CHAPTER 9

SEDIMENTATION AND PALAEOGEOGRAPHY

9.1 Introduction

The five preceding chapters have each dealt with a major stratographic-sedimentologic unit in isolation from the adjacent units. Below, information from the units is compared and related in order to bring out broader aspects of sedimentation and palaeogeography.

9.2 Smalfjord Tillite at Varangerfjord and Smalfjord

There is a striking contrast in facies between the Smalfjord Tillite at Varangerfjord and Smalfjord. At Varangerfjord, terrestrial braided stream deposits are a dominant facies, as are large-scale delta foresets. Marine deposits are also important, but sedimentation was by gravity driven resedimentation mechanisms such as turbidity currents, slumping and mass-flow. These interpretations suggest that the depositional surface flucuated around sea-level (or vice-versa). Glacial deposits are subglacial and supraglacial: marine glacial deposits with ice rafted clasts were not observed. This suggests that the ice terminus was generally on land and not in the sea.

In contrast, subaqueous glacial deposits are the only important proglacial sediment in the Smalfjord area. Fluvioglacial outwash is scarce. The laminated siltstone with ice rafted clasts suggests that the ice terminus, whether or not developed as an ice shelf, was in the sea. Thus, during interglacials, the Smalfjord area was submerged and subaqueous deposits accumulated, while at Varangerfjord both terrestrial and shallow marine deposits formed.

At Trollfjord subaerial conditions probably followed the retreat of the ice sheet as indicated by the loess.

This, in addition to the presence of possible wave formed ripples in the laminated tillite above, suggests that conditions were shallow compared to those at Smalfjord.

As a generalisation for interglacial conditions, the Varangerfjord area was shallow, near sea-level, Smalfjord was submerged within the basin, and Trollfjord was shallow, but not near a sediment source (fig. 88).

The west and northwest palaeocurrents at Varangerfjord clearly indicate a source to the east and southeast. In the Smalfjord area ice movement was largely to the south suggesting derivation of material from the north.

Intergrating palaeocurrent and facies data, it appears that sediment was brought into the basin from both the north and south (fig. 88). Currents brought material into the basin from the shallow southwest margin, while ice brought material into the basin from the lower lying northern area.

It was stated in Chapter 4 that the Smalfjord Tillite is believed to have been deposited within an ESE-WNW trending trough with crystalline rocks on the southern side, and the Older Sandstone Series on the northern side, similar to the present disposition of lithologies around Varangerfjord. To what extent was this trough filled at the commencement of Nyborg sedimentation? Ripple cross-lamination and soft-sediment deformation in member 1 of the Nyborg Formation indicate a northward dipping palaeoslope. This suggests that a trough did not exist to the south at that time. The presence of flutes indicating flow to the northwest in member 2 of the Nyborg Formation (turbidites), and the absence of coarse grained turbidites in the Bergeby section, but at Nesseby (fig. 17) suggest that the transport direction was west of north, rather than due north.

The presence of both dolomite (derived from member 1 of the Nyborg Formation) and terrigenous quartz, feldspar and

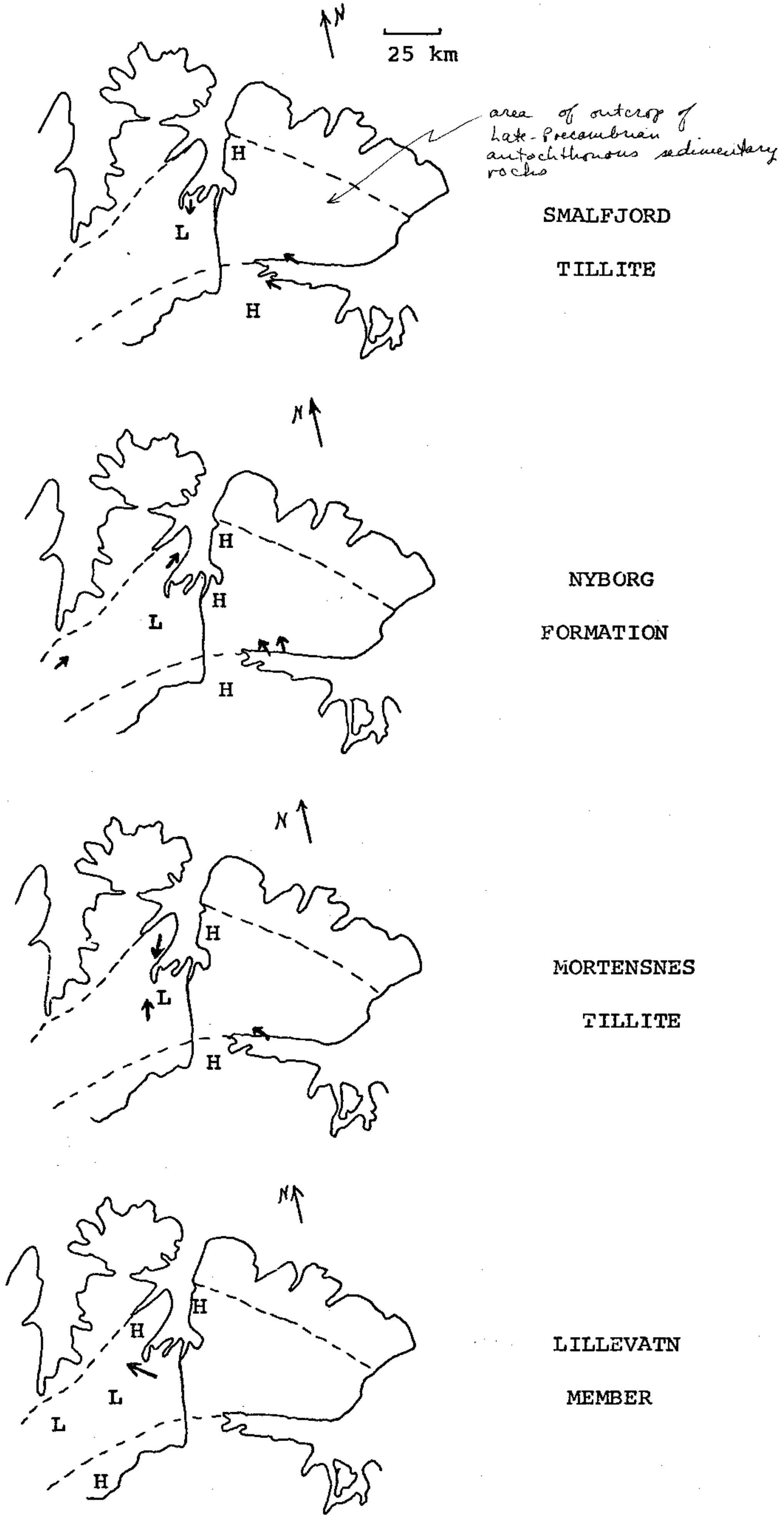

Figure 88. Summary of Palaeocurrents and Palaeogeography for the sediments related to the late Precambrian glaciation. H=high, L=low.

other minerals in member 2 turbidites and fluxoturbidites suggests that member 1 dolomite was eroded in shallow water rather than having been buried and preserved by quiet water deposits as happened in the Vestertana area. A possible explanation for this is isostatic uplift of the basin margins upon which dolomite had been deposited during the postglacial transgression.

9.3 Smalfjord and Mortensnes Tillites

As mentioned in Chapter 7, the Smalfjord Tillite at Smalfjord and the Mortensnes Tillite have many similarities. Most striking is the dominance of ground moraines and laminated subaqeous deposits, siltstones and tillites. While four of the members in the Smalfjord Tillite may represent glacial retreat sequences from a marine area, two are found in the Mortensnes Tillite. Varve siltstone is almost absent from the Mortensnes Tillite, while being abundant in the Smalfjord Tillite. Also, the units are much more laterally continuous and uniform in the Mortensnes Tillite, but vary considerably in the Smalfjord Tillite. While the Smalfjord Tillite passes into a shallow water facies towards the south, this does not happen with the Mortensnes Tillite, but both tillites thin to the north at Trollfjord. Finally, ground moraines in both formations appear to have been deposited by dry-based ice sheets, the one exception being the thick middle member of the Mortensnes Tillite. The similarities point to the significance of the processes identified in the interpretation of the tillites, and suggest that these processes may have wider applications.

Regarding palaeogeography, both tillites seem to be associated with shallow conditions, even emergent, at Trollfjord. The Mortensnes Tillite appears to have been derived from the south in the southern part of the area (lower member), and derived from the north in the northern part of the area (thick middle member). This pattern, similar to that in the Smalfjord Tillite, appears to define a fundamental aspect of the area of sedimentation: derivation was from both the southern and northern margins into the basin.

9.4 Nyborg Formation and Lillevatn Member

Neither the Nyborg Formation nor the Lillevatn Member contain any direct evidence for glacial activity: deglaciation within the basin appears to have been completed prior to the deposition of both units. Member 1 of the Nyborg Formation, and the conglomerate bed of the Mortensnes Tillite and the overlying thin lower submember of the Lillevatn Member record a postglacial transgression. Immediately following the transgressions were periods of vigourous regression, or basin filling. For the Nyborg Formation this was accomplished by the deposition of turbidites on the basin floor (members 2 and 3), and the progradation of a submarine slope across the basin (top of member 3). The lower thick submember of the Lillevatn Member represents the progradation of a prodelta slope not associated with the formation of turbidity currents. At the top of the basin fill of the Nyborg Formation, shallow marine deposits (members 4 and 5) formed under a change to transgressive conditions. Fluvial deposits are present at the top of the basin fill of the Lillevatn Member (upper submember, facies A and B) and also were deposited during overall transgressive conditions. Thus, in a broad sense the sedimentation of the interglacial and postglacial formations was remarkably similar.

Assuming that each formation was related to the preceding glacial episode, then several explanations can be offered for these similarities. The first transgressive phase would be related to the eustatic rise in sea-level caused by the melting of the ice sheets. The regressive basin fill sequences would be related either to isostatic uplift of the basin margins where the ice may have been thickest, or to the release of large quantities of mechanically formed glacial sediment with the melting of the ice sheets, or both. The final transgression would be caused by the gradual depletion of the glacial sediments, and a return to the normal processes of chemical and mechanical weathering.

The sediments which succeed the Lillevatn Member (Chapter 1) are entirely marine and appears that the Lillevatn - Innerelv boundary represents the "final" transgression to normal marine sedimentation.

If the conditions following each glaciation were broadly similar, thenwhy are turbidites such an important part of the Nyborg Formation but not of the Lillevatn Member? Two possible factors are the water depth, and the importance of marine activity. The Nyborg basin fill is four times as thick as that of the Lillevatn Member. Also wave and current activity is detected 50 m below the shallow marine, subtidal deposits of the Nyborg Formation, whereas no evidence of wave agitation is seen except at the very top of the thick lower submember. Deposition of the Nyborg Formation was in much deeper water, and waves and tidal currents were far more influential than for the Lillevatn Member. How these factors caused the propagation of turbidites is uncertain.

Turning to the palaeogeography, the Nyborg Formation was derived from the south, where the source of the sediment must have been. In the Vestertana area indications of wave and current activity independent of turbidites is scarce, and absent from most of members 2 and 3. However, east of the Tana River, and at Trollfjord, the coarser background of members 2 and 3, the presence of straight crested ripples, and the thin turbidite accumulations suggest that these areas were relatively shallow, and were not receiving turbidity currents from either the north or south. The source of the Lillevatn Member is not easy to pinpoint, but an easterly source seems to have been most likely. Shallow conditions were maintained in the north, while deeper conditions prevailed in the south. Thus the overall morphology of the basin during the deposition of members 2 and 3, and of the lower submember appears to have remained relatively unchanged.

9.5 Tectonic Setting

The view generally held concerning the palaeogeography of East Finnmark during deposition of the tillites and adjacent rocks is that a source area to the south, in the Fennoscandian shield, contributed sediment (Holtedahl, 1918; Føyn, 1937; Reading and Walker, 1966) to a basin subsiding more rapidly to the north (Reading and Walker, 1966, p. 204). However, in a recent study of the marine sediments overlying the tillites, it was suggested that a source to the northeast was also important (Banks et al., 1971, p. 231). The evidence cited in the previous sections also suggests a source to the north. A reconsideration of the tectonic setting may throw light on the validity of the palaeogeographic interpretations as well as offer an explanation for a seemingly anamolous situation: a northern source area.

While the autochthonous late Precambrian sediments appear to be an eastward continuation of the Caledonides, the similarity of the sediments in the Barents Sea Region (Barents Sea and Raggo Groups, see Chapter 1) to those in parts of the neighboring Russian Platform has been pointed out most recently by Siedlecka and Siedlecki (1967). Those rocks which occur on the Rybachiy Peninsula, Kildin, the Kanin Peninsula, and in the Timan Range (fig. 89) are also of late Precambrian age (1,000 m.y. and younger as dated by glauconite (Bekker, Negrutsa and Polevaya, 1970), termed Riphean), and form sections up to 10-12 km thick (Provodnikov, 1970). These sediments were folded and intruded at the end of the Precambrian, 675-585 m.y. (Provodnikov, 1970), during the Baikalian orogeny.

The suggestion that these sediments once formed a continuous belt was made by early workers (including Reusch, 1900), and recent geophysical evidence obtained from the adjacent Barents Sea shelf has provided support for the idea. It appears that a major tectonic line, the Karpinski fracture (Emelyanov et al., 1971) continues through the Rybachiy Peninsula and across the Varanger Peninsula (fig. 89) (Siedlecka and Siedlecki, 1967). Also, the Murmansk rise may be a continuation on the Barents shelf of the Timan Range. These structures, part of the Baikalian zone (basement for Palaeozoic sediments) are apparently truncated to the northwest by younger Caledonian structures (Emelyanov et al., 1971). Thus, East Finnmark sediments have sedimentological and tectonic affinities with the coeval rocks of the Russian Platform, and knowledge of the latter may help explain the former.

On Precambrian basement (pre-Baikalian) southwest of the Timan Range are thin platform deposits (fig. 89) (Nalivkin, 1960). Thick accumulations of Riphean sediments underlie the Timan Range and the area to the north. The palaeotectonics of these areas has been described in a series of maps (Vinogradov, 1960), two of which are shown in simp lified form in figure 90. In late Precambrian time, the area of the present Timan Range separated a geosyncline to the north from a platfrom to the southwest. Basic

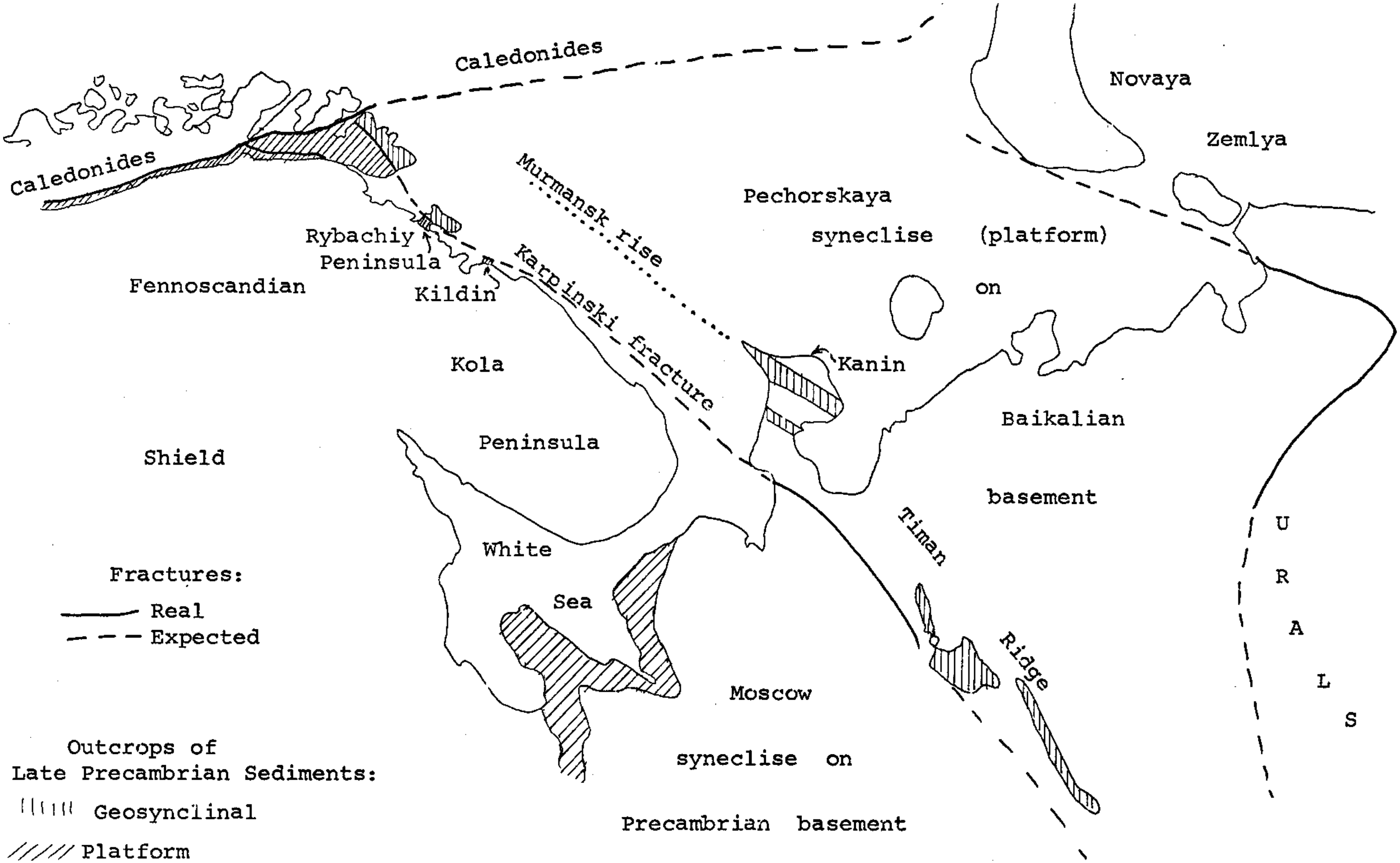

Figure 89. Tectonics of the northern Russian Platform, southern Barents Sea region. Modified from Emelyanov et al., 1971 and Nalivkin, 1960.

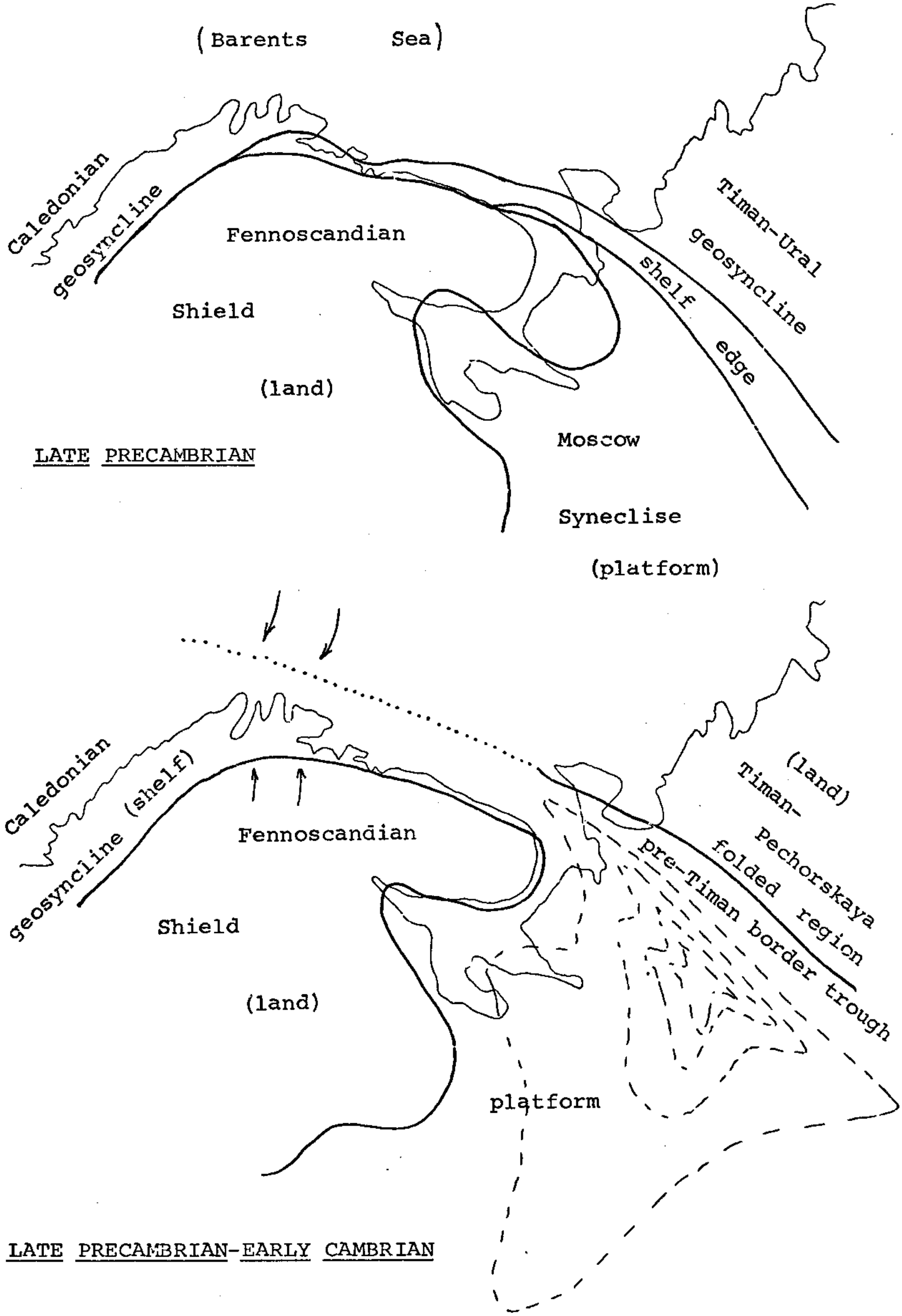

Figure 90. Palaeogeography and palaeotectonics of the Fennoscandian Shield, Russian Platform area simplified from Vinogradov, 1960. Dashed line shows relative isopachs, dotted line shows author's extrapolation of the Timan structure into the Finnmark area. Arrows show source areas.

effusives were deposited in the region of the Urals. During late Precambrian-early Cambrian time, the geosyncline was replaced by a land area, and a marginal trough developed southwest of the land area. If the land area and the adjacent trough are extended to the northwest, which appears to be justified by the geophysical evidence cited above, then the tectonic setting for late Precambrian-early Cambrian sedimentation in East Finnmark emerges. To the north was a land area of predominantly sedimentary and meta-sedimentary rocks, possibly with some intrusives and extrusives, while to the south were the crystalline rocks of the Fennoscandian shield.

It would thus appear that during the Baikalian orogeny the Barents Sea and Raggo Groups were thrust into place from the northeast, along a major fault. Following the uplift associated with this deformation was the deposition of the Older Sandstones Series and younger rocks. This suggests the existence of a major unconformity between the Barents Sea Region rocks and the Older Sandstone Series. Evidence concerning the nature of this junction nas not yet been published. The present day Trollfjord-Komagelv fault which separates the Barents Sea Region from the autochthonous sediments may be the Baikalian fault reactivated during the Caledonian orogeny.

In summary, the late Precambrian basin which the Older Sandstone Series, and Vestertana and Digermul Groups accumulated may have been an extension of the Timan Border Trough developed over the present Timan Range. At the time land areas were present both to the north and the south. This picture is consistent with the palaeogeographical evidence available from the Vestertana Group and the Digermul Group. Insufficient evidence is available from the Older Sandstone Series.

9.6 Conclusions

Thickness and facies variation, and palaeocurrents indicate that:

1) The Smalfjord Tillite was deposited both from the south and the north. Deepest conditions were around Smalfjord, while shallower conditions were around Varangerfjord and Trollfjord.

2) The Nyborg Formation was deposited largely from the south, with maximum depth and subsidence in the Vestertana area, and shallow conditions around Varangerfjord and east of Tanafjord.

3) The Mortensnes Tillite was deposited both from the south and the north, with maximum subsidence in the Vestertana area.

4) The Lillevatn Member was deposited from the east, with maximum depth and susbidence in the area south of Vestertana, and minimum depth and subsidence north of Vestertana.

Together, these observations suggest that a northerly land mass was an important sediment source during the late Precambrian glaciation in East Finnmark.

Examination of the tectonics of the adjacent area, particularly the Barents Sea shelf and the Russian Platform, suggest that sedimentation was controlled by Baikalian tectonics and not Caledonian tectonics. During the Baikalian orogeny a land area was raised to the north of Finnmark,and a trough formed between this land area and the Fennoscandian shield. The record of the late Precambrian glaciation was preserved in this trough.