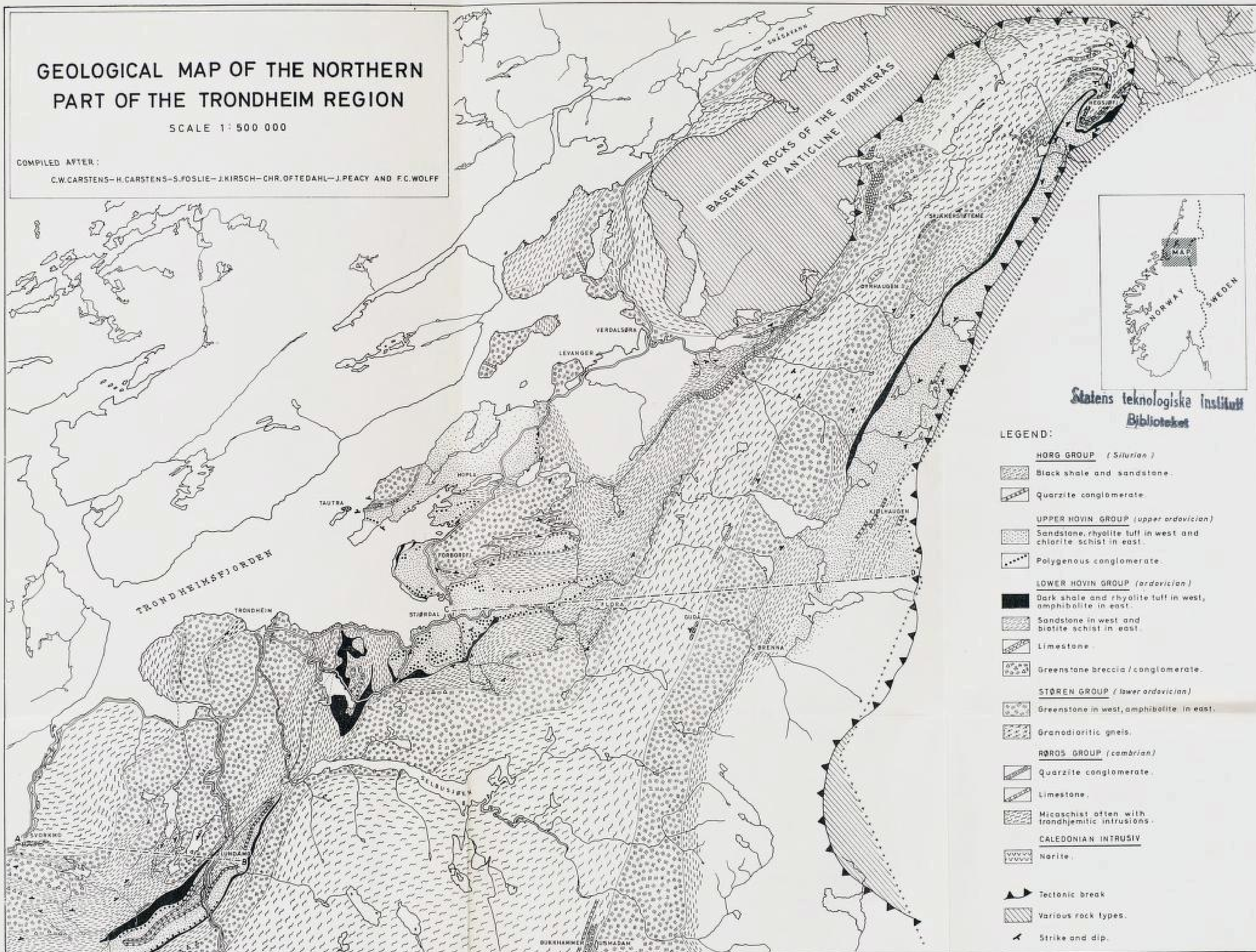


Fig. 32. Geological map of the Tømmerås anticline.


GEOLOGICAL MAP OF THE NORTHERN PART OF THE TRONDHEIM REGION
SCALE 1:500 000
COMPILED AFTER:
C.W.CARSTENS–H.CARSTENS–S.FOSLIE–J.KIRSCH–CHR.OFTEDAHL–J.PEACY AND F.C.WOLFF
BASEMENT ROCKS OF THE TØMMERÅS ANTICLINE
VERDALSØRA
LEVANGER
HOPLA
TAUTRA
TRONDHEIMSFJORDEN
TRONDHEIM
STJØRDAL
FLORA
GUDÅ
BRENNA
KJØLHAUGEN
SELBUSJØEN
LUNDAMO
MAP
NORWAY
SWEDEN
LEGEND:
HORG GROUP (Silurian)
Black shale and sandstone.
Quarzite conglomerate.
UPPER HOVIN GROUP (upper ordovician)
Sandstone, rhyolite tuff in west and chlorite schist in east.
Polygenous conglomerate.
LOWER HOVIN GROUP (ordovician)
Dark shale and rhyolite tuff in west, amphibolite in east.
Sandstone in west and biotite schist in east.
Limestone.
Greenstone breccia / conglomerate.
STØREN GROUP (lower ordovician)
Greenstone in west, amphibolite in east.
Granodioritic gneis.
RØROS GROUP (cambrian)
Quarzite conglomerate.
Limestone.
Micaschist often with trondhjemitic intrusions.
CALEDONIAN INTRUSIV
Norite.
Tectonic break
Various rock types.
Strike and dip.