GEOLOGY OF THE HESTBREPIGGAN AREA PRELIMINARY ACCOUNT

By

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Abstract. Within the Hestbrepiggan area, on the southern margin of the N.W. Basal Gneiss Complex of S. Norway, it can be demonstrated that the Basal Gneisses were intruded by basic bodies, deformed by N–S earth-movements, metamorphosed in the almandine-amphibolite facies, felspathized and intruded by foliated granite before the emplacement of the overlying Eo-Cambrian and younger metasediments.

These supracrustal rocks, which are of both miogeosynclinal and eugeosynclinal type, have been deformed (the dominant folds being isoclines plunging NE), metamorphosed in the upper part of the greenschist facies (accompanied by retrograde metamorphism of the underlying Basal Gneisses), and thrust to their present position from the WNW.

Subsequently, as the result of N–S earth-movements the area has been block faulted (with associated, local, retrograde metamorphism) and large, open, easterly plunging folds have been developed in the metasediments.

Introduction

The Hestbrepiggan area lies on the southern margin of the N.W. Basal Gneiss Complex of S. Norway. Within the area, to the south and east, the gneisses are overlain by metamorphosed sediments.

No work concerned specifically with the larger part of the Hestbrepiggan area has previously been published; the area was reconnoitred by REKSTAD (1914) and the SW corner more fully studied by LANDMARK (1948), both of whom, however, were concerned with producing a small scale map of a relatively very large area to the south of the Hestbrepiggan area. (Other central and marginal parts of the Basal Gneiss Complex have been much studied; unfortunately, a review of the relevant literature cannot be undertaken here. The views

of the majority of experts are, however, expressed in several review articles and guides published at the time of the XXI International Geological Congress held at Copenhagen in 1960. For example, HOLTEDAHL, O. (1960), STRAND (1961), DONS (1960).) The only complete map of the area is the 1:1,000,000 geological map of Norway, by HOLTEDAHL and DONS (in HOLTEDAHL 1960).

The Basal Gneisses

General

The N.W. Basal Complex is generally believed to consist at least partly of the granitized equivalents of the over-lying Eo-Cambrian-Silurian metasedimentary succession. Further, the usually foliated granitic bodies have often been found (see especially STRAND 1949) to be the results of *in situ* granitization of the surrounding gneisses.

Two types of gneisses have been observed, namely early formed plagioclase gneisses and later developed K-felspar gneisses, both of which, near the southern margin of the Gneiss Complex at least, show mineral assemblages indicative of the greenschist facies of metamorphism.

A simple structural pattern has been recorded; within 75 km of the Hestbrepiggan area the gneissose foliation strike is generally E–W.

The Hestbrepiggan area.

The Basal Gneisses of the Hestbrepiggan area consist in the main of biotite-rich granodioritic to granitic gneisses, with lesser amounts of amphibolite and K-felspar augen gneiss. These lithologies are often replaced by regionally developed, unfoliated, K-felspar-quartz pegmatite. Within the gneisses one large mass and several smaller bodies of granite occur.

Although the regional, E–W foliation of both the biotite gneisses and the granites is the fundamental structural element around Hestbrepiggan, there are several complications. First, associated with an important 40° striking, high-angled, sinistral shear (the Briedalen tear fault) occurs an approximately 1.5 km wide zone within which, under shear stress, felspars, biotite and hornblende have broken down to muscovite, chlorite and quartz, with epidote, clinochlore, dolomite, stilbite, etc. as vein minerals.

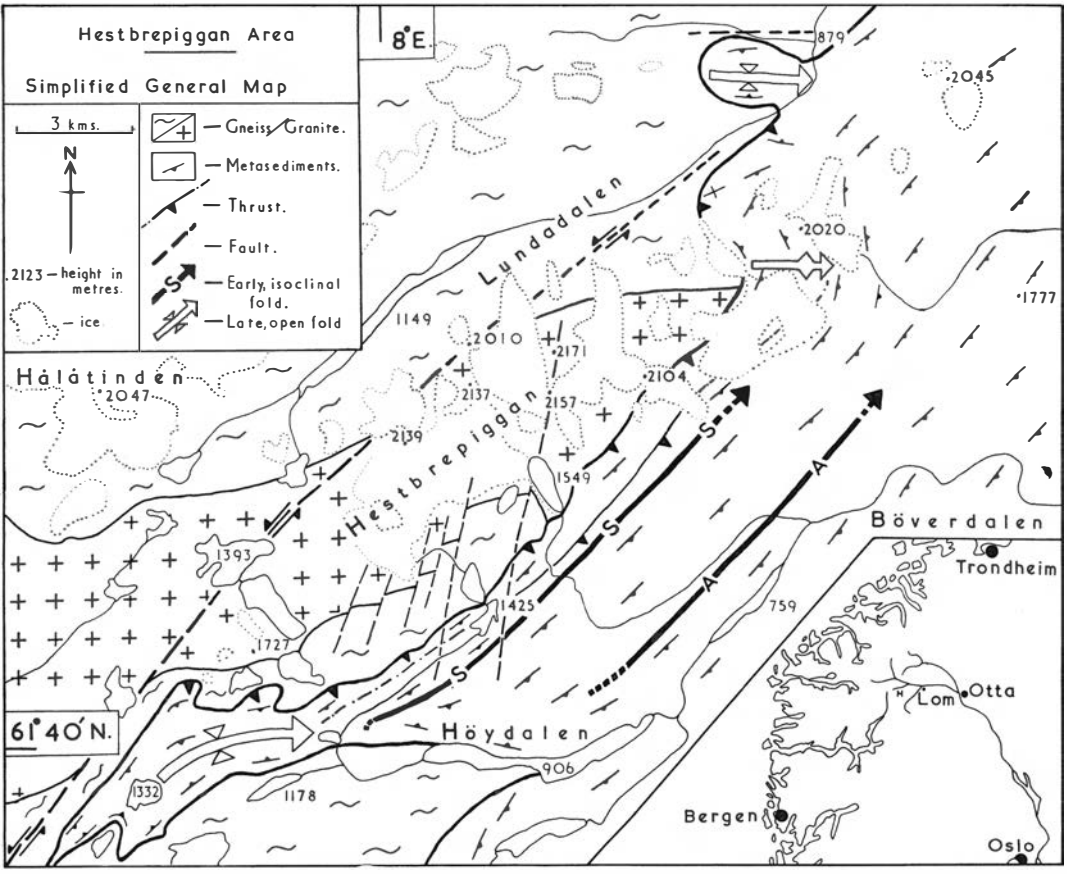

Fig. 1. Simplified map of the geology of the Hestbrepiggan area; for topographic detail see AM Series M711, sheet 1518, parts I, II, III, and IV.

NB 1. On the inserted small scale map of Southern Norway H represents the location of the Hestbrepiggan area.

2. Only those portions of the metasedimentary basal plane that have been satisfactorily demonstrated as thrust have been so indicated; it is probable, however, that this plane is everywhere a thrust or (décollement) plane.

3. Only essentially uncomplicated portions of the early and late fold axes have been indicated; full details will appear in the near future.

The foliation of the schistose gneisses so formed is conformable to the plane of the tear fault. Further, the 'biotite foliation' of the gneisses and granite up to 2 km on either side of the shear zone has been deformed into a sinistral, sigmoidal flexure, the middle limb of which is replaced by the tear fault. Numerous other, usually much narrower, zones of schistose gneiss with muscovite and chlorite occur throughout the area, particularly in association with a set of sinistral, probably second order, high-angled shears striking 10°–20°.

Second, gneisses within a few tens of metres of the overlying metasediments have been sheared, along planes conformable to the base of the metasediments, to form flaggy gneisses consisting largely of quartz and muscovite. It is just possible that elsewhere this type of superficial foliation has given a somewhat exaggerated impression of fundamental conformity between the metasediments and the underlying Basal Gneisses.

On a large scale (see map, Fig. 1), however, it is clear that the main E–W striking lithologies and structures of the gneisses are progressively overstepped in the east by the N.E. regional strike of the metasediments. Further, there are usually very distinct lithological, mineralogical, and chemical differences between the two geological units, and little difficulty has been experienced in placing a boundary plane between alternating pelitic schists and psammites on the one hand and flaggy, muscovite gneisses grading downwards to biotite gneisses, etc., on the other. However, in the eastern part of the area, more and more arkosic sparagmite occurs in the lower part of the metasedimentary succession, and, where this has been basally sheared, greater difficulty has been experienced in defining the boundary.

The third complexity in the simple E–W foliation pattern is that although the gneissose and granite structures are generally conformable, they are often markedly discordant in detail. The foliated granite/gneiss contacts are invariably sharp, usually cross-cutting and often agmatitic. Further, the granites are lithologically, mineralogically, and chemically much more homogeneous than the gneisses and there is no *in situ* 'granitizational gradient' towards the granite within the gneisses. It is concluded that the Hestbrepiggan granites have been intruded into the 'country-rock' gneisses.

The predominant, stable, mineral assemblage of the Hestbrepiggan Basal Gneisses (and granite) is quartz, K-felspar, plagioclase (An8),

epidote, muscovite and chlorite, indicating that metamorphism occurred in the greenschist facies. The fact that the metasediments also consist of minerals stable in this facies could be taken as support of their synchronicity if it were not for the abundant evidence within the Basal Gneisses that retrograding from a higher facies has occurred. Large volumes of aluminous hornblende have been only partially altered to biotite, epidote, etc., and primary plagioclase grains have suffered extensive alteration to albite, epidote, muscovite and calcite. Chemical analyses of plagioclase grains plus their included alteration products indicate an original plagioclase with a composition of An24 (approx.). It is concluded that the Basal Gneisses were originally metamorphosed in the almandine-amphibolite facies, but were subsequently retrograded, very probably at the time of the greenschist metamorphism of the metasediments.

It is noteworthy that the presence of alkali-felspar intergrowths within the Basal Gneisses has been used as evidence of the replacement of plagioclase (gneisses) by later introduced K-felspar (gneisses). Apparently identical textural relations at Hestbrepiggan are interpreted as the result of alkali-felspar exsolution to albite and microcline on decreasing temperature. On the other hand, replacement of plagioclase, biotite, and quartz by K-felspar within the gneisses is abundantly evident at the margins of the extensive K-felspar pegmatites. However, this K-metasomatism, which must have been largely responsible for the development of the K-felspar pegmatites, is not believed to be essentially later than the Na metasomatism which also pervaded the Basal Gneiss area, but merely less complete (i.e. less pervasive). This belief is supported by chemical analyses of widely differing Basal Gneiss lithologies; these show an almost constant Na cation percentage, whereas, outside the regional, K-felspar pegmatites, the K cation percentage varies considerably.

The often stated Caledonian age (or 'stamp') of large parts of the Basal Gneiss Complex (see, for example, HOLTEDAHL 1960 p. 231) has been based upon their widely observed structural, lithological, mineralogical, and chemical conformity with the Eo-Cambrian-Silurian metasediments above. As has been shown, this does not hold in the Hestbrepiggan area, and it is concluded that the Basal Gneisses were here deformed, metamorphosed in the almandine-amphibolite facies, felspathized and intruded by granite before the emplacement of even

the oldest member of the metasedimentary sequence. (It should be noted that LANDMARK (1948) postulated a pre-Cambrian 'plinth' to the south-west of the Hestbrepiggan area; this plinth was further noted to have only a superficial conformity with the metasediments above.)

The Metasediments

General

The metasediments to the south of the N.W. Basal Gneiss Complex have been classified as autochthonous, Eo-Cambrian-Silurian deposits of miogeosynclinal type (i.e. 'eastern facies'; see, for example, STRAND 1961 p. 164, map). Although granitization of the lower parts of the metasediments is common in other marginal parts of the Basal Gneiss Complex, Landmark does not record it within 40 km of the south-westerly part of the Hestbrepiggan area.

The Hestbrepiggan area

The supracrustal succession in the Hestbrepiggan area is tabulated in Fig. 2. It consists of two (possibly three) thrust slices, with miogeosynclinal sediments in the lower slice and eugeosynclinal sediments in the upper slice. The lower slice is composed mainly of psammitic schists, sparagmites, with subordinate pelitic horizons and has a quartzite conglomerate sporadically developed at its base; the upper slice(s) consist of sparagmites, mica-schists, a limestone horizon, hornblende schists with ultrabasic intrusions, and pyritous, graphitic schists. Amphibolitic schists have not been previously recorded from the area, and their presence, along with limestones and mica-schists, invites comparison with the 'Trondheim type' of succession described by STRAND (1951) from the lower Jotun (Otta) Nappe of the Vågå and Sel district 40 km to the east (Fig. 2).

Lateral variation in the thickness and type of sediment is marked especially in the psammitic bands which thicken greatly eastwards. Psammitic intercalations in the amphibolitic schists also thicken eastwards and there is a strong possibility that all members of the Hestbrepiggan succession pass laterally into a large, sedimentary 'cedar tree' of 'sparagmite'. If this is so, considerable difficulties could be raised concerning the assumed Eo-Cambrian age of this formation to the east.

HESTBREPIGGAN AREA		SEL AND VÅGÅ
Flags and limestone (Valdres)	?	Sel schist
		Serpentine conglomerate
Conglomerate		Conglomerate
		Trondheim Orogeny
Phyllite Group (pyritous, grey phyllite)		
Holleindalen Greenstone Group (metabasalts)		Greenstone Group (metabasalts)
Limestone-Pelite Group (mica-schists and limestone)		Heidal Group (mica-schists and flags)
Sparagmite		
Thrust		*Thrust*
Sparagmite		Sparagmite
Thrust		*Thrust*
Not found		Rudihö Complex (high grade gneisses)
		Thrust
Basal Gneisses		Basal Gneisses

Fig. 2. Metasedimentary stratigraphy in the Hestbrepiggan area, and a tentative correlation with the Otta Nappe (after Strand, see HOLTEDAHL 1960, Plate 8) in the Sel and Vågå area.

The entire sequence of sedimentary, volcanic, and ultrabasic intrusive rocks has been folded at least twice with the production of a variety of different styles of folds. What was possibly the earliest folding produced similar folds with very well developed axial plane cleavage and gave rise to the dominant foliation throughout the area. Subsequent folding produced major, isoclinal folds with steep, southeasterly dipping axial planes and a regional NE or Caledonoid trend. Metamorphism in the quartz-albite-epidote-almandine sub-facies of the greenschist facies accompanied this folding (broadly) and preceded an important (but probably not the only) phase of thrusting.

Thrust planes were developed at the base of the supracrustals and near the top of the sparagmite sequence. Within the thrust zones a pronounced lineation (including the conglomerate pebbles) trends ESE

and is accompanied by minor folds which trend normal to the lineation and are consistently overturned to the ESE, probably indicating derivation of the thrust slices from the WNW. The thrusts have locally caused the deformation of earlier formed porphyroblasts (e.g., rolling, stretching, and folding of garnets) and retrograde metamorphism to the lowest greenschist sub-facies (muscovite-chlorite from biotite-garnet, etc.) The effects of these metamorphisms and the thrusting upon the Basal Gneisses below have already been mentioned.

Later, major stresses oriented N–S caused the development within the metasediments of very large, open folds which have to some extent re-oriented the earlier structures. The Basal Gneisses responded to this last phase of deformation in an apparently largely brittle manner. The Briedalen and other tear faults were instigated (and/or re-activated?) and large lateral and vertical displacements occurred. Further retrograde metamorphism occurred in the vicinity of these faults in the Basal Gneisses. That the Briedalen tear fault penetrated through a reactivated plane of décollement at the base of the supracrustal rocks may be shown at the western end of the area where a late (probably originally E–W) fold in metasediments is rotated (and truncated) by the fault.

It is considered possible that these large fractures are related to the major 'fosse of folding' whose axial region to the south of the Hestbrepiggan area trends at 40°.

Summary and Conclusions

It has been concluded that the Basal Gneisses were deposited, intruded by basic bodies, deformed by N–S earth-movements, metamorphosed in the almandine-amphibolite facies, felspathized, intruded by granites, uplifted and deeply eroded before the Eo-Cambrian-Silurian metasediments.

After the deposition of a basal conglomerate and the sparagmite sequence, an eugeosynclinal succession was deposited accompanied by basic and ultrabasic igneous activity. Subsequently, major (Taconic?) earth-movements caused the deformation of this succession primarily into isoclinal folds with a typical, Caledonoid, NE–SW trend. The associated metamorphism caused the growth of minerals stable in the

upper part of the greenschist facies in both the metasediments and the Basal Gneisses (retrograde metamorphism).

Following the folding movements, pressures from the same general direction caused the overthrusting of the metasediments from the WNW to their present general position. Retrograde metamorphism accompanied this thrusting.

Subsequent (Svalbardian?) earth pressures caused the development of the large, open, E–W trending folds in the metasediments and the fault block movement of the Basal Gneiss basement.

Postscript

Very recent work by *Mr. D. R. Cowan* (Nottingham University) to the east and south of the Hestbrepiggan area may clarify the early structural history of the metasediments.

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