On "The nature of the basement contact".

Critical comments on Chr. Oftedahl's paper in Norges geologiske undersøkelse. Nr. 227, 1964.

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The theory put forward in a recent paper by Chr. Oftedahl (1964) is controversial to the results of the extensive field studies done by several geologists. A few critical comments should be necessary in order to avoid a profound misunderstanding of the nature of the problems presented.

Incidentally, the paper by Chr. Oftedahl concerns the contact, or the absence of a contact, between the high-grade metamorphic sediments of "Infra-Cambrian" or Cambro-Silurian age and the "basal gneisses", including also a discussion of the origin of the gneisses below this contact.

In his abstract Oftedahl mentions the structural conformity between the Eocambrian flagstones (or Cambrian schists) and the gneisses below. He states that "the contact is always concordant" and that this "fact . . . . . has been explained (by earlier geologists) as due to Caledonian tectonization". Against the earlier view Oftedahl concludes that the Precambrian rocks (i. e. below the flagstones) "were essentially flat-lying at the begin of Cambrian time". In other words, he regards the conformity as primary, and he even thinks this hypothesis to be valid for the grater part of the central Caledonides in southern Norway.

Apart from the fact that the contact is *not* concordant everywhere, Oftedahl disregards the possibility that the conformity may be secondary, due to high-grade metamorphism. He does not seem to be well acquainted with the actual relations over large and important parts of the central Caledonides, namely in the Oppdal–Surnadal district, though many of his references concern this district.[1]

[1] See note on the next page.

The structural conformity (in general) between the basal gneisses and the overlying flagstones (or micaschists etc) constitutes a major problem to the geologists who are investigating the tectonic structures and geological history of the metamorphic and metasomatic rocks of the Oppdal–Surnadal district, and also more southerly areas. In 1944 O. Holtedahl opened one of his papers on the Caledonides of Norway with the following words: "One of the most interesting and important, but also most intricate problems of Norwegian Caledonian geology is that of the true character and genesis of the gneiss and granite masses of the north-western areas", and later ".... the age question of various gneiss or granite masses lying *below* the said younger sedimentary rocks, e. g. in the Oppdal district, is a very difficult one and not yet settled".

In this recent paper Chr. Oftedahl forgets to emphasize that, in general, during Caledonian orogeny, both sediments and gneisses in the Oppdal–Surnadal district have been completely changed, mineralogically and structuarally, in part also chemically (granitized). In most places any pre-existing structural unconformity should be expected to have vanished. However, when studied from locality to locality within a greater area, the gneiss at the contact shows considerable variation in composition, from granite to biotite schist. This fact should rather indicate a primary unconformity at the base of the flagstone. This applies to the Oppdal area. In Surnadal, however, the relations seem different. According to T. Strand (1953) a quartzite occurs as a horizon considerably below the contact flagstone/basal gneiss. Consequently, the upper part, at least, of the basal gneiss seems to belong to a conformable series below the flagstone member; no indication is given by Strand as to the primary nature of these gneiss members.

Thus, in referring to O. Holtedahls statement above, the problems concerning the basement contact cannot possibly be settled in the way proposed by Oftedahl, by simply pretending that the problems do not exist.

Oftedahl avoids mentioning a conglomerate near (or at) the base of the flagstone in the Oppdal area. This conglomerate, described by Ivan Th. Rosenquist (1944, p. 199, see also 1941, p. 34), offers, so far, the only

[1] E. Wegmann, during his long stay in Norway about 1924, was probably the first to realize that high-grade metamorphic sediments of Cambro-Silurian age constitute parts of the north-western gneisses of southern Norway, at that time considered to be of archaean age. According to his verbal account, his view was strongly contradicted by leading Norwegian geologists.

Fig. 1. Basal gneiss west of Lønset. Intensely folded bands and veins, resulting in a secondary schistosity ⊥ axial planes.

exact information, although scarce, of the primary nature of the Precambrian basement rocks within the Oppdal district. The conglomerate occurs in several places along the Lønset anticline (a dome-shaped, overturned anticline consisting of basal gneisses and the covering flagstone, micaschist, etc). In a few localities the conglomerate has escaped deformation and complete recrystallization, and the original nature of the boulders can easily be recognized. Boulders of quartzite are most common, but granite boulders occur locally in approximately equal amounts; other rock types are rare.

Neither does he mention another conglomerate near Otta, that offers some information of the Precambrian basement rocks within that area. Among Norwegian geologists the conglomerate is commonly well known as the Rosten conglomerate. It was visited by the 1960 Congress excursions A 13 and C 9 (excursion guide, 8th day, stop 1., p. 25, see list of references). The conglomerate occurs at the deepest known level of the Eocambrian sparagmite (roughly equivalent to the flagstone of the Oppdal district). The boulders, in part angular and big-sized and arranged at random, consist of various crystalline Precambrian rocks. Most common are medium-grained and coarse-grained granites ("augengranite") of

Fig. 2. Basal gneiss west of Lønset. Intensely folded light and dark bands, granitic vein in part cutting the bands, in part conformable with the bands. Schistosity of the gneiss ≒ with axial planes of small folds.

faint pink and lilac colours. At the best locality the boulders are not deformed, and the primary nature cannot be questioned. The shape and manner of arrangement of the boulders indicate a short transport (the conglomerate is certainly not a tillite). The size of the boulders (up to one meter) should indicate a rugged topography at the time of deposition.

Moreover, the crystalline basement within the Otta nappe, described by T. Strand (1951) as the Rudihø complex, representing the Precambrian substratum of the flagstone of the nappe, consists of various anorthosites and norites, not of tuffs or tuffites.

Even if these informations are scarce, they should be taken into account when discussing the nature of the Precambrian basement rocks.

Let us turn to Oftedahls description of localities under the heading OBSERVATIONS.

The section described by him (p. 7) as locality No. 2, west of Oppdal is most illustrating as to the nature of the basement contact. Also this locality was visited by the 1960 Congress excursions A 13 and C 9. The members of the excursions will recall the road section west of Lønset, stop No. 4 on the 9th day (excursion guide p. 27, see list of references).

This section was first mentioned by O. Holtedahl (1938, pp. 34–41), later by Ivan Th. Rosenqvist (1941, pp. 29–30 and 1944, p. 123), still later by H. Holtedahl (1949, p. 10). During the 1950 years new road cuts were opened, and shortly before 1960 the contact between the basal gneiss and the flagstone was disclosed but for one meter. The short gap seems to be occupied by a very schistose, micaceous rock, according to the character of the debris that fills the gap. Considerable tectonic displacement may have taken place along a thrust plane parallel to the bedding (and schistosity) of the flagstone (above) and the schistosity of the basal gneiss (below the contact). The dip is 60° WNW, on the northwestern limb of the Lønset anticline. The heterogeneous basal complex consists of *intensely folded bands*, the small folds seemingly formed by fracture cleavage or by shear. Shear folding, or cleavage folding should be a propriate term. The axial planes of the small folds give the rocks a secondary schistosity by which a secondary gneiss "sheeting" is formed. This secondary sheeting is conformable with the contact, but the important thing is that the primary banding or foliation *is not so*.

The composition of the basal gneiss vary from granite to biotite schist, and probably a granitization process has played a part in changing the original composition. In most granitic sheets the original banding has nearly disappeared, the rock being more or less a homogeneous gneiss-granite. Some of the biotite-rich sheets are partly transformed into augen-gneiss, the augens consisting of microcline porphyroblasts. Ptygmatic veins occur, often folded together with the original banding, but also veins cutting the banding occur. Younger granitic dikes also occur, cutting the gneiss structure.

Figs. 1 and 2 illustrate the structural appearance of the basal gneiss in this locality. In H. Holtedahl's (1949) paper a similar illustration is presented as fig. 2 (p. 11), namely a photo taken from the same section before the new road cut was opened.

In O. Holtedahl's (1938) paper a number of good illustrations are presented, showing the intense deformation of various rocks along the same road, alterations into augengneisses where the primary structures are on the point of disappearing, and granitization effects.

Obviously, the schistosity of the basal gneiss, marked by the axial planes of the small folds, developed in connection with the folding of these. This folding did not affect the flagstone, where only a schistosity developed parallel with the bedding planes. This structural difference between the two formations may be due to variation in competence during

folding, but it may as well indicate *a primary unconformity* at the base of the flagstone. All authors before Oftedahl (including myself) are of the opinion that the semi-conformity developed in connection with Caledonian orogeny under deep-seated conditions. But even the time of shear folding within the basal complex may possibly be discussed. What cannot possibly be discussed is that the parallelism between the flagstone beds and the (secondary) schistosity of the basal gneiss provides no evidence for the postulate of Oftedahl that the basal gneiss consisted of flat-lying volcanites (or sandstones) at the time when the arcosic flagstone was deposited. And that is, nevertheless what he postulates.

The several others of Oftedahl's locality descriptions need only short comments. – No. 1: the contact is lacking. No. 3: some hundred meter is missing, including the contact. Nos. 4, 5, 6: these numbers refer to a paper by Dr. Janet S. Peacey (1964), who describes, very convincingly, a primary conformity at the contact between the "leptite" (possibly of volcanic origin) and the overlying sediments. She does not attempt, however, to correlate this "leptite" of the Tømmerås anticline with the basal gneisses of the Oppdal–Surnadal district. No. 7: this locality consists of two subordinate ones, the one showing "a clear angular unconformity at the contact" (Oftedahl's words). No. 8: the basal gneiss is of a rather homogeneous nature without clear bedding, and should be omitted. No. 9: a granitic gneiss occur below micaschist with no sharp contact, only a parallelism. No. 10: the critical 20 meter, including the contact, is lacking. No. 11: this seems to be the only locality, apart from those described by Dr. Peacey, where any definite conclusion can possibly be drawn as to the primary nature of the basal gneiss.

As the important locality No. 2, west of Oppdal, is so inadequately described, it is not easy to accept Oftedahl's conslusions as to the original nature of the basal rocks of all the other localities. What remains then to form a basis for the theory put forward? obviously, it is the observations by Dr. Janet S. Peacey, and Oftedahl's locality No. 11. These observations cover only the northern part, however, of the large area denominated by Oftedahl as the central Caledonides.

On these premises Oftedahl has come (p. 11) to the theory that the sub-Cambrian basement within the central Caledonides (comprising the Oppdal–Surnadal district etc.) originally consisted of flat-lying volcanites. In a chapter with the heading DISCUSSION (p. 9) he tries to find support for this theory: The granitic gneisses of the basal complex are metamorphosed tuffs or tuffites of granitic composition because such

rocks will easily recrystallize into granitic gneisses, and because such rocks occur frequently within other districts of Fennoscandia.

It may be permitted to think that these reasons are too weak for a generalization.

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