Innerelv Member: Late Precambrian Marine Shelf Deposit, East Finnmark

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Banks. N. L. 1973: Innerelv Member: late Precambrian marine shelf deposit, East Finnmark. *Norges geol Unders. 288*, 7–25.

The Innerelv Member forms part of the succession between the late Precambrian tillites and the Lower Cambrian rocks in eastern Finnmark and it has a considerable lateral extent. It is about 300 m thick in the Tanafjord area but thins to 70 m to the west, at the head of Laksefjord. It can probably be correlated with Member II of the Dividal Group at Halkkavarre 60 km to the southwest (Føyn 1967). Apart from a complex basal zone the Member can be divided into six facies, the first five of which form a gradational series from mudstones with siltstone laminae through thinly bedded, parallel sided siltstones and very fine sandstones to lenses of intercalated sandstone, siltstone, and mudstone. These five facies represent a series of environments of gradually increasing energy and it is suggested that this energy was related to depth and proximity to a shoreline. The siltstones and sandstones were possibly deposited by currents generated by the backflow of storm surges from an otherwise low energy coastline.

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Introduction

In East Finnmark the rocks lying between the late Precambrian Upper Tillite Formation and the Lower Cambrian Breivik Formation are known as the Stappogiedde Formation (Reading 1965, Banks et al. 1971). The middle of the three members of the Stappogiedde Formation is known as the Innerelv Member. This name was proposed by Banks et al. (1971) for the blue-green and red-violet slate member of Reading (1965). Outcrops of the Innerelv Member extend from the eastern side of the Varanger Peninsula (Røe 1970) to Kunes at the head of Laksefjord (Føyn 1960) (Fig. 1) and the Member can very probably be correlated with member II of the Dividal Group at Halkkavarre 60 km further to the southwest (Føyn 1967, Banks et al. 1971).

The Innerelv Member consists mainly of red and green mudstones with subordinate rippled siltstones and very fine sandstones. It reaches its maximum thickness, now thought to be about 300 m, on the Digermul Peninsula and thins southwestward to only 70 m at Kunes and Halkkavarre. The transition from the underlying Lillevatn Member into the Innerelv Member has been described at several localities (Føyn 1937, Reading & Walker 1966, Banks 1971). The sequence has been interpreted as a transgressive one from the fluvial conditions of the upper part of the Lillevatn Member into the quiet marine conditions of the Innerelv Member (Reading & Walker 1966). This transgression initiated Dividal Group sedimentation in eastern and central

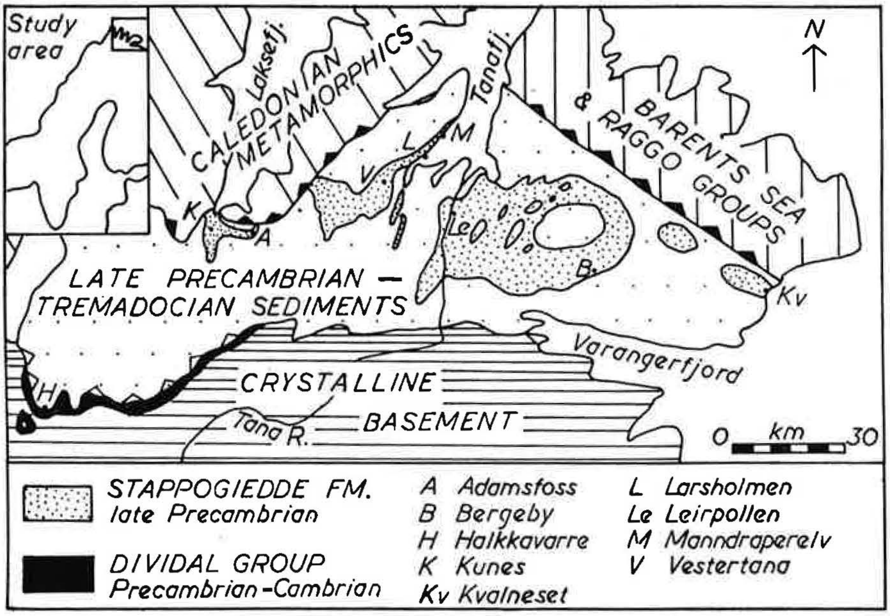


Fig. 1. Geological map of east Finnmark showing the outcrops of the Dividal Group and the Stappogiedde Formation, which includes the Innerelv Member. After Føyn (1937, 1967), Reading (1965), Beynon et al. (1967), Siedlecka & Siedlecki (1967), and Røe (1970).

Finnmark. The lowest 5 m of the Innerelv Member is variable in lithology, containing sandstones and conglomerates as well as red siltstones and mudstones. Characteristically it fines upward. Above this complex basal zone, which has been described in detail by Banks (1971) and will not be considered further here, the Member can be defined in terms of six facies, the first five of which form a gradational series.

The purpose of this paper is to give detailed descriptions of these six facies of the Innerelv Member and to discuss briefly their environment of deposition A fuller discussion of their origin has been given by Banks (1971).

Description

1. FACIES 1: GREEN AND RED MUDSTONE

Description

This facies consists of green and red strongly cleaved mudstone with very thin parallel laminae of siltstone which are laterally persistent. Very rarely cross-laminated siltstones and sandstones up to 25 cm thick are found. The mudstone is calcareous and occasionally very thin, brown-weathering beds within it are composed of > 50% of fine-grained ferroan calcite. In general there is no difference in grain size between red and green coloured beds but where thin green bands occur in a predominantly red sequence they are often slightly coarser or contain some coarser beds.

Interpretation

This facies was deposited under very quiet conditions with deposition of fine-grained material entirely from suspension. The origin of the carbonate is an enigma. Possibly it is derived from the shells of planktonic micro-organisms but alternatively it may have formed largely from the diagenetic alteration of the terrigenous fraction. The thicker beds of siltstone and sandstone testify to the occasional presence of strong currents.

2. FACIES 2: PARALLEL LAMINATED SILTSTONE

Description

This facies consists of parallel laminated green siltstone interbedded with mudstone (Fig. 2). The laminae are up to 2 cm thick and are laterally persistent. Internally the laminae are either massive or show fine parallel laminations; small scale cross-lamination is occasionally seen and its orientation is usually unidirectional. Small burrows are sometimes found in this facies (Banks 1970, Fig. 3a) but bioturbation has had virtually no effect on the sedimentary structures. This facies is gradational between Facies 1 and 3.

Fig. 2. Facies 2: parallel laminated siltstone with interbedded mudstone: about 145 m in Manndraperelv Section.

Fig. 3. Facies 3: laminae and very thin beds of siltstone and very fine sandstone: about 115 m in Manndraperelv Section.

Interpretation

Deposition of the parallel laminated siltstone probably occurred primarily by fall out from suspension but occasionally currents were sufficiently strong to cause bed load transport as small scale migrating ripples, thus producing cross-lamination.

3. FACIES 3: VERY THIN-BEDDED SILTSTONES AND VERY FINE SANDSTONES

Description

This facies consists of laminae and very thin beds of green-grey siltstone, silty sandstone, and very fine sandstone with subordinate interbedded mudstone (Fig. 3). The beds are mostly less laterally continuous than those of Facies 2, usually dying out within 5 m, and they pinch and swell in thickness. Internally they mostly have an irregular wavy cross-lamination, but thinner beds are parallel laminated. Bedding surfaces show asymmetrical and very occasional symmetrical ripples, the latter always seeming to have formed as a modification of an earlier bedform. Cross-lamination is apparently unidirectional but it is often difficult to measure accurately. Bioturbation is rarely present in this facies, which is intermediate between Facies 2 and 4.

Interpretation

The increased grain size and abundance of cross lamination in these beds suggest that they were deposited from stronger currents than those which deposited the beds of Facies 2. The presence of symmetrical ripples, which are absent in Facies 1 and 2, shows that wave activity was capable of modifying the sea floor.

Fig. 4. Facies 4: a band of thin- to thick-bedded sandstones underlain by beds of Facies 3 and overlain by beds of Facies 2. Manndraperelv Section, 110–140 m.

4. FACIES 4: THIN TO THICK-BEDDED SANDSTONES AND SILTSTONES

Description

Sharp-based, green-grey, very fine sandstones, silty sandstones, and siltstones (Figs. 4, 5) occur as beds from 3 to 100 cm thick interbedded with thinner-bedded siltstones. Whilst the thin beds are mostly parallel sided and moderately laterally continuous, the thicker ones are sometimes markedly lenticular and fill steep-sided channels a few metres wide. In one case the beds were seen to be grouped together into discrete packets, all the beds dying out laterally at approximately the same place (Fig. 6).

The bases of beds are poorly exposed but where they were seen no sole marks were found. Internally many beds are slightly graded, particularly in their upper parts. Some beds, particularly siltstones, appear massive but others show cross-lamination and parallel lamination. Where parallel lamination is present it is usually confined to the lower part of the bed and is overlain by cross-lamination. No primary current lineation was seen associated with the parallel lamination. Alternatively cross-lamination is often present throughout the bed; cosets of type A climbing ripples (Allen 1970a) are the most common structures although type B 1 climbing ripples also occur. Palaeocurrent directions are predominantly unimodal but occasional beds show directions 180° apart. Several beds greater than 20 cm thick show various types of contorted stratification, as illustrated in Fig. 5. In all the occurrences of ball and pillow structures (e.g. Fig. 5a) one ball or pillow encompasses the whole vertical thickness of the bed. The laminae within a ball or pillow may be simply curved up or strongly contorted and in some cases bundles of laminae may be truncated by overlying ones, as figured by Sorauf (1965, Fig. 10) in Devonian examples from New York. Although the structures cannot be fully seen in three dimensions the pillows seem to show a strong alignment which is usually perpendicular to the current direction as indicated by cross-lamination. There is no consistent asymmetry to the structures; undeformed beds can often be traced laterally into and out of a zone of deformation. Forms such as Fig. 5b are best described as 'convolute lamination with vertical fold axes'. In all types of deformed lamination the laminae are often truncated at a planar erosion surface at the top of the bed.

Symmetrical ripples are occasionally seen in this facies but bioturbation is very rare. The facies is intergradational between Facies 3 and 5.

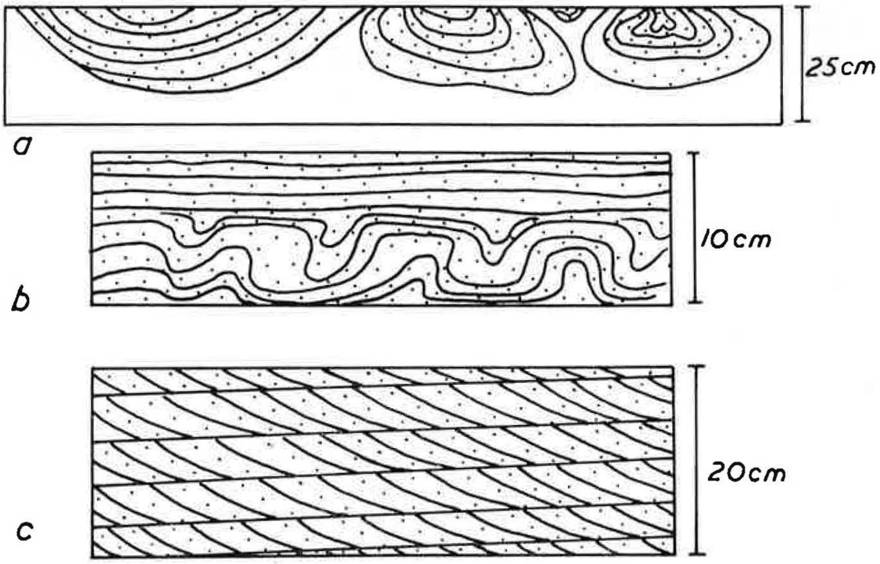


Fig. 5. Sedimentary structures in beds of Facies 4. (a) Ball and pillow structures in a sandstone bed underlain by a mudstone. (b) Convolute lamination in the lower half of a sandstone bed. (c) Sandstone bed with Type A climbing ripples of Allen (1970a).

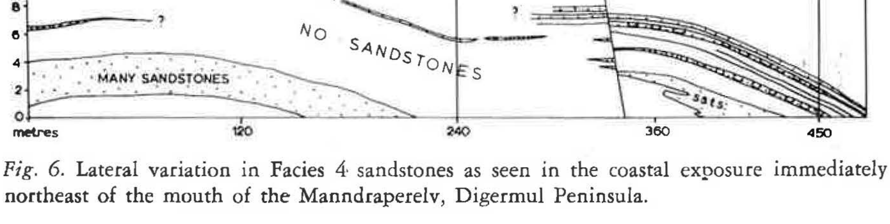


Fig. 6. Lateral variation in Facies 4 sandstones as seen in the coastal exposure immediately northeast of the mouth of the Manndraperelv, Digermul Peninsula.

Interpretation

The sandstones and siltstones were deposited from stronger currents than those which deposited the beds of Facies 3. This is shown by the predominance of sand over silt and the common parallel lamination which is interpreted in most cases as the result of plane bed with movement conditions in the upper flow regime (Simons et al. 1965) even though no primary current lineation was seen. Goldring (1966) noted that this lineation is rarely well seen in beds of this fine grain size. In the majority of instances plane beds are overlain by cross-lamination and thus the beds were deposited by waning currents (Walker 1965). However, since the angle of the climbing ripples is usually approximately constant throughout the cross-laminated division most of each bed was probably deposited within a fairly narrow range of flow power. Given the grain size of very fine sand the absence of dune structures is to be expected (Allen 1970b). The presence of symmetrical ripples shows that this facies was deposited above wave base.

The syndepositional origin of some of the ball and pillow structures is shown by the internal truncations of laminae at the edges of balls. In other cases the truncation at the tops of beds shows that deformation certainly occurred before burial. Thus in contrast to the opinions of Potter & Pettijohn (1963) there is no rigid distinction between ball and pillow structures and load balls.

The orientation of the pillow axes perpendicular to the palaeocurrent direction is problematical. Either the palaeoslope or current shear could have had an effect on controlling this orientation, but there is little evidence of either process.

5. FACIES 5: LARGE LENSES OF IRREGULARLY BEDDED SILTSTONE, SANDSTONE, AND MUDSTONES

Description

This facies consists of lenses of irregularly bedded siltstone, sandstone, and mudstone up to at least 10 m wide and 1·5 m deep, each lens being separated from its neighbours by distinct surfaces of discontinuity (Figs. 7, 8, and Banks et al. (1971) Plate 5 A). The lower bounding surface of each lens is usually concave upward; it is smooth or slightly irregular and rarely dips at more than 10°, except where sandstones form the margin. The upper surface may also be concave upward, forming the base of the next lens or may be flat when overlain by horizontally bedded sediment. The three-dimensional form of the lenses is not clearly seen but they seem to be channel-shaped rather than dish-shaped.

Many different types of sediment occur in rapid alternation within the lenses. These include lenticular rippled laminae and very thin beds of siltstone and very fine sandstone (Facies 3), and thin to medium-bedded lenticular very fine sandstones. The latter are similar to Facies 4, but all are lenticular, wedging out towards the margins of the lenses. Parallel lamination is the predominant internal structure; cross-lamination, if present, is confined to the topmost parts of beds except in thin beds; many varieties of cross-lamination are found. There are also siltstones with wispy subparallel lamination and many other irregularly

Fig. 7. Facies 5': lenses of irregularly bedded sandstone, siltstone, and mudstone: On the left is an erosively-based sandstone and in the bottom right there is a sharp contact between two lenses of siltstone with sandy streaks. About 200 m in the Manndraperelv Section.

bedded siltstones, sandstones, and mudstones, including some beds resembling the silty streak-sandy streak facies of de Raaf et al. (1965, Fig. 9). Sparse palaeocurrent measurements suggest a very varied pattern of sediment transport although an overall bipolar distribution may be present. Symmetrical ripples are apparently orientated roughly perpendicular to the axes of the channel lenses but again the data are meagre. As in other facies the symmetrical ripples formed as modifications of earlier bedforms.

Within a lens the layers are thickest in the middle and wedge out towards the sides; this is true both of the sandstones, which cut channels within, and parallel to, the larger channel lenses, and also of the finer grained sediments, which seem to be draped into the channel lenses. Small rotated slump packets $\leq$ 20 cm occur infrequently within the lenses.

Interpretation

The smooth nature of the lower margins of the lenses, their fill, which is broadly similar to the surrounding sediment, and the draping effect of material within them might suggest that these lenses are slump scars (Laird 1969). However, other evidence suggests that slumping is not the most important process in the production of the lenses:

1) There is a lack of associated rotated slump packets except for very small ones preserved within the lenses.

2) There is a lack of shears or contortions in the sediments immediately beneath the 'scars'.

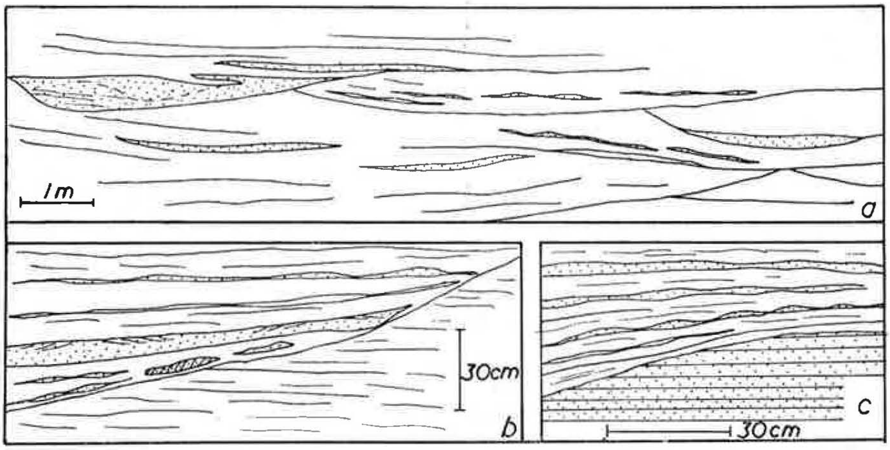


Fig. 8. Sketches of Facies 5 at about 200 m in the Manndraperelv Section. Sandstones are dotted and the blank areas represent siltstones and mudstones with sandy streaks. In (b) the lens with steeply inclined bedding is a slump packet.

3) The fill of the lenses is very variable, which suggests great fluctuations in environmental energy; in particular the presence of erosively based sandstones suggests that there were currents available to produce scours of the observed dimensions.

Thus it is suggested that the lenses certainly have channel-shaped forms and that they formed by infilling of current-eroded scours. In most cases the current which cut the channel deposited little or no sediment within it and the channel was later infilled by sediments mostly deposited under less turbulent conditions. After the initial cutting the margins of the channels were sometimes modified by small scale rotational slumping. The presence of lenticular sandstone beds orientated parallel with the channel axes suggests that the open or partly filled channels acted as funnels for further sediment transport. The predominant parallel lamination in these lenticular sandstone is interpreted as the result of plane bed movement in the upper flow regime and thus these beds were deposited from stronger currents than those which deposited the sandstones of Facies 4.

The presence of symmetrical ripples indicating wave activity at the sea bed, combined with the generally irregular, rippled nature of the bedding implies a fairly shallow water environment for this facies, and one in which there were great variations in the strengths of currents and possibly waves also.

6. FACIES 6: BLACK LAMINATED SILTSTONE

Description

This facies is distinguished from all others by its colour, which is due to pyrite which can be seen as small cubes within the coarser laminae. The facies consists mainly of flat, very thin, grey laminae of coarse siltstone intercalated with darker, finer siltstone. However, in some parts this lamination occurs in discontinuous wavy sets (Fig. 9) in which there is frequent evidence of truncation of laminae. There is no evidence of biogenic activity in this facies.

Fig. 9. Facies 6: wavy laminated black siltstone. Manndraperelv section, 220 m.

Interpretation

The general environment was obviously one of fairly quiet water but in the beds with truncated sets of laminae scouring of the sea bed is evident. The irregular 'scoopy' appearance of this scouring suggests that it might have been produced by wave activity. The bedding may have been produced by the stirring up of the sea floor and suspension of sediment during storms followed by redeposition as the storm died down. The flatly laminated sediment could also have been deposited by settling of storm-stirred material transported from other areas by weak wave-induced currents; however, alternatively it could have been deposited by some other weak current, as was the sediment of Facies 1 and 2. The factors which caused a reducing environment within these sediments and hence the development of pyrite are not understood. The absence of biogenic activity is probably due to the scarcity of animals capable of burrowing into the sediment at that time (Banks 1970) rather than to the presence of an anaerobic environment.

7. SANDSTONE PETROGRAPHY

The very fine sandstones of Facies 4 and 5 are well-sorted subarkoses (McBride 1963) with a cement of iron bearing carbonate, microcrystalline quartz, and small amounts of chlorite. The original grain boundaries have been lost because of pressure solution and attack by the carbonate cement. In the silty sandstones the sorting is less good and the coarser particles float in an ill-defined matrix of chlorite, sericite, clay minerals, and fine-grained carbonate and quartz. Again, the original grain boundaries have been considerably modified.

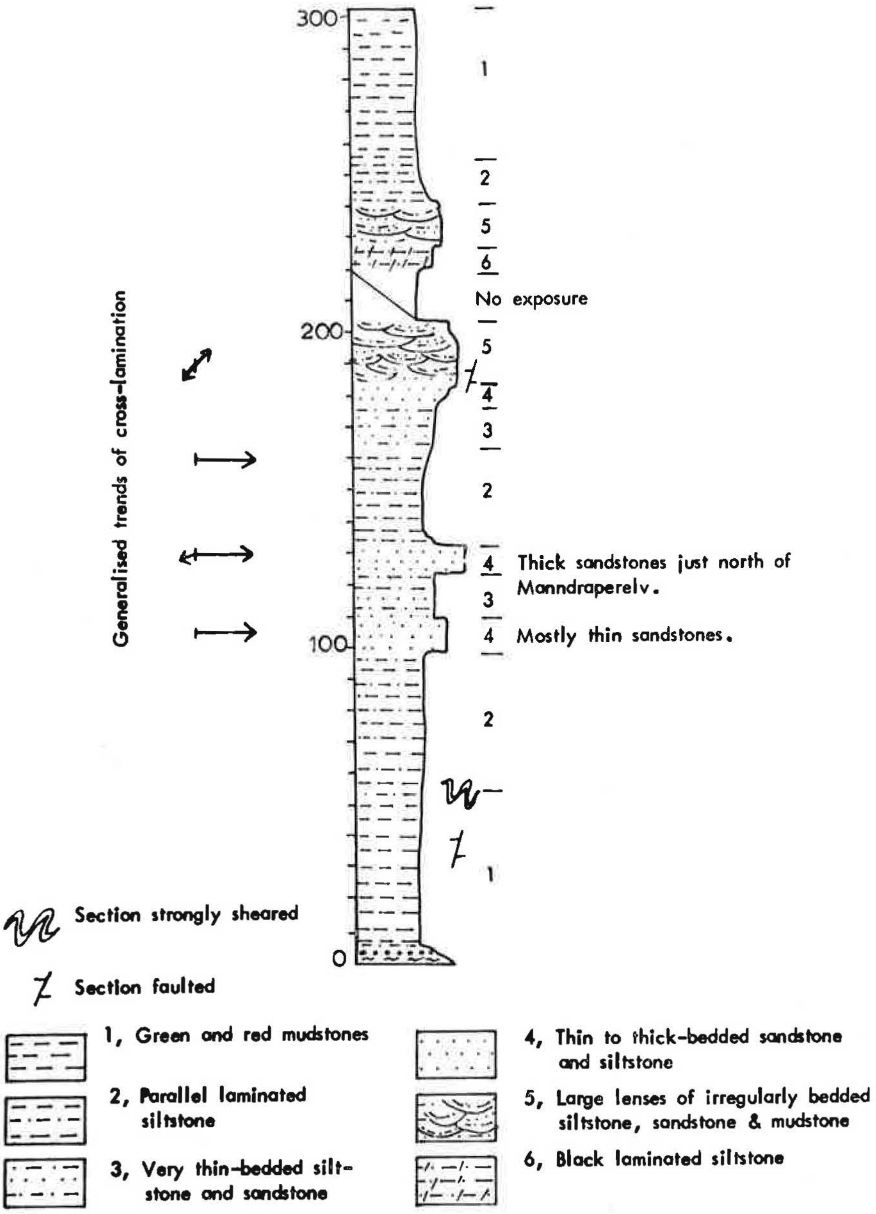


Fig. 10. The Manndraperelv section of the Innerelv Member.

8. MEASURED SECTIONS

The main section of the Innerelv Member is the coastal section on the SE side of the Digermul Peninsula immediately SW and NE of the mouth of the Manndraperelv. The base of the section is the 'Areholmen' section described by Reading & Walker (1966, p. 101). The section is shown in Fig. 10 and exact details of the localities are given in the Appendix. In broad outline two coarsening upward sequences (5–130 m, 130–205 m) are present, followed by a

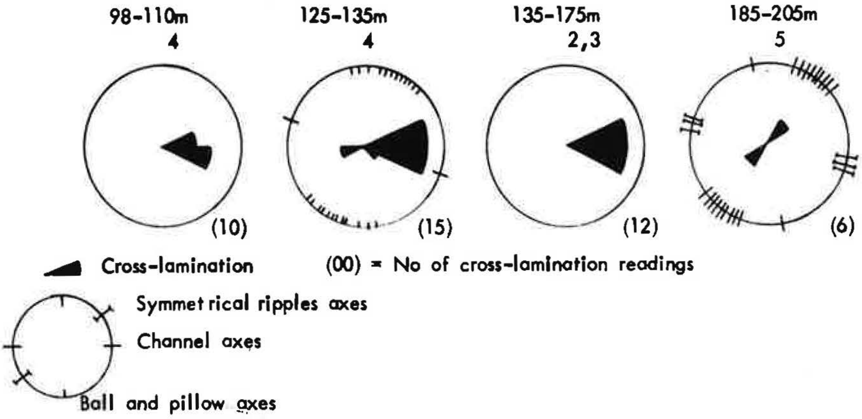


Fig. 11. Palaeocurrent data for the Manndraperelv Section.

reversion to finer-grained sedimentation towards the top of the member. Palaeocurrent data (Fig. 11) show a predominantly easterly transport but with some variation.

The lateral variation within this member is summarised in Fig. 12. The most obvious feature is the marked thinning southwestwards from the main (Manndraperelv) section such that the member is about 80 m at Adamsfoss and 70 m at Kunes and Halkkavarre. Eastwards from the main section the thicknesses are not so accurately known but the member does not seem to thin more than a little. Characteristically the lowest 10–40 m of the member is red coloured in all the sections and above this it is predominantly green, although turning to red again at the top in some places. A few points about the sections are given below. Exact localities of the sections are given in the Appendix.

Larsholmen

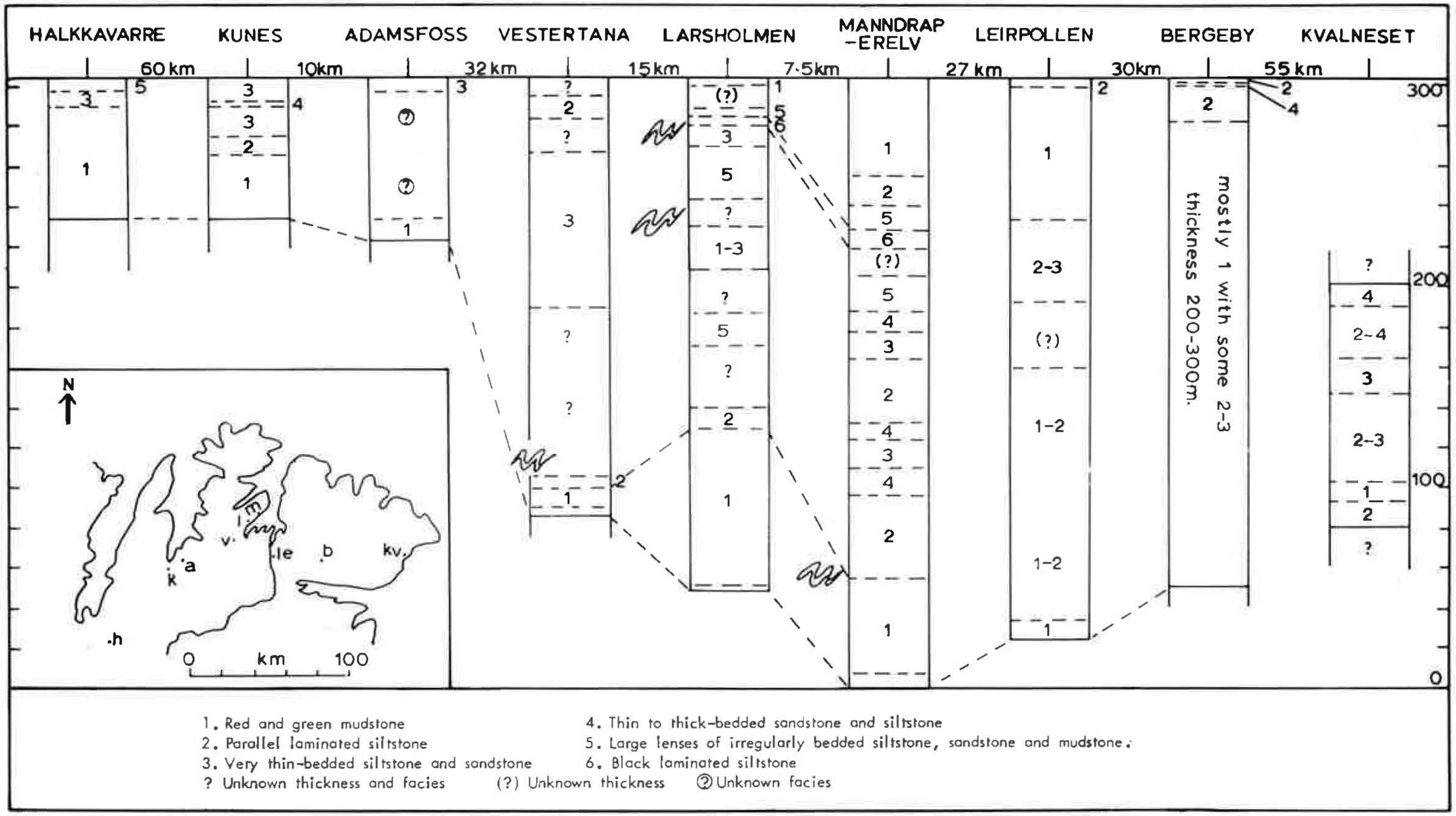
The member is patchily exposed along the shore southwest of Larsholmen and is strongly folded in its upper half so that some of the rocks are inverted. Facies 5 is well developed at two levels but 4 is absent. The uppermost part of the section seems to be very condensed compared with the main section; although this may be partly due to tectonism, a similar, relatively condensed section is also present in the Innerelv valley just to the north and there the rocks are less deformed.

Vestertana

Near the base of the member Facies 1 passes up rapidly into Facies 2 before the section becomes strongly folded. The remainder of the member is poorly exposed except for some localities near the E4 road and thus no estimate of the thickness can be made.

Kunes

In the outcrops south of Kunes (Føyn 1960) there is considerable variation in the thickness and the lithology of the Member, but this is largely due to



1. Red and green mudstone
2. Parallel laminated siltstone
3. Very thin-bedded siltstone and sandstone
4. Thin to thick-bedded sandstone and siltstone
5. Large lenses of irregularly bedded siltstone, sandstone and mudstone.
6. Black laminated siltstone

? Unknown thickness and facies (?) Unknown thickness ⓻ Unknown facies

Fig. 12. Lateral variation within the Innerelv Member including Member II at Halkkavarre.

tectonic complications. In most sections 10 m of red mudstones are overlain by green beds, which become gradually coarser upward. A few beds in Facies 3 show northwesterly dipping cross-lamination. At some localities Facies 1 occurs again in the top 5 m.

Halkkavarre

Member II of Føyn (1967) coarsens upward in the top 15 m and lenticular sandstones occur within largely silt-filled lenses (channels?) in the top 5 m. Small burrows are present on the bases of a few siltstone layers in the upper half (Føyn 1967, Banks 1973).

Leirpollen

In this area much of the member is distinctly calcareous. It is less sandy than on the Digermul Peninsula and no distinct coarsening upward sequences were seen, although the member is coarsest in its middle part. No silt-filled channels (Facies 5) were seen, although Beynon et al. (1967) mention their presence.

Bergeby

The member is patchily exposed in the valleys of the Bergeby and its westerly tributaries, the uppermost part being well seen in Perledalen. The rocks dip very gently northwards and the thickness can only be roughly estimated from the width of outcrop.

Kvalneset

Good exposures on the shore and in the raised cliff are found in the most easterly outcrop of the member. The beds are characterised by the relative abundance of simple burrows above the lowest 30 m of the exposure. However, bioturbation is still very slight compared with most Phanerozoic marine deposits. The Member consists of laterally persistent siltstones and very fine sandstones from a few millimetres to 20 cm thick, intercalated with mudstones and fine sandstones. Symmetrical ripples are absent but asymmetrical ripples are seen on the tops of sandstone beds. The ripples and cross-lamination show a consistent tranport direction to the northwest, a striking contrast to the main section. However, there are no obvious petrographic differences between these two areas.

Neither the base nor the top of the member is present in the coastal section and so it cannot be correlated with other sections.

Summary

In contrast to the two coarsening upward sequences in the Manndraperelv section, only one such sequence is present in the thinner western sections. This may be because only one was developed there, but a possible unconformity at the base of the overlying Manndraperelv Member may have removed some material (Banks et al. 1971, p. 227). On the Varanger Peninsula the succession is finer grained than on the Digermul Peninsula except at Kvalneset in the extreme east and no clear pattern of coarsening upward sequences was seen.

Discussion

Facies 1–5 make up a continuous sequence of increasing current and wave activity. Assuming that wave activity is related to water depth this sequence can be interpreted as a result of shallowing of the sea, and it can also be inferred that current activity fell off gradually with depth. In several sections the facies are arranged in more or less regular shallowing, and thus coarsening upward, sequences (e.g. two coarsening upward sequences in the Manndraperelv Section, one at Halkkavarre). By assuming that these coarsening upward sequences represent the superposition of laterally equivalent facies as a result of progradation a model can be developed for the ways in which sediment was transported with the system.

In Facies 5 sediment was funnelled through narrow channels during periods of strong current activity when transport was largely in an upper flow regime plane bed phase. In Facies 4 transport was still largely confined to channels (e.g. Fig. 6) but they were much wider and the deposits less lenticular. In Facies 3, 2, and 1 deposition occurred effectively as sheets of sand and silt under much lower energy conditions as the currents spread out into deeper water. The sequence of different types of sandstone and siltstone with decreasing current strength are shown in Fig. 13. From its position above and below units of Facies 5 it seems that Facies 6 was probably deposited in shallow water, possibly during periods of cut off supply or in areas sheltered from strong current activity. Given these relationships between the facies it remains to try to estimate values of depth and possibly distance from shore for one facies in order to define the whole system more closely.

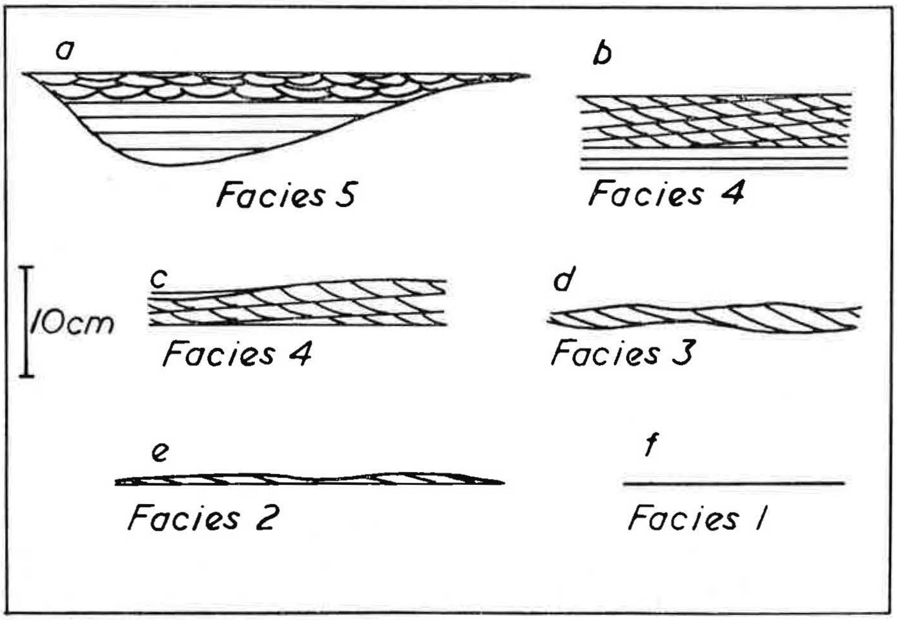


Fig. 13. Idealised sketch showing the gradual changes in bed thickness and sedimentary structures from Facies 1 to Facies 5. a–d = very fine sandstones, e–f = siltstones.

Biogenic features of these late Precambrian rocks give no clues since body fossils are absent and trace fossils are very scarce due to the scarcity of burrowing animals at that time (Banks 1970). Another approach to the problem is by comparing the Innerelv Member with other described sediments whose origins have been discussed. Wunderlich (1970) has described a series of Devonian sediments very similar in some respects to Facies 4–5 and he attributed a shallow marine and tidal flat origin to these beds by comparing them with the modern sediments of the North Sea. The intercalation of lenticular sandstones with irregularly bedded lenses of largely finer material (e.g. Wunderlich's Figs. 27, 28, 37) is very reminiscent of Facies 5 and his more parallel sided sandstones (op. cit. Fig. 32) are similar to Facies 4. However, a tidal flat origin for any part of Facies 4 or 5 can probably be excluded because of the absence of lateral accretion deposits, which are so characteristic of gulley sedimentation in intertidal areas. Richter (1967) described beds from the Devonian of S.W. England which are similar to Facies 4. Lenticular and parallel sided sandstones occur within a shale sequence and the channels are orientated parallel to the inferred shoreline. Shell beds with a diverse offshore fauna and the absence of wave activity led Richter to infer a moderately deep shelf environment and he attributed the presence of the sandstones to tidal currents. The sandstones show some features in common with turbidites, but a turbidity current origin, at least in deep water, is unlikely in view of the evidence of wave activity in Facies 4 and 5 and the complexity of the lithologies in Facies 5.

Thus these comparisons suggest that Facies 4 and 5 might have been deposited in a sub-tidal to moderately deep shelf environment.

Another approach is to attempt to determine from more general reasoning what type of current is most likely to have produced the features of the succession. The following features of the currents seem to be important:

1) Transport direction is unimodal except in the shallower water beds.
2) Currents decrease in strength with increasing depth and possibly, though not certainly, have an offshore component of flow.
3 Sediment transport is channelised in the shallowest water facies but as sheets in deeper water.
4) Currents fluctuate greatly in strength; this is particularly noticeable in the highest energy facies.

Tidal currents are important in sediment transport on many modern continental shelves but the predominance of unimodal rather than bimodal palaeocurrent distributions argues against their importance in the deposition of the Innerelv Member. Another possibility is that the beds were deposited by river generated currents. Walker (1969) has suggested that rivers in flood may be capable of transporting sand far beyond their mouths. However, considering the considerable lateral extent and relatively uniform lithology of the Member such currents would have needed to be exceptionally powerful to overcome the resistance resulting from the greater salinity of the sea water relative to the river water.

Perhaps a more likely origin for the beds is that they were deposited by storm surge currents similar to those described by Hayes (1967) and Gadow & Reineck (1969). These currents are produced by large scale movements of water either onshore or offshore during the passage of a storm over an area. Backflow from onshore water surges can carry near-shore sand considerable distances offshore. It is envisaged that Facies 5 was developed in an immediately sub-tidal environment, the cutting of the channels being due to a localised back flow of water as the storm surge retreats. The sand was largely derived from a shoreline where very fine sand was accumulating. As sand moved further offshore is was no longer confined to channels and spread out as a thin sheet of material. The finest grained material was carried offshore in suspension and finally settled out to give the siltstone laminae of Facies 1. The palaeocurrent pattern is explicable if the main mode is considered to be the offshore direction, whilst some onshore and locally variable transport is to be expected in the shallowest water facies. During fair weather the channels were infilled by finer material.

One objection to this is the absence of any form of intraformational clasts of mud or sand such as might be expected to form during violent storm erosion; this absence cannot be explained by a lack of cohesiveness of the sediment because at least some of the material must have been relatively cohesive to give the small slump packets seen in Facies 5. Nevertheless, accepting the storm surge model as the most likely of the alternatives, the relationships of the various facies to each other and to other postulated facies is synthesised in Fig. 14. This model is rigid in that it demands that sediment supply and the distribution of facies with depth be constant with time. This was probably not the case, as might be shown by the development of Facies 6.

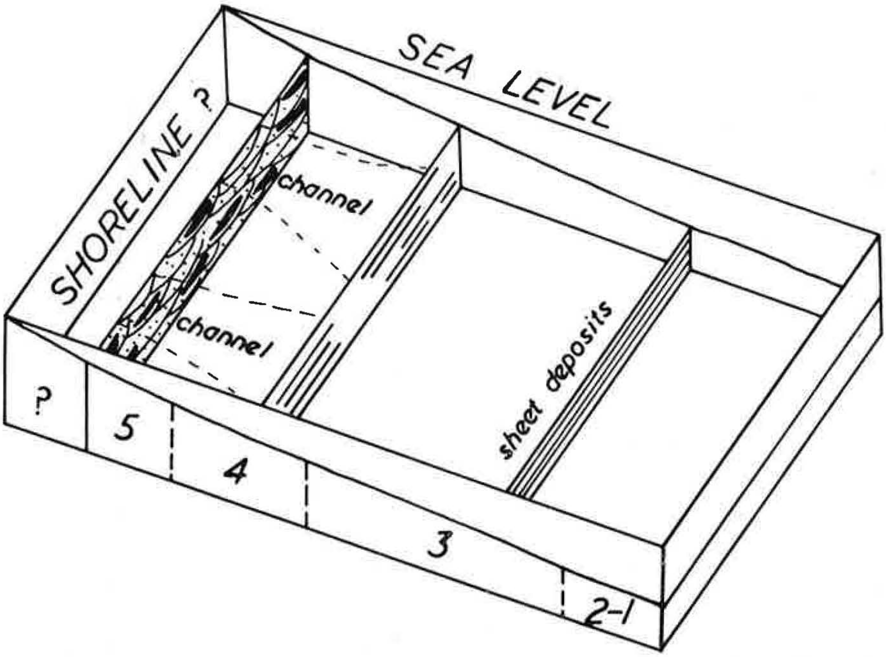


Fig. 14. A model of sediment transport in the Innerelv Member. The numbers refer to the different facies.

If the model has any validity the palaeocurrent data suggest that land areas existed to both the west of the Digermul Peninsula and to the southeast of the Varanger Peninsula.

In conclusion, the beds of the Innerelv Member are believed to have been deposited in a generally quiet, marine, shelf environment in which occasional storm surge currents deposited siltstones and sandstones. Wave activity modified the current deposited sediments in the shallower parts of the basin, but not in the deeper parts.

Acknowledgements. – I am grateful to Dr. H. G. Reading for his help at all stages of this work, which was done during the tenure of a studentship from the Shell International Petroleum Co. Ltd. at the Department of Geology and Mineralogy, Oxford.

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APPENDIX

Note: Grid references given for AMS 1 : 50,000 maps.

Manndraperelv section

The section was measured along the southeast coast of the Digermul Peninsula from opposite the island of Areholmen northeastwards. About 200 m southwest of the mouth of the Manndraperelv the section was measured from the coast up a fault gulley, and the prominent sandstone band (Fig. 4) was correlated with the sandstones outcropping on the coast immediately northeast of the Manndraperelv. The section was then continued along the coastal outcrop until the outcrop fails at about 200 m. The remainder of the section was measured along a traverse directly away from the coast at this point.

Vestertana section

The section is based on outcrops near the road from Vestertana to Ifjord about 8 km west of the head of Vestertana. Map 2235 I 256145 to 230140.

Kunes section

Section measured in a small fault gulley just north of the Fierramelv, a western tributary of the Austerelv, 5 km SSW of Kunes. Map 2315 I 797012.

Halkkavarre section

Locality is the stream section described by Føyn (1967).

Leirpollen section

Measured in and near a small stream flowing into the Tana River directly east of the point 374 m on Lievlamfjeldet between Austertana and Seida. The base of the Member is not exposed here and the section has been completed from other exposures near Leirpollen. Map 2235 I 194985 to 183993.

Kvalneset section

The base of the section is located at the western end of the outcrop and the top is seen on the top of the cliff at the eastern end.