Low-grade Sediments on Precambrian Gneiss on Vanna, Troms, Northern Norway

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Presumed Precambrian, quartzo-feldspathic gneisses on Vanna, Troms, northern Norway, are overlain by two formations of arkosic sandstone and siltstone, the Tinnvatn and Bukkheia formations. The gneiss/sedimentary sequence boundary is an undulating primary unconformity. Bedforms and sedimentary structures suggest that the two formations are fluviatile-deltaic and shallow-marine, respectively. Diorite sheets intrude the upper formation. The sedimentary sequence is slightly metamorphosed and has been affected by at least three deformation episodes. Its age is discussed.

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Introduction

The island of Vanna lies at the northern end of a coastal tract of gneisses extending at least 200 km north-eastwards from the Lofoten Islands, in northern Norway (Fig. 1A). The geology of this area has been little studied since the pioneer work of Pettersen (1882, 1887, 1890). However, it is well established (e.g. Pettersen 1887, Gustavson 1966, Landmark 1973, Binns 1978) that the inner islands an adjacent mainland of the county of Troms form part of the Caledonian mountain chain and consist of highly deformed and metamorphosed (up to uppermost amphibolite facies) allochthonous sediments and subordinate igneous rocks, whereas the outer islands are largely formed of acidic gneisses which are presumed to be partially Caledonised Precambrian rocks.

The geology is being re-examined by the authors following a gravity survey of the area (Chroston 1974), and initial results were briefly cited by Roberts (1974). Pettersen (1887, 1890) showed that Vanna consists largely of gneisses, with some 'Dividal Group' sediments and a small area of 'Tromsø Mica-Schist Group'. Landmark (1973) correlated the sedimentary rocks with schists in Balsfjord and Ullsfjord to the south. The present work has shown that the sedimentary rocks are generally weakly metamorphosed, display a wealth of sedimentary structures, rest unconformably on the basal gneiss complex, are intruded by diorite, and are unlikely to be directly related to the allochthonous schists to the south.

This paper gives a preliminary description of part of the geology of Vanna

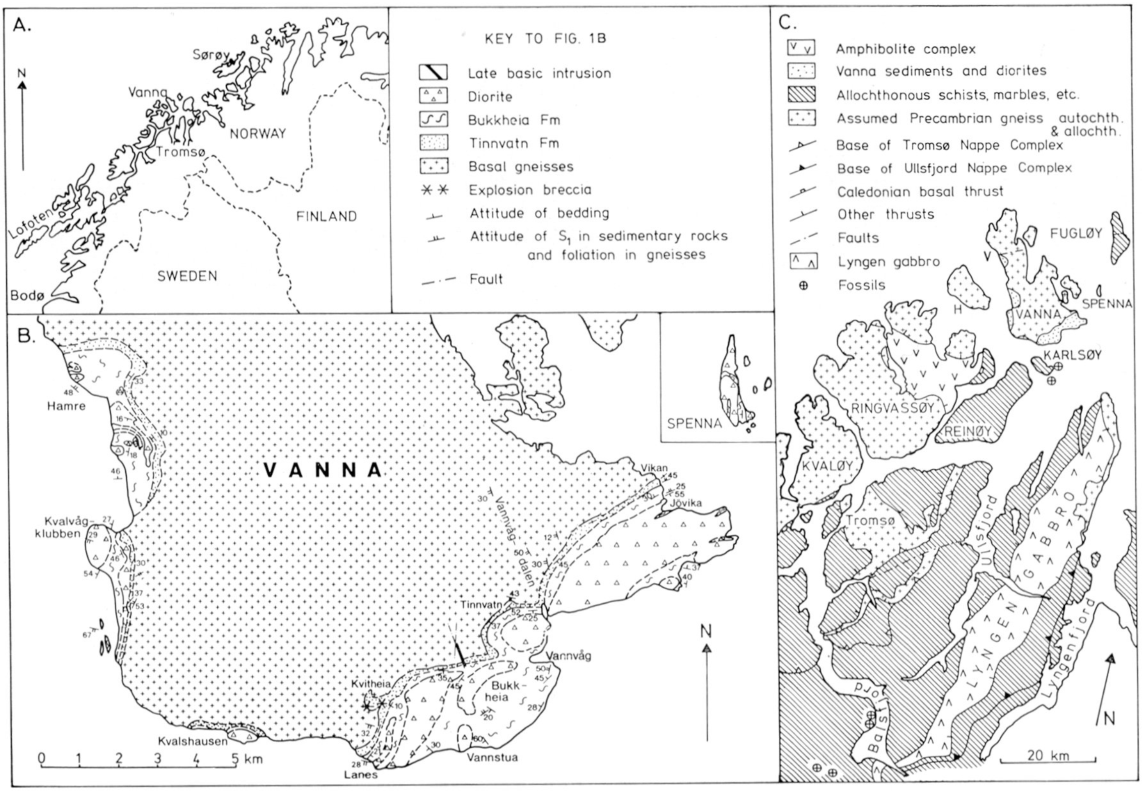

Fig. 1. Geological map of Vanna, with inset (Fig. 1C) showing the generalised geology of the surrounding area. V – Vannareidet, H – Helgøy (Fig. 1C).

and discusses its regional relationships. The names 'Dividal Group' and 'Tromsø Mica-Schist Group' (Pettersen 1887, 1890) will not be used here because we have no evidence supporting a correlation between the Vanna sedimentary rocks and the Dividal Group. The rocks Pettersen correlated with 'Tromsø Mica-Schist Group' have proved to be highly sheared basal gneiss.

Description of the geology

BASAL GNEISS

The gneisses forming the bulk of the island are generally massive, medium- to coarse-grained, grey to pale green, quartzo-feldspathic rocks. Reddish, medium-grained granodioritic gneiss occurs in a small area in the north-east, north of a major normal fault traversing the island (Fig. 1C). Occasional layers of quartzite show that some of the gneiss complex has a sedimentary origin, but the major part is believed to be orthogneiss (mainly tonalitic); these varieties are not differentiated on Fig. 1. At least two generations of the grey orthogneiss are recognisable, and at least two generations of small basic sheets cut the gneiss. The youngest sheet observed is intruded along a fault which

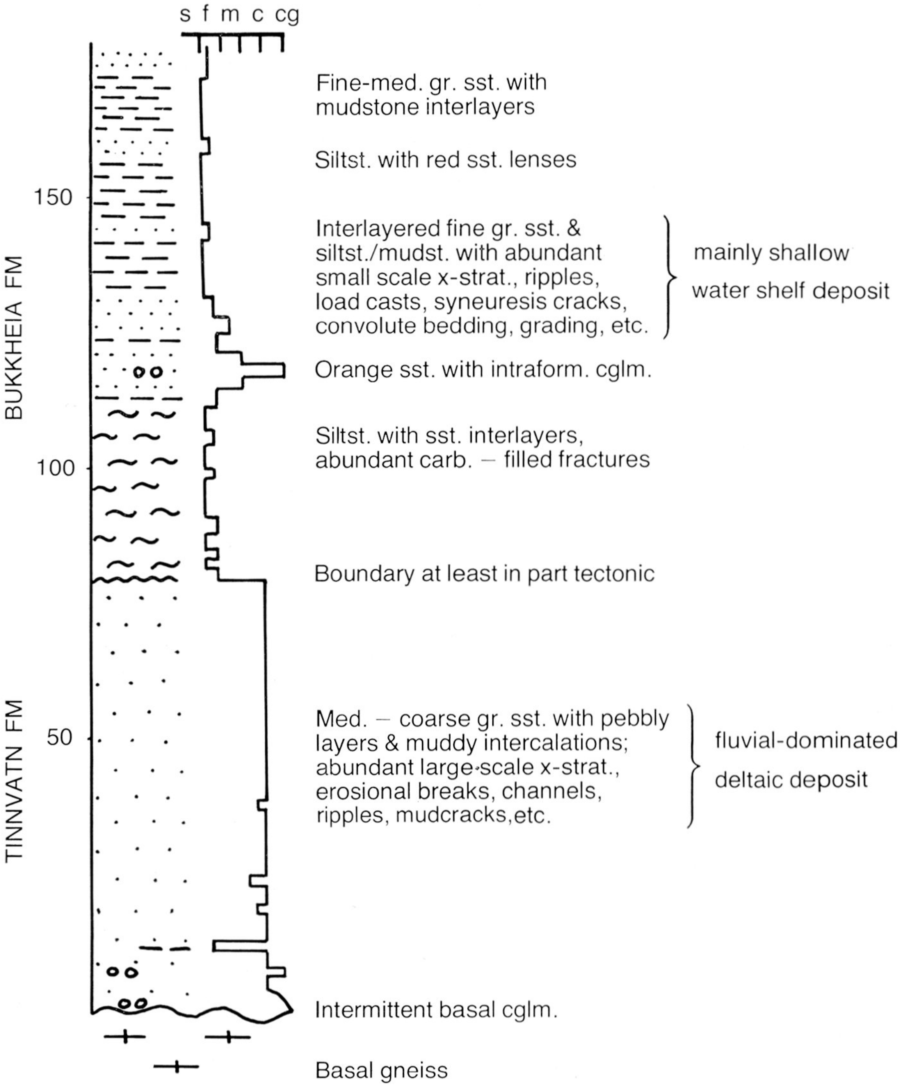

Fig. 2. The generalised stratigraphy and sedimentology of the Tinnvatn and Bukkheia formations.

transects the gneiss/sediment boundary about 2 km north-west of Vannvåg (Fig. 1). Quartz veins and tourmaline veins and quartz-feldspar-mica pegmatites are common. The gneiss usually has a distinct foliation. Based on considerations of the regional geology and preliminary Rb/Sr work (P. N. Taylor, pers. comm. 1977) the basal gneisses are thought to be Precambrian in age.

SEDIMENTARY ROCKS

The sedimentary rocks which unconformably overlie the gneiss can be divided informally into a lower psammitic formation, the Tinnvatn formation, and a upper formation of more mixed lithological character, the Bukkheia formation.

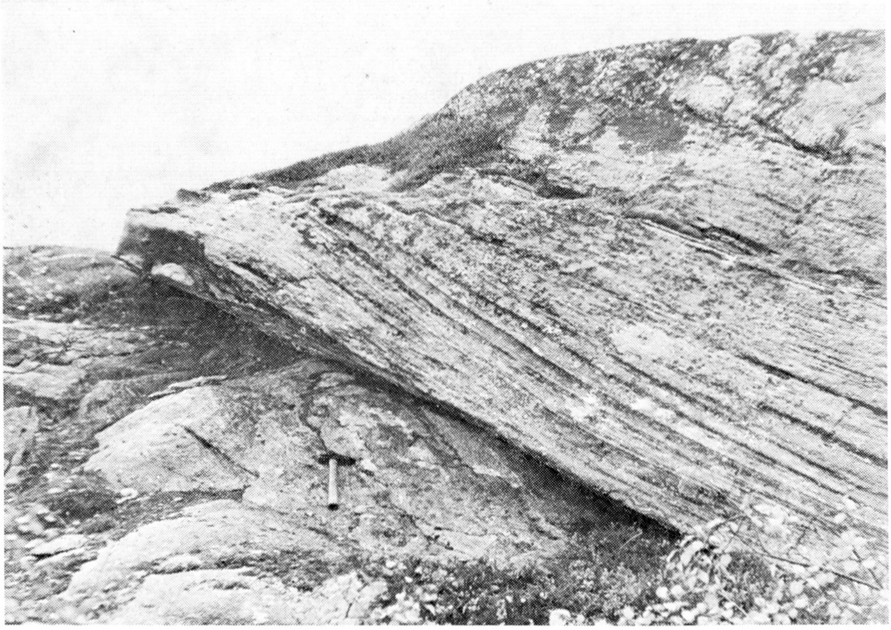

Fig. 3. View of the primary unconformable boundary between the grey, foliated quartzo–feldspathic basal gneiss below and the overlying Tinnvatn formation, on the hillside north of Lanes.

The latter is extensively intruded by diorite. Fig. 2 shows the generalised stratigraphy of the two formations.

Tinnvatn formation

The Tinnvatn formation is a white to light green or buff sandstone. It reaches a maximum thickness of about 80 m, and is almost fully exposed at Tinnvatn (Fig. 1B). A more readily accessible stretch of good exposure is located on the east coast, near Vikan. The formation is predominantly arkosic to subarkosic and calcareous (Fig. 2), but on the east coast the upper 25–30 m are quartzitic and essentially non-calcareous, and thin layers of that composition also occur at lower levels there and elsewhere. The calcite cement is entirely recrystallised. A basal conglomerate up to 0.5 m thick is sometimes present, the clasts frequently being angular and up to 6 cm in size. They consist chiefly of vein quartz and subordinate quartzite. The unconformity surface is slightly undulating and the conglomerate tends to occupy the depressions. Between Vikan and Lanes an angular sedimentary unconformity (Fig. 3) is commonly exposed, but in the Kvalshausen–Hamre area thrust movements along the boundary have removed a large part (locally all) of the formation. Because of subsequent folding the boundary is generally inclined at angles between 40° and vertical, and is even overturned in places.

The most prominent feature of the Tinnvatn formation is the large-scale (>1 m), mainly planar, low-angle (<20°) cross-stratification of the medium-

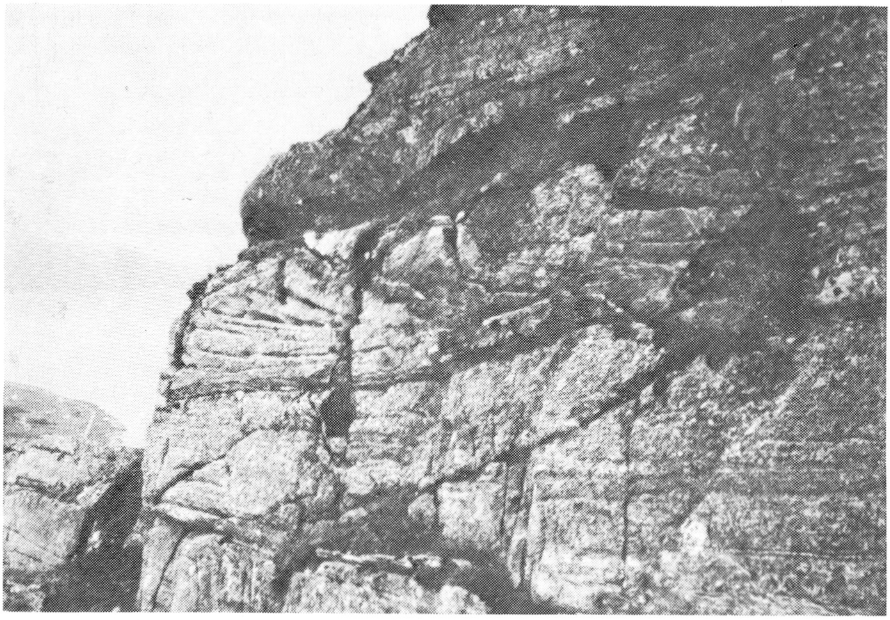

Fig. 4. Medium-scale, erosive-based, cross-stratified sandstone in the Tinnvatn formation, near the coast 200 m south of Vikan. (Photo: S.-L. Røe).

to coarse-grained (partially pebbly) lower half of the sandstone (Fig. 4). Beds of parallel-stratified, medium- to coarse-grained sandstone are subordinate lithologies. Detrital grains are usually oval or ellipsoidal to elongate, subrounded to well rounded. Sorting is generally bimodal.

The information so far available relating to the genesis of the Tinnvatn formation is imprecise and equivocal. The bimodal texture and such structures as channels and erosion surfaces could suggest a largely fluvial-dominated environment. But in that case one would expect abundant trough cross-beds rather than planar cross-stratification. A deltaic origin may be the most suitable model on which to base further investigations.

Bukkheia formation

The precise boundary between the Tinnvatn formation and the overlying Bukkheia formation is rarely exposed. Where the two formations are in fairly close contact, strike and dip attitudes of bedding are parallel suggesting conformiy. However, on the east coast, and near Tinnvatn, the boundary can be seen to be a plane of tectonic discontinuity. On the coast the Tinnvatn formation overlies an inverted sequence of the Bukkheia formation, the angle of discordance being large, whereas at Tinnvatn sedimentary structures imply that the two formations have a normal stratigraphic relationship.

The Bukkheia formation is named after Bukkheia, west of Vannvåg; all the constituent lithologies crop out on that hill and the adjacent coast, but the lower units are better exposed on the east coast. The Bukkheia formation on

Vanna is over 100 m thick, but overfolding and the diorite intrusions impede thickness estimations. The formation also occurs on Spenna (Fig. 1B). Bedding and sedimentary structures are best preserved in south and south-east Vanna, especially on Bukkheia and on the coast between Jøvika and Vikan.

The main sedimentological features of the Bukkheia formation are shown in Fig. 2. The lowest unit is grey, calcareous, feldspathic siltstone with light grey, fine- to medium-grained, calcareous feldspathic sandstone layers about 1 to 10 cm thick. Its characteristic feature is the marked differential weathering caused by solution of pockets of buff carbonate which tend to be concentrated along cleavage planes and fractures oblique to the bedding. This unit grades upwards into a thinly interlayered, light grey to greenish-grey, sandstone-siltstone sequence of similar thickness. This is also feldspathic, but is less calcareous. Near the base of this sequence is a 1–6 m thick, medium- to coarse-grained, orange-weathering sandstone (Fig. 2) which forms a good marker horizon. On the coast north of Jøvika, on Spenna, and at several other places this contains intraformational conglomeratic lenses of angular to subangular pebbles. A variety of small-scale sedimentary structures, notably ripples, ripple cross-lamination, load structures, syneuresis cracks and sand polygons are found in this sandstone-siltstone unit, including the orange sandstone member; they are especially frequent near Jøvika.

The remaining 50 m or more of the Bukkheia formation is predominantly unbedded to thinly bedded, light grey, fine- to medium-grained sandstone, with darker mudstone-siltstone intercalations. The lithologies are subarkosic to arkosic, and generally calcareous. A marker horizon is a ca. 5 m-thick, fine-grained, purple-grey siltstone with coarser, reddish, iron-rich sandy layers which are frequently disrupted into lenses and 0.5–2 cm large 'pellets' probably as a result of syngenetic slumping.

In eastern and southern Vanna the Bukkheia formation has generally suffered little or no regional metamorphism, and angular to subangular detrital grains of quartz and feldspar are common; sorting is moderate to good.

In the absence of fossils and a detailed knowledge of the petrography and sedimentology of the rocks, it is hazardous to discuss the depositional environment of the Bukkheia formation. However, the data available suggest dominance of low regime conditions and seem most indicative of a shallow-water, shelf origin for the bulk of the formation.

DIORITE INTRUSIONS

Several diorite bodies are found in the sedimentary sequence. The intrusions are almost confined to the Bukkheia formation in which they are elongated sub-parallel to the strike. The diorites are generally green and medium- to coarse-grained, and display a distinct igneous texture chiefly made up of lath-shaped oligoclase and hornblende, with some biotite. Augite is occasionally present; sphene and ore minerals are accessories. The plagioclase is slightly saussuritised and hornblende is often rimmed by actinolite. Aggregates of epidote and veins of scapolite are found, especially in the east.

A fragmentary rock interpreted as an explosion breccia and probably dating from a late phase of the main intrusion, is found at many places within the diorite or adjacent sedimentary rock. Several good examples are seen at Kvalshausen. Most occurrences of the breccia are only a metre or so in size in outcrop, and consist of variously shaped fragments of Bukkheia lithologies — diorite clasts have not been observed — in a matrix consisting chiefly of carbonate. A large occurrence of the breccia, some hundred metres across, is situated in the Tinnvatn formation on the upper part of Kvitheia (Fig. 1B) where it extends into the underlying gneiss. Here the Tinnvatn sandstone dominates the clast content.

A second unusual rock variety is a light-coloured, often reddish-weathering, albite–quartz–carbonate rock which occurs as patches up to tens of metres in size within or near to the diorite. Up to almost 100% of the rock is composed of albite laths. One of the largest outcrops is found south of the quay at Hamre.

METAMORPHISM

Little petrographic study of the sedimentary and igneous rocks has so far been undertaken, but it is clear that the regional metamorphism generally does not exceed low greenschist facies. However, green biotite forms a penetrative schistosity in a small area north of Hamre. In areas where cleavages are well developed, such as the coast south of Bukkheia, part of the Jøvik–Vikan coast section, and western Vanna, small flakes of white mica have crystallised in the cleavage planes.

Contact metamorphism of the Bukkheia formation is sometimes distinct within a metre or two of the diorite boundaries. The sedimentary rock is then tinged green owing to crystallisation of tremolite–actinolite and biotite, the former sometimes occurring as fine needles or prisms up to 5 mm long.

TECTONIC DEFORMATION

The Tinnvatn and Bukkheia formations have been exposed to polyphasal deformation which also affected the gneiss, albeit less severely.

Early, medium-scale, open, asymmetric to overturned folds plunging about 20° towards 060°, are conspicuous in the upper part of the Tinnvatn formation in the shore section south of Vikan. The Bukkheia formation is locally overfolded in the same area, and an apparent large-scale repetition of the Bukkheia lithologies in the Bukkheia area may reflect the existence of a tight overfold. A cleavage axial planar to these early folds is found locally in both formations, especially where overturned folds are conspicuous. In the Jøvik area, open to isoclinal, upright, locally overturned, small- to fairly large-scale antiforms and synforms fold the locally inverted Bukkheia sequence. These second generation folds have axial trends between about ENE–WSW and E–W, and a weak to moderate axial planar cleavage is developed, mainly in their hinge zones. Such folds are also found in southern Vanna and occasionally in western Vanna.

Still younger, large- and small-scale, open flexure folds with axes trending between NW–SE and N–S are seen both in eastern and western Vanna, for example in the valley west of Vannvåg. It is not clear what age relationship exists between these and a locally pronounced, gently dipping cleavage which post-dates the second generation folds.

The thrust at the boundary between the gneiss and the sandstone in the south-west, may be related to the earliest folding episode in the sedimentary rocks, whereas the tectonic discordance apparent between the two sedimentary formations in the east may be somewhat younger.

Minor faulting occurred locally at a late stage in the deformation sequence. The Vannareidet fault within the gneiss complex (Fig. 1C) has a substantial downthrow to the south, perhaps several hundred metres, and is probably partly post-Precambrian in age as it is in line with a large normal fault on the island of Fugløy some 20 km to the east (Fig. 1C).

DISCUSSION

The sedimentary rocks may represent (i) Precambrian or Cambro–Silurian sediments deposited on autochthonous Precambrian gneisses; (ii) Precambrian or Cambro–Silurian sediments deposited on a gneiss complex which was subsequently thrust to its present position; or (iii) late-Caledonian (Devonian?) sediments deposited after the main Silurian thrusting of the orogeny.

Concerning the third alternative, the apparent absence from northern Norway of other occurrences of late-Caledonian sediments precludes direct comparison. However, the polyphasal deformation, regional metamorphism and igneous intrusion undergone by the Vanna sedimentary sequence seem inconsistent with such an age.

With regard to alternatives (i) and (ii), the rocks seem to bear at best only a superficial resemblance to known Precambrian or Cambro–Silurian sedimentary sequences farther east in northern Norway (e.g. Føyn 1967, Vogt 1967, Roberts 1968, 1974, Ramsay & Sturt 1970, 1976, Banks et al. 1971, 1974, Curry 1975). Roberts (1974) suggested a Silurian or possibly Ordovician age. Immediately south of Vanna (Fig. 1C), the Ullsfjord Nappe Complex (Binns 1978) comprises a metamorphosed volcano–sedimentary sequence (Randall 1971, Landmark 1973, Munday 1974) of largely mid-Ordovician–Silurian age (Olaussen 1977, Binns 1978, Binns & Matthews, in press). Recent detailed study of this sequence (Binns & Matthews, in press, Binns & Humphreys, unpublished data) has revealed a much more complex orogenic history than is shown by the Vanna sedimentary rocks. No dioritic intrusions have been observed, and little lithological similarity with the Vanna sedimentary rocks is apparent, even in areas where the rocks of the Ullsfjord Nappe Complex have been equally little metamorphosed. The contrast is striking, and does not seem to support the correlation between them suggested by Landmark (1973). However, the contrast could be accounted for if the sequences are of similar age but had widely separate locations prior to nappe translation.

It does not seem possible to directly determine whether or not the gneissic basement to the Vanna sedimentary sequence is truly autochthonous. However, Matthews (in prep.) has recently established that the adjacent island of Ringvassøy (Fig. 1C) is largely composed of a basal gneiss complex overlain by a nappe of basic rocks which in turn is overlain by a nappe of acidic to intermediate gneisses of similar composition and appearance to the gneisses underlying the Vanna sedimentary sequence. Such gneisses are also known to occur on Helgøy (Fig. 1C), (Pettersen 1887, Chroston 1974), and it is conceivable that all three occurrences belong to a single nappe sheet or nappe complex. Hence, the second of the above alternatives is preferred, but the age of the sedimentary rocks remains open.

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