HELLEFJORD SCHIST GROUP — A PROBABLE TURBIDITE FORMATION FROM THE CAMBRIAN OF SÖRÖY, WEST FINNMARK

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The sedimentary character of the Cambrian Hellefjord Schist Group is described and it is concluded that this sequence is composed of alternating pelagic sediments and distal turbidites; a local slide-conglomerate is also represented. There follows a discussion of the probable sedimentation conditions and associated tectono-environmental implications. The turbidite sequence is here looked upon as the last stage in a pre-orogenic geosynclin al depositional cycle. Finally, some Eocambrian-Cambrian successions in other parts of Finnmark are reviewed briefly in the light of the results of the present study.

Before the beginning of the last decade knowledge of the geology of the island of Söröy was more or less confined to short references contained in a series of accounts written by Karl Petersen (1868, 1873, 1883). The geological map of the island published by this same author (1883) is that which appears on the most recent map of Norway (Holtedahl & Dons 1960). Holtedahl (1944) has also made brief references to aspects of the geology of Söröy.

Since 1959 a detailed tectonic and petrological survey of the island has been in progress under the leadership of Drs. B. A. Sturt (Bedford College, London) and D. M. Ramsay (University of Dundee), and it has become evident that the various earlier ideas on the structures and stratigraphy require considerable revision (e. g. Ramsay & Sturt 1963, Stumpfl & Sturt 1964, Sturt & Ramsay 1965, Appleyard 1965, Roberts 1965).

Investigations by the present writer in N. E. Söröy, while mainly of a structural and metamorphic petrological nature, have also confirmed and in part added to the provisional stratigraphy tabulated by Ramsay Sturt (1936). The succession in this part of Söröy shows:

Top	Hellefjord Schist Group	≧ 700—900 m
	Falkenes Limestone Group	ca. 60 m
	Storelv Schist	110 m
	Transitional Group	0—25 m
Klubben Quartzite Group	Quartzite 3	(?) ca. 540 m
	Upper semi-pelite	0—75 m
	Quartzite 2	280 m
	Lower semi-pelite	0—280 m
	Quartzite 1	≧ 1120 m

Although carefully estimated thicknesses are given, it should be noted that these cannot be taken as the primary depositional thicknesses in view of the polyphase tectonic and metamorphic events which have affected the succession. Briefly, at least two major episodes of folding have been recognised but these are complicated and can be subdivided into several phases. The metamorphic history is also rather involved but the highest grade of regional metamorphism (sillimanite-almandine-orthoclase sub-facies of the almandine-orthoclase facies) was established late in the static interval separating the major first and second fold episodes (Ramsay & Sturt 1963, Roberts 1965).

Recently it has been shown that this complex tectonic activity can be dated to late Tremadocian—early Arenig times (Sturt et al. 1967). Although fossils have not been found in N. E. Söröy, archaeocyathids indicating a Lower Cambrian age have been discovered in a limestone within the uppermost part of the Klubben Quartzite Group in the south of the island. This means that the upper half of the stratigraphical succession must be of Cambrian age, whilst the older members of the Klubben Quartzite Group are probably Eocambrian. The Hellefjord Schist Group can be conjectured as being of Middle or even partly Upper Cambrian age.

The present account is concerned principally with the character of the youngest litho-stratigraphical unit, the Hellefjord Schist Group, its recognisable sedimentary structures and probable depositional environment. Brief notes follow on the associated tectono-envireonmental implications and comparisons with other Finnmark successions. It is to be noted that the name Hellefjord Schist Group now replaces the previous designation Hellefjord Schist (Roberts 1965).

THE HELLEFJORD SCHIST GROUP

This member of the succession crops out extensively over N. E. Söröy (Fig. 1). The outcrop extent is, however, a consequence of repetition by folding and faulting and the fact that bedding dip values are commonly quite low, often approaching the horizontal. The Hellefjord Schist Group also occurs over a smaller area in the extreme western part of Söröy on Åfjordnæringen. An upper boundary to this group has not been found.

Lithological features: The most conspicuous feature of the Hellefjord Schist Group is the monotonous and regular alternation of medium- to fine-grained schist and even finer grained, dark, phyllitic schist. This rhythmic banding is disturbed only by the local development of a gneissic horizon and by local facial changes near the boundary with the subjacent Falkenes Limestone Group. In addition a primary slide-conglomerate (or breccia) interrupts the sequence at Gamnes point not far above the base of the Hellefjord Schist Group.

In hand-specimen, the relatively coarser grained rock-type is of greenish-grey colour, often appearing rather pale on certain weathered surfaces.

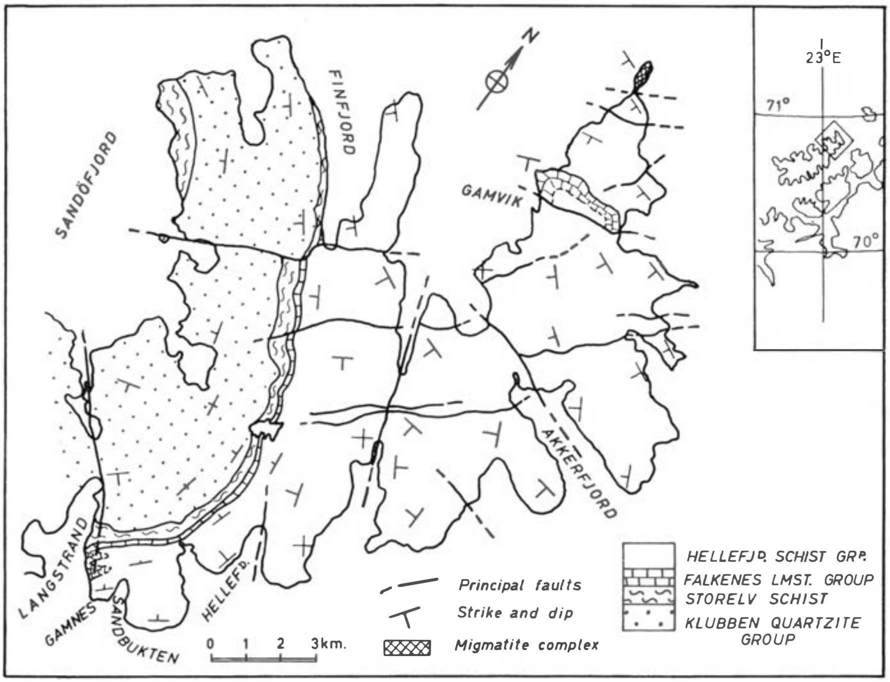

Fig. 1. N. E. Söröy. Occurrence of lithologies, much simplified. Map area shown on key map of Söröy and adjoining parts of W. Finnmark.

It is possible to distinguish the main constituent minerals with the naked eye; these are quartz, feldspar and amphibole, the amphibole occurring both as small grains and as porphyroblasts, usually up to 4—5 mm in length though occasionally up to 2 cm. Biotite is uncommon, as confirmed by modal analyses, while garnets occur only sporadically. A marked structural feature is the lineation of the amphibole (actinolitic hornblende) needles or laths, this orientation corresponding to the axial direction of second episode folds.

With the exception of the amphibole, microscopic examination shows the grain-size to be in the range 0.1—0.4 mm, and although a fairly even-grained fabric is generally apparent a systematic change is sometimes noticeable; this will be referred to again later.

The phyllite or phyllitic schist is invariably dark grey or purple grey although a subtle colour change is often perceptible which can be correlated with mineralogical and grain-size differences. Biotite is now the dominant mineral comprising nearly 50 % of the mode (Table 1), with amphibole usually absent. The texture is therefore lepidoblastic and schistosity planes frequently display a satiny lustre. Porphyroblastic garnets, $\leq$ 2 mm across, are common, particularly in the darkest variant of phyllite. The general quartz-feldspar grain-size is in the range 0.02—0.08 mm.

Both these lithologies are metamorphosed sediments and display primary structures which are described below. In order to facilitate these descriptions and subsequent discussion, the quartz-amphibole schist and the biotite-

Table 1. Mineral composition of representative Hellefjord Schist Group metasediments

	3 D88	2 D816A	3 D319	4 D607	5 D530A	6 D544
Quartz	23.2	26.6	31.4	32.2	41.5	40.2
Plagioclase	21.4	15.6	20.2	14.4	23.8	24.0
Biotite	48.5	47.9	24.3	23.5	8.4	1.8
Garnet	5.9	7.7	4.2	–	–	–
Amphibole	–	–	4.4	16.8	20.9	28.0
Diopside	–	–	9.8	x	–	–
Scapolite	–	–	3.6	11.7	–	–
Ores	0.1	1.8	0.3	0.4	0.2	–
Apatite	x	0.5	0.6	0.4	0.3	0.3
Sphene	–	–	1.4	0.6	1.8	1.7
Clinozoisite	0.2	–	–	–	0.2	1.7
Tourmaline	0.3	x	x	–	–	–
Chlorite	0.4	–	–	–	–	1.2

1 and 2) Garnet-biotite phyllite (pelite) — 3 and 4) Calc-silicate schist (intermediate lithology) — 5 and 6) Quartz-amphibole schist (psammite). 1,500 points per specimen.

garnet phyllite will hereafter be referred to as psammite and pelite respectively.

In many instances it is found that the grain-size of the psammite decreases gradually in one direction. The quartz-feldspar grain-size in these psammitic bands is frequently at a maximum at or near the bases of the bands: no definite examples of primary grains have been found however. Away from this basal zone a perceptible decrease in the average grain-size is observed until, in the uppermost parts of the paler-coloured psammite units, it approaches that of the coarser variants of phyllite. At the same time biotite, and to a lesser extent garnet, increases rapidly in amount at the expense of amphibole and quartz, the rock darkening and becoming less psammitic in character. There is, therefore, a discernible vertical grading and this, where present, is seen to be constant and confirms the stratigraphical positioning of the Hellefjord Schist Group above the Falkenes Limestone Group. Where grading is recognisable, the junction between the top of a pelite band and the overlying psammite is invariably well-defined and abrupt in comparison with the gradation noted in moving up from a psammite into a pelite band.

Another characteristic feature of this bipartite lithology is the regular, plane-parallel banding or stratification, individual bands or units having a considerable lateral extent. Quite often even the thinnest of psammite ribs appears to be continuous over the scale of the large outcrop or cliff-face.

Thicknesses of psammite bands for the most part range between 5 and 15 cm, but ribs and stringers $\leq$ 1 cm are noted locally. In the typical sequence pelite and psammite are present in roughly equal proportions. In parts of the area, however, the psammitic rock-type may constitute up to 75 % of the sequence with individual bands attaining thicknesses of 70—80 cm. A distinction must be made between thickness increases of primary origin and those related to a positioning at the closures of similar folds. The examples mentioned above are, however, clearly of sedimentary origin. Throughout the area, thickening at fold closures occurs quite frequently and in certain instances a thinning of phyllite or psammite along the limbs of shear folds is almost certainly of tectonic derivation. Amalgamation of psammite bands due to primary processes (Wood & Smith 1959, Walker 1966) has not been observed, though shearing associated with the folding has sometimes resulted in two psammitic units lying in juxtaposition.

Graded bedding: Although grading is observed in several localities, it is a relatively uncommon structure taking the N. E. Söröy region as a whole. It is also rarely perfectly developed but nevertheless, despite the protracted recrystallisation and tectonic history, it has survived as a recognisable feature of this schist/phyllite sequence (Fig. 2).

Where grading is discernible, it is without exception restricted to those parts of the succession in which psammite bands are thinly developed. The grading is often accompanied by notable coloration changes, mainly on weathered surfaces but to a lesser extent on freshly broken surfaces, and falls into the category of continuous (Radomski 1958) or, sometimes, indistinct grading (Unrug 1963). At all localities in which grading is well developed the younging direction is constant and can be traced from normality to inversion around fold closures. Contiguous psammite bands

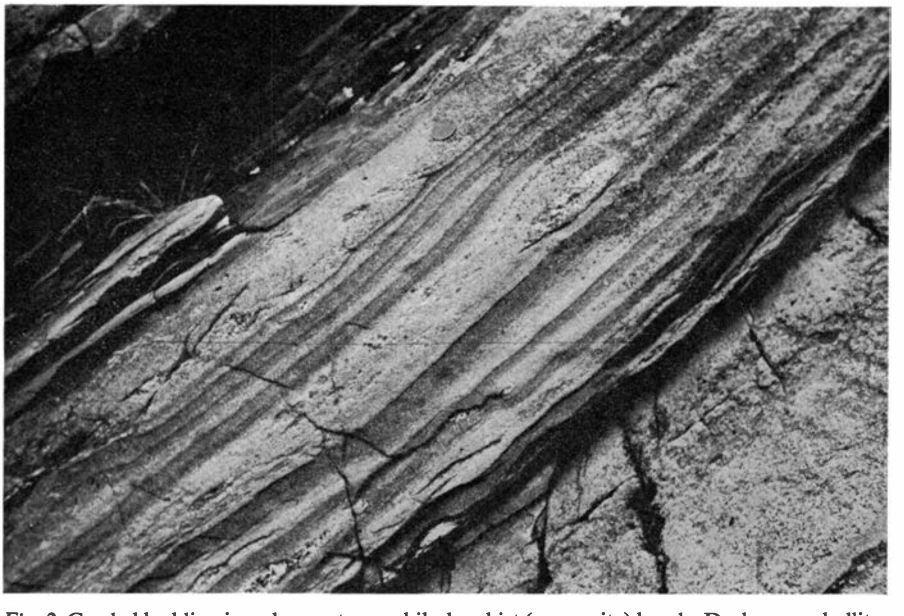

Fig. 2. Graded bedding in pale quartz-amphibole schist (psammite) bands. Dark grey–phyllite; note two small 'flames' of phyllite projecting up from base of uppermost psammite band (on which a 2. 6 cm coin rests). Hellefjord Schist Group. 1 km ESE of Bismerviken, Akkerfjord.

may not necessarily be graded to the same degree, and, indeed, one may display good continuous grading while its neighbour appears to be structureless or homogeneous.

Load casts and flame structures: These terms are here used descriptively as it is too difficult in this metamorphic environment to choose between the mechanisms of load casting (vertical movement — Kuenen 1953) and flow casting (horizontal movement — Prentice 1956).
Load casts, with associated 'flames' of pelite, have been noted from five different localities, though two of these (some 400 m apart) belong to approximately the same niveau. These structures are irregularly shaped or bulbous downward protrusions of psammite into the subjacent pelite. On one side or both sides of these load casts, flame-like tongues of pelite appear to extend up into the overlying psammite band (Figs. 3 and 4). Most flame structures tend to be inclined in a constant direction in any one exposure but in one horizon on the Gamvikfjord coast such asymmetry is quite irregular.

Rarely, thin clasts or wisps of phyllite occur in the lower parts of psammite bands, particularly in those units which are load-casted. An interpretation of their occurrence is hindered by the lack of a three-dimensional appreciation of their shape, but it is possible that they represent fortuitous sections through flame structures. Similarly, a small oval 'ball' of psammite in the uppermost part of one phyllite band (beneath a load-casted psammite band) may represent a chance section through the extremity of a load cast.

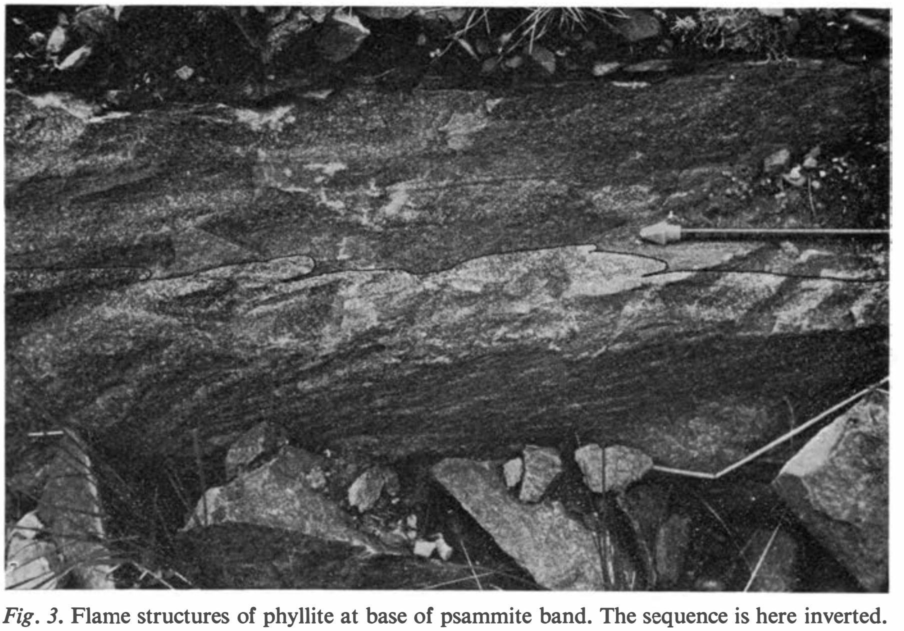

Fig. 3. Flame structures of phyllite at base of psammite band. The sequence is here inverted. Hellefjord Schist Group, road-cut on west side of Akkerfjordhavna. Pencil 15 cm in length.

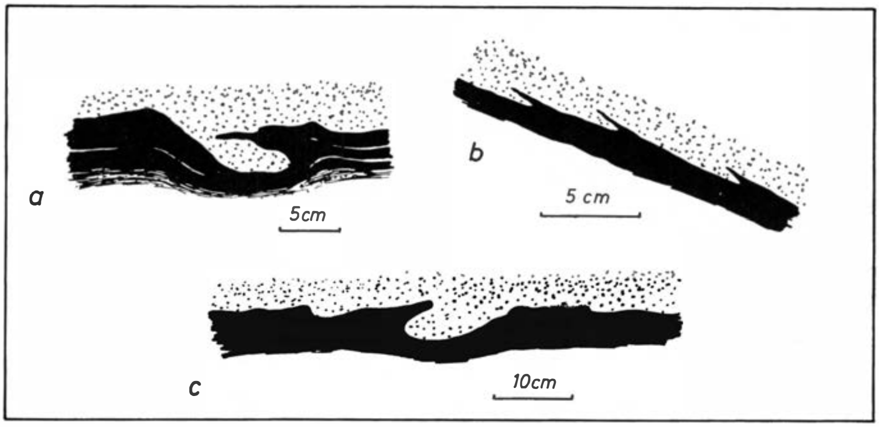

Fig. 4. Load casts and flame structures, Hellefjord Schist Group: (a) drawn from photograph, (b) and (c) field sketches.

Other structure: On account of the high grade of metamorphism it has generally not been possible to detect any other sedimentary structure or lamination in the psammites, but within the transitional zone grading into phyllite and locally within the phyllite itself, laminae of paler (coarser) metasediment are sometimes observed. These may be $\leq$ 1 mm in thickness and are usually discontinuous.

In one locality near Gamvik asymmetrical current ripple marks have been observed on the upper surfaces (or just below the upper surface) of three psammite bands (Fig. 5). The 'way-up' of the sequence is known from grading and load-casting in this same area, so that these ripples are undoubtedly of the depositional and transverse type similar to those depicted by Kuenen & Carozzi (1953). While a determination of the direction of current flow is here severely hampered by the complexities of folding, a flow towards a direction between WNW and NNW is conjectured; this would be roughly normal to the supposed axial trend of the sedimentation trough (p. 242).

The Gamnes slide-conglomerate: A lithology with the appearance of a complexly deformed conglomerate is present at Gamnes headland, some 100—130 m above the base of the Hellefjord Schist Group. Although a description is given elsewhere (Roberts 1965, 1967), the main features of this lithology can here be summarized as follows:

a) It is massive, some 8—9 m thick, largely unbedded but with a poor lamination in its upper parts.

b) Fragments are strongly deformed and lineated and consist mostly of fine-grained psammite with subordinate phyllite and other pelitic material: in size they are rarely $>$ 2 cm across in transverse section — maximum size 4 cm $\times$ 15 cm. Matrix fine-grained, semi-pelitic.

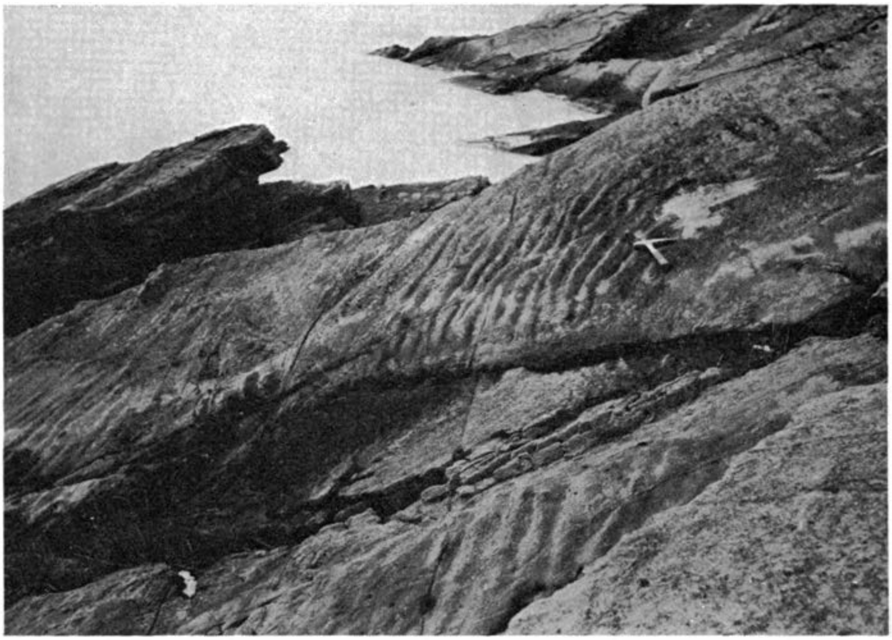

Fig. 5. Transverse current ripple marks on top surface of psammite bed, Hellefjord Schist Group. The currents probably came from the right. Shaft of hammer lies parallel to axes of local F_2 folds (not seen here). Photo looking due north.

c) An indistinct overall grading is perceptible; fragments rapidly become less abundant near the top.

d) Where visible the base is irregular with apparent channelling into the underlying laminated psammite.

Despite the limited outcrop at the very tip of Gamnes, it is thought that this confused lithology is of rather restricted lateral extent. It has been found neither immediately to the N. E. along the strike on the eastern shore of Sandbukten nor anywhere else at a comparable stratigraphical level. In this Sandbukten—Gamnes area the Hellefjord Schist Group is of a more irregular lithological character comprising semi-pelitic schists with phyllites and psammitic bands. Since the conglomerate fragments are composed almost entirely of these same metasediments, particularly of a psammite which immediately underlies the lithology in question, and in view of the irregular channelled base and limited lateral extent of this rock-type, it seems highly likely that this is a metamorphosed and deformed slump lithology, in all probability a slide conglomerate.

CONDITIONS OF DEPOSITION

Taking the Söröy stratigraphy as a whole, many of the lithological and sedimentary features described in the Hellefjord Schist Group are unique and necessarily suggest a derivation in a depositional environment differing appreciably from that (or those) in which the older metasediments were laid down. Although fossils have not been found, the presence of grading and other primary structures, a slide-conglomerate, and the considerable extent of individual beds point strongly in favour of a marine origin. Furthermore, the accumulated evidence is, in the writer's opinion, suggestive of the psammite units of this Hellefjord Schist Group having been deposited by turbidity currents in fairly deep water.

Much has been written about the concept of turbidites since the initial application of the turbidity current hypothesis (Kuenen & Migliorini 1950), and a bibliography dealing with this subject has been presented by Kuenen & Humbert (1964). On attempting a comparison between the present rhythmic sequence of psammites and pelites and the features of the typical turbidity series described by e.g. Kuenen & Carozzi (1953) and Ten Haaf (1959), the Hellefjord Schist Group is put at a disadvantage because of its strong metamorphism and recrystallisation. Accordingly, some of the characteristics accepted for the recognition of a deep-water turbidite cannot be observed. In spite of these disadvantages it is interesting to compare the features described above — for the Hellefjord Schist Group — with those listed by Kuenen & Carozzi (1953) for coarse deep-water deposits of turbidity current origin. Analogies are found in:

1. The interstratification of fine-grained and coarser grained beds.
2. The regularity and plane-parallel nature of the banding.
3. An absence of shallow water characteristics, cross bedding, channel scouring, wave ripples, etc.
4. The presence of graded bedding.
5. The frequently well-defined lower boundaries of psammite bands, and gradational upper boundaries.
6. The occurrence of load casts and flame structures.
7. The presence (uncommon in this case) of pelite clasts in the basal parts of psammites.
8. The thicker psammite bands are generally of coarser grain than thin psammites.
9. The occurrence of a slide-conglomerate within the general sedimentary sequence.

These several features would appear, therefore, to point towards the interpretation of the Hellefjord Schist Group psammites as being of deep-water turbidity origin. Although the recognition of other criteria such as the degree of sorting and fossil evidence has been precluded by the strong recrystallization, it is significant to note that features arguing against a bathyal origin have nowhere been found.

The precise character of the original sediments which gave rise to the present quartz-amphibole schist (psammite) and garnet-biotite phyllitic schist is a matter of some conjecture. It is not unreasonable to suppose, however, that in view of its consistent amphibole-bearing nature, the psammite represents a metamorphosed partly calcareous sandstone or even perhaps a variant of greywacke. The interturbidite phyllite of the present sequence is thought to have been derived from a pelagic mud-type sediment. An interesting feature is that the garnet porphyroblasts commonly contain an inclusion fabric which clearly predates that of the phyllite groundmass and which is of extremely fine grain. This fabric dates from the incipient greenschist facies metamorphism, prior to the development of the present schistosity, and could possibly be regarded as approaching the grain-size and general fabric of the original lithified sediment.

It is generally accepted that a turbidity current can only develop on a declivity, then following the direction of maximum slope 'even when it is less than 1 in 1,000' (Kuenen 1964). Both the grain-size and bed thickness of turbidites tends to decrease as the distance of travel increases, a relationship which has led to the concept of distal and proximal resedimentation (e. g. Wood & Smith 1959, Walker 1967). In a recent article Walker (1967) has listed a series of features characteristic of turbidites and differentiated them according to proximal and distal environments of deposition. According to Walker it is well-established that 'changes with increasingly distal conditions include: (1) reduction in bed thickness, (2) reduction in grain-size, (3) increase in bedding regularity, (4) increase in proportion of laminae and cross-laminae, (5) increase in proportion of well-developed graded beds and (6) reduction in abundance and depth of erosion'. Furthermore, in distal turbidites individual sandstone beds rarely amalgamate, whereas amalgamation is a common feature of proximal conditions. When the features of the psammites of the Hellefjord Schist Group are examined comparatively against these criteria, they fall quite readily into the distal category.

Summarizing the various evidence, it is suggested that the Hellefjord Schist Group psammites were deposited mostly as distal turbidites in a generally pelagic bathyal environment, with mudstone or siltstone as the probable autochthonous sediment. The source of the clastic material available for resedimentation was thus relatively far away, and it is probable that deposition occurred on a near-horizontal sea-floor or else on an exceedingly gentle slope within a large basin. Local thickening of the psammitic bands at the expense of the pelite could be interpreted as indicating either a temporarily increased proximity of environment or an intensification of turbidity current development; both these suggested causes imply limited instability of the sedimentary basin. The presence of the slide-conglomerate towards the base of the group is quite significant as, in that southern area at least, it is possible that it may have heralded a changing depositional environment. Below the horizon of this slide, lithology turbidites are not especially well developed; they become increasingly important, however, above the conglomerate. Further north, the situation is somewhat different as there a regular turbidite/pelite series appears to have been developed slightly lower down in the succession. An interpretation of these changes follows below.

TECTONO-ENVIRONMENTAL CONSIDERATIONS

A necessity in any palaeogeographical reconstruction is a thorough knowledge of the lithologies involved, combined with information gleaned from directional sedimentary structures. While it is possible here, on considering the various metasediments, to recognise changes of sedimentary pattern with time, little information can be compiled on palaeocurrent directions. This is because of the rapid variations within the massive quartzites (Klubben Quartzite Group) and scarcity and ambiguity of observations in the Hellefjord Schist Group turbidites, and secondly because the protracted deformation history would cause considerable difficulties in establishing the true pre-tectonic current directions.

The current flow direction, or range of directions, suggested from an examination of the transverse current ripples (p. 237) is approximately normal to the supposed trend of the depositional trough, but this information is of little use without a knowledge of current flow deduced from erosional sole-structures. It is quite possible that the currents responsible for the transverse ripples may have flowed in a direction almost orthogonal to that indicated by erosional structures on the basal surfaces of psammite bands; such directional divergence has been emphasized by several workers (e. g. Prentice 1960, Kelling 1962). Furthermore, the possibility that the ripple marks may be ascribed to ocean-bottom currents — as distinct from the main turbidity currents — cannot be ruled out (Craig & Walton 1962, Hubert 1967), but the evidence available from N. E. Söröy is, however, far too scanty for any conclusions to be reached on this problem. An allied problem is the actual provenance of the material constituting the turbidites. Here again, tectonic compexity coupled with lack of palaeocurrent directional evidence makes a determination of the main source area, or areas, well nigh impossible.

The salient litho-environmental features are as follows. The quartzites of the Klubben Quartzite Group display striking and quite abundant examples of tabular tangential cross bedding (Potter & Pettijohn 1963), herringbone cross lamination and locally, scour- and fill-structures, and would appear to have been deposited in a rather shallow water environment. Both the Storelv Schist and Falkenes Limestone Group are considered to be representative of quieter, relatively shallow water 'shelf-sea' deposition, with probable temporary and local sub-aerial conditions (Roberts 1965).

A general and fairly sudden deepening of the sedimentary basin is then thought to have taken place with deposition of the Hellefjord Schist sequence of turbidites and autochthonous sediments. The appearance of this association, as already noted, seems to have been slightly earlier in the northern part of N. E. Söröy than further south (e. g. near Sandbukten). This suggests that at this time a shallow water environment existed in the south (with a possible shoreline further to the south or south-east). Before long, however, this environmental difference was erased, as indicated by the occurrence of the Gamnes slide-conglomerate which reflects a marked change in the sedimentation conditions. This slide lithology was formed subaqueously on an unstable slope concomitant with a sudden deepening of the basin, and was followed by extensive turbidite sedimentation.

The picture is thus of a deepening trough accumulating considerable thicknesses of turbidite and autochthonous pelagic sediment, the deeper water extending south with time. Taking the full stratigraphy into consideration, changing environments of sedimentation can be recognized (from littoral and/or neritic to bathyal) which appear to be related to a developing geosynclinal basin. That the complex tectonic activity affecting the Eocambrian-Cambrian rocks of Söröy can be dated to late Tremadocian—early Ordovician times has been fairly convincingly demonstrated by Sturt et al. (1967). This would therefore seem to fit in well with the generally accepted supposition that many turbidite formations — in this case the Hellefjord Schist Group — represent the latter stages of pre-orogenic cycles (Bouma 1964).

REGIONAL IMPLICATIONS

Sturt et al. (1967) have recently correlated the Klubben Quartzite Group with the upper part of Reading's (1965) Vestertana Group and lower part of the succeeding Digermul Group from Tanafjord, East Finnmark. This particular segment of the E. Finnmark succession is regarded as mainly Eocambrian but extending up into the Lower Cambrian, although it is possible that the Eocambrian-Cambrian boundary may eventually be placed within the uppermost Vestertana Group. If Sturt's correlation is valid then the younger members of the Söröy succession, including the Hellefjord Schist Group, would be equated with part or most of Reading's (1965) Kistedal Formation. If this is so, then shallower water conditions probably existed in Eastern Finnmark at the time of the turbidity current deposition (Hellefjord Schist Group) in deep water in the Söröy region.

In this regard, Reading's (1965) comments on the metamorphic complex of Laksefjord (Føyn 1960) are not without interest. He tentatively considered this metasedimentary sequence as possibly representing 'the basinward equivalent of the Tanafjord sediments' although, as yet, 'no precise correlation can be made'.

The indications are, therefore, that the more central parts of the Middle to Upper Cambrian geosynclinal trough were situated in the coastal West Finnmark region, the basin having a general NE-SW trend; this latter point has also been suggested by Holtedahl (1920).

Evidence of a relative uniformity of Eocambrian-Cambrian sedimentary conditions over what is now West Finnmark is provided by the stratigraphy erected by Ball et al. (1963) from the Loppa-Andsnes area 50 km S. W. of Söröy, so much so that this succession and that from Söröy can be correlated without much difficulty (Roberts 1967). Unfortunately the pelites above the equivalent of the Falkenes Limestone Group in the Loppa-Andsnes area are of rather restricted occurrence, and consequently a sedimentary gestions for its improvement.

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REFERENCES

APPLEYARD, E. C. 1965: A preliminary description of the geology of the Dönnesfjord area, Söröy. *Norges Geol. Unders. 231*, 144-164.

BALL, T. K., GUNN, C. B., HOOPER, P. R. & LEWIS, D. 1963: A preliminary geological survey of the Loppen District, West Finnmark. *Norsk Geol. Tidsskr. 43*, 215-246.

BOUMA, A. H. 1964: Turbidites. In BOUMA, A. H. & BROUWER, A. (eds.), *Turbidites*. Elsevier, Amsterdam, Netherlands, pp. 247-256.

CRAIG, G. Y. & WALTON, E. K. 1962: Sedimentary structures and palaeocurrent directions from the Silurian rocks of Kircudbrightshire. *Trans. Edinb. Geol. Soc. 19*, 100-119.

FÖYN, S. 1960: Tanafjord to Laksefjord. In: *Aspects of the Geology of Northern Norway*. Ed. J. A. DONS, Guide to excursion A3, XXI Intern. Geol. Congress, Norden 1960 (N.G.U. 212a), 45-55.

HOLTEDAHL, O. 1920: Paleogeography and diastrophism in the Atlantic-arctic region during Paleozoic time. *Amer. Jour. Sci.* (*4th Ser., 49*), 25 pp.

HOLTEDAHL, O. 1944: On the Caledonides of Norway. *Det Norske Vidensk.-Akad., Skrifter, Kl. I, 1944, No. 4*, 31 pp.

HOLTEDAHL, O. & DONS, J. A. 1960: Geologisk kart over Norge. *Norges Geol. Unders. 208*.

HUBERT, J. F. 1967: Sedimentology of Prealpine flysch sequences, Switzerland. *Jour. Sed. Petrol. 37*, 885-907.

KELLING, G. 1962: The petrology and sedimentation of Upper Ordovician rocks in the Rhinns of Galloway, south-west Scotland. *Trans. Roy. Soc. Edinb. 65* (6), 107-137.

KUENEN, P. H. 1953: Graded bedding with observations on Lower Palozoic rocks of Britain. *Verhandel. Koninkl. Ned. Akad. Wetenschap, Afdel. Natuurk., Sect. I, 20* (3), 1-47.

KUENEN, P. H. 1964: Deep-sea sands and ancient turbidites. In: BOUMA, A. H. & BROUWER, A. (eds.), *Turbidites*. Elsevier, Amsterdam, Netherlands, pp. 3-33.

KUENEN, P. H. & CAROZZI, A. 1953: Turbidity currents and sliding in geosynclinical basins of the Alps. *Jour. Geol. 61*, 363-373.

KUENEN, P. H. & HUMBERT, F. L. 1964: Bibliography of turbidity currents and turbidites. In BOUMA, A. H. & BROUWER, A. (eds.), *Turbidites*. Elsevier, Amsterdam, Netherlands, pp. 222-246.

KUENEN, P. H. & MIGLIORINI, C. I. 1950: Turbidity currents as a cause of graded bedding. *Jour. Geol. 58*, 91-127.

PETERSEN, K. 1868: Geologiske Undersögelser i Tromsö Omegn. *Kongl. Norske Vidensk. Selsk. Skr. 5*, 113-250.

PETERSEN, K. 1873: Om de inden Tromsö og Finmarkens Amter optrædende Bergslag. *Geol. Fören. Forhandl., Stockholm, 1, No. 14*, 274-280.

PETERSEN, K. 1883: Bidrag til de norske kystströgs geologi, III. *Archiv f. Math. og Naturv. 8*, 322-370.

POTTER, P. E. & PETTIJOHN, F. J. 1963: *Paleocurrents and basin analysis.* Springer-Verlag, Berlin, 296 pp.

PRENTICE, J. E. 1956: The interpretation of flow markings and load-casts. *Geol. Mag. 93*, 393-400.

PRENTICE, J. E. 1960: Flow structures in sedimentary rocks. *Jour. Geol. 68*, 217-225.

RADOMSKI, A. 1958: The sedimentological character of the Podhale flysch. *Acta Geol. Polon. 8*, 335-410.

RAMSAY, D. M. & STURT, B. A. 1963: A study of fold styles, their associations and symmetry relationships, from Söröy, Northern Norway. *Norsk Geol. Tidsskr. 43*, 411-431.

READING, H. G. 1965: Eo-Cambrian and Lower Paleozoic geology of the Digermul Peninsula, Tanafjord, Finnmark. *Norges Geol. Unders. 234*, 167-191.

ROBERTS, D. 1965: The structure and metamorphic petrology of the Eocambrian rocks of the Langstrand area, Söröy, Northern Norway. *Unpublished Ph. D. thesis.* Univ. of London.

ROBERTS, D. 1967: The structural and metamorphic history of the Langstrand-Finfjord area, Söröy, N. Norway. *Norges Geol. Unders. 523.*

STUMPFL, E. F. & STURT, B. A. 1965: A preliminary account of the geochemistry and ore mineral parageneses of some Caledonian basic igneous rocks from Söröy, Northern Norway. *Norges Geol. Unders. 234*, 196-230.

STURT, B. A. & RAMSAY, D. M. 1965: The alkaline complex of the Breivikbotn area, Söröy Northern Norway. *Norges Geol. Unders. 231*,

STURT, B. A., MILLER, J. A. & FITCH, F. J. 1967: The age of alkaline rocks from West Finnmark, Northern Norway, and their bearing on the dating of the Caledonian orogeny. *Norsk Geol. Tidsskr. 47*, 255-273.

TEN HAAF, E. 1959: Properties and occurrence of turbidites. *Geol. Mijnbouw 21*, 217-222.

UNRUG, R. 1963: Istebna Beds—a fluxoturbidity formation in the Carpathian Flysch. *Ann, Soc. Géol. Pologne 33* (1), 49-92.

WALKER, R. G. 1966: Shale Grit and Grindslow Shales: transition from turbidite to shallow water sediments in the Upper Carboniferous of northern England. *Jour. Sed. Petrol. 36* 90-114.

WALKER, R. G. 1967: Turbidite sedimentary structures and their relationship to proximal and distal depositional environments. *Jour. Sed. Petrol. 37*, 25-43.

WOOD, A. & SMITH, A. J. 1959: The sedimentation and sedimentary history of the Aberystwyth Grits (Upper Llandoverian). *Quart. Jour. Geol. Soc. Lond. 114*, 163-195.