CHAPTER 1

INTRODUCTION

1.1 Context and Aims

Evidence for an ancient glaciation in Finnmark, North Norway has interested geologists for many years. The earliest account of these rocks, now known to be of late Precambrian age, was given by Hans Reusch in 1891 (see Frontispiece), who described a claystone with dispersed boulders, some of them striated and facetted and a striated pavement overlain by a boulder sand. Reusch attributed these sediments to a glacial origin.

At that time, the glacial theory was accepted by most geologists; this new theory was an attractive way to interpret parts of the geologic record, analogous to plate tectonics theory of the present day. For the next 60 years, the glacial theory was used to explain most rocks of till-like appearance, diamictites, until the development of the turbidity current hypothesis made feasible the long-distance transport of pebbles and mud in a subaqueous flow.

In the past 20 years, geologists who have questioned the glacial origin of certain diamictites have, in some cases, failed to take into account a sufficient range of alternatives, or in other cases based their interpretation on a fixed set of "criteria". These studies were made with an inadequate understanding of glacial processes and deposits.

It was mainly to further the understanding of glacial environments that Reading and Walker (1966) studied the Finnmark tillites and adjacent sediments. The present work follows from the main findings of Reading and Walker: that the tillite formations are indeed glacial in origin, and that the deposition of the adjacent formations was glacially influenced. In this thesis, the author presents in considerable detail an account of the glacial and related sediments, a consideration of the factors responsible for their deposition, and a discussion of sedimentation in a glacially-influenced shelf environment.

1.2 Geological Setting

The late Precambrian and Cambro-Ordovician sedimentary rocks in East Finnmark occur in a WSW-ENE trending belt about 230 x 50 km (fig. 1). The main geological features of these rocks were established by Føyn (1937) following the extensive preliminary investigations made by Holtedahl (1918, 1931). In the south the rocks rest unconformably on Precambrian crystalline basement of the Fennoscandian Shield, in the northwest they are overthrust by "Caledonian" metamorphic rocks, and in the northeast are in tectonic contact with the contrasting sediments of the Barents Sea and Raggo Groups, believed to be of late Precambrian age (Siedlecka and Siedlecki, in press). The basement includes a wide variety of lithologies: mica and garnet gneiss, schist, granite, metavolcanics and metsediments, dykes of granite and diorite and serpentinized ultrabasics (Bugge, 1960), and yields isotopic ages up to about 1650 m.y. (Kratz et al., 1968).

The "Caledonian" metamorphic rocks consist of several thrust sheets, of progressively increasing metamorphic grade to the northwest. Northeast of the sediments, the Barents Sea Group is a thick (c. 8,500 m) basin-fill sequence with greywacke (?turbidites) at the base passing up into a sandstone and shale red-bed facies, followed by alternating carbonates and clastics (Siedlecka and Siedlecki, 1967, 1971). Thrust over the Barents Sea Group is the Raggo Group (c. 9,000 m) which consists of conglomeratic sandstone at the base, fining up through sandstones into dark phyllites and turbidites at the top. The Raggo Group may be an eastward extension of the lowest and least metamorphosed thrust sheet in the "Caledonian" metamorphics, the Laksefjord Group (Føyn, 1969).

The late Precambrian to Cambro-Ordovician sediments are divided into three major stratigraphical units (Table 1). Their age was established by Føyn (1937) who discovered Cambrian fossils in the upper part of the sequence on the Digermul Peninsula. At the base, the Older Sandstone Series (Føyn, 1937),

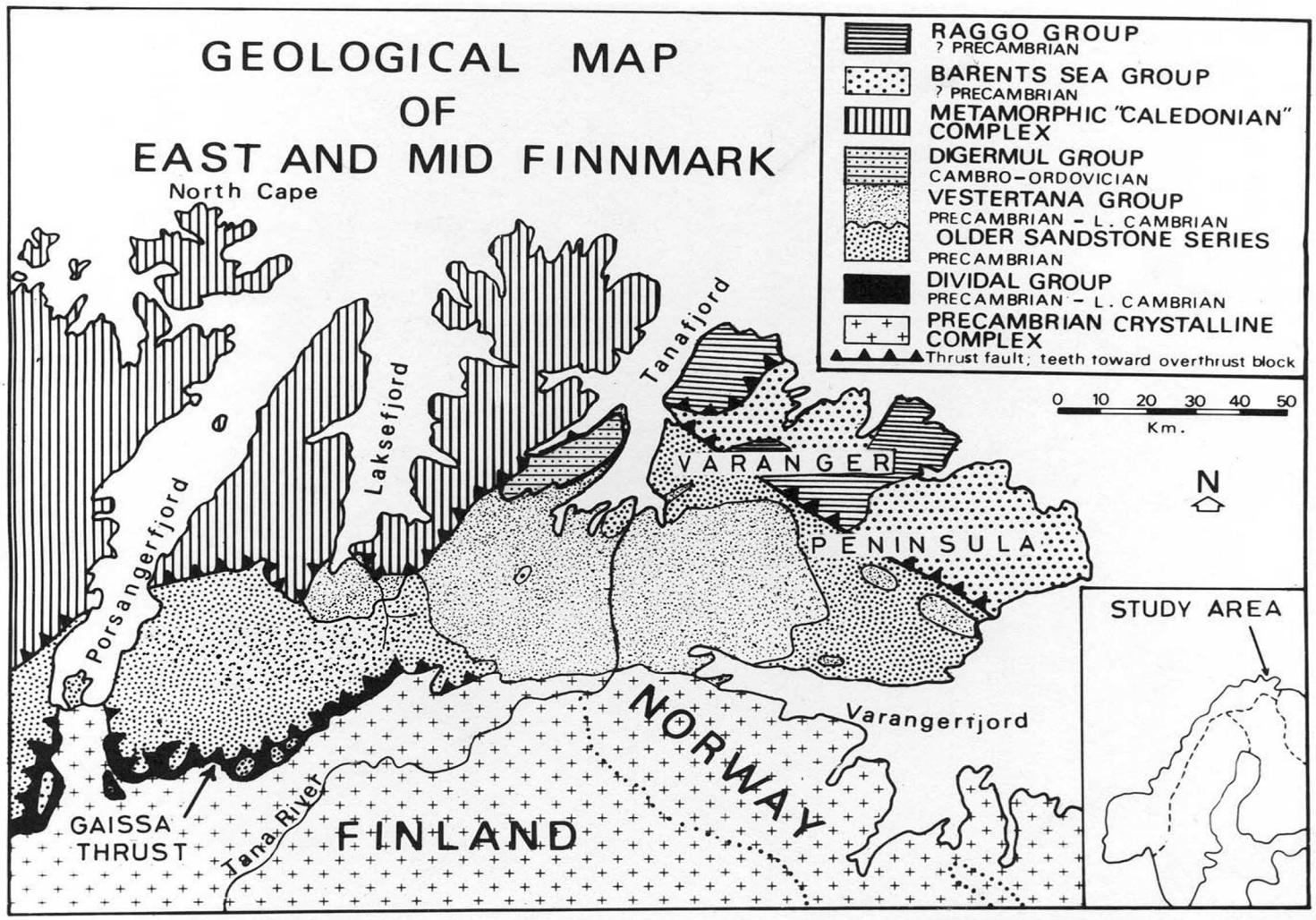

Figure 1. Geological sketch map of East and Mid Finnmark (after Holtedahl, 1918; Holtedahl and Dons, 1960; Føyn, 1937, 1967; Reading, 1965, and Siedlecka and Siedlecki, 1967, 1971).

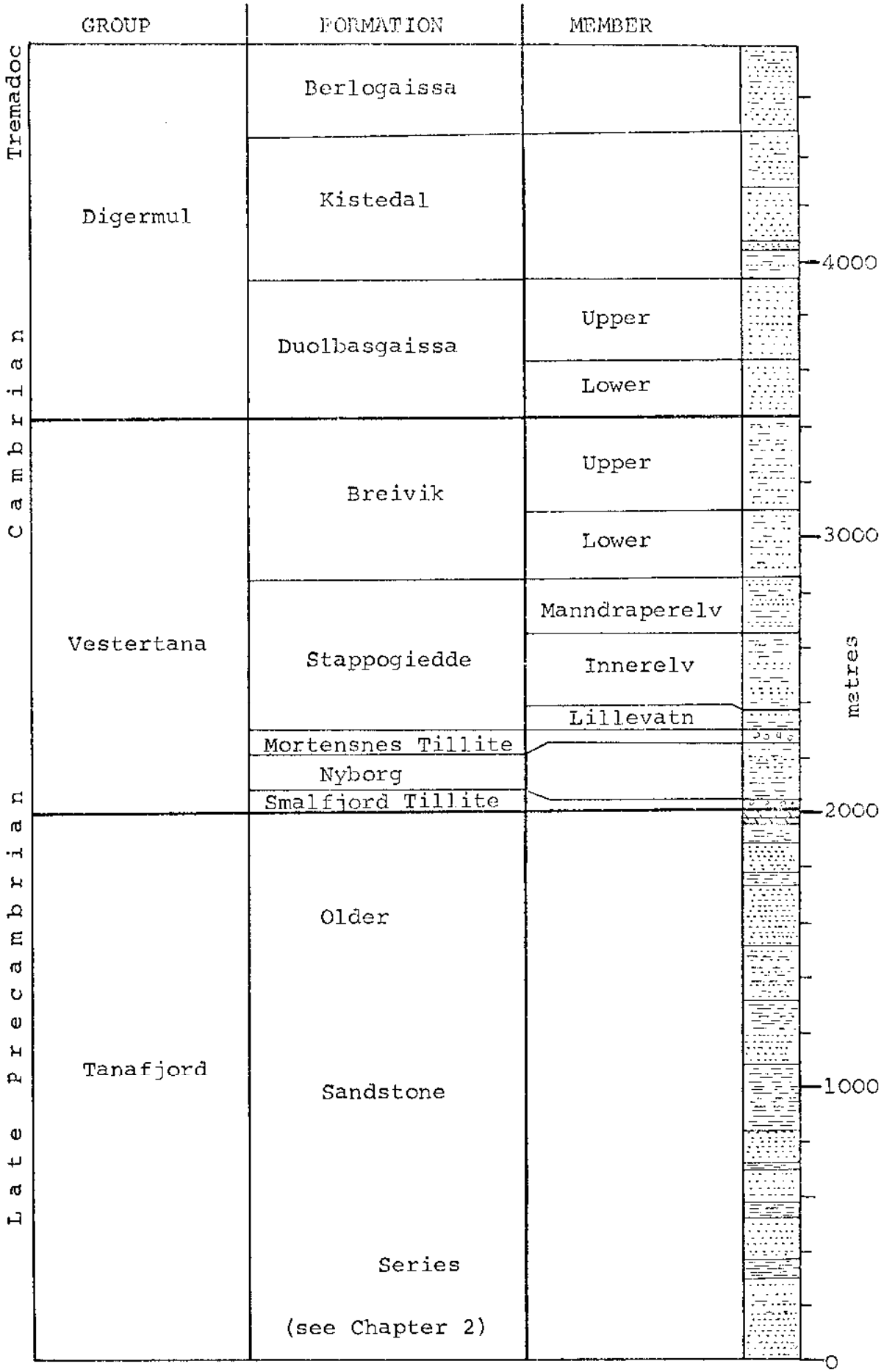

Table 1. The late Precambrian to Tremadocian autochthonous sedimentary succession in East Finnmark.

more recently termed the Tanafjord Group (Siedlecka and Siedlecki, 1971) is about 2,000 m thick and consists largely of sandstone and shale formations, with a distinct dolomite horizon at the top.

The Vestertana Group, about 1,500 m, rests unconformably on the Older Sandstone Series, the passes up into the Digermul Group, of similar thickness. These two groups are composed almost entirely of sandstone and shales. At the base of the Vestertana Group are the two tillite formations. In addition to the lower (Smalfjord) tillite at the base of the Vestertana Group, the upper (Mortensnes) tillite horizon also rests on a regional unconformity, cutting down through the interglacial Nyborg Formation into lower units. These three formations, and the overlying Lillevatn Member of the Stappogiedde Formation comprise the rocks to be described in detail in this thesis. The overlying rocks are marine in origin (Reading, 1965; Banks et al., 1971).

The boundary between the late Precambrian and the Lower Cambrian has been taken at the junction between the Vestertana and Digermul Groups (Reading, 1965). However, the trace fossil Platysolenites, indicating a Lower Cambrian age, has been collected in the Upper Breivik Member (Føyn, 1967) and the presence of many trace fossils, some also of possible Lower Cambrian age, below the Platysolenites horizon, indicates that the Lower Breivik Member at least may be referred to the Lower Cambrian (Banks, 1970). A Tremadocian age for the lower part of the Berlogaissa Formation is shown by trilobites and graptolites (Reading, 1965).

The Older Sandstone Series has recently been described from the south coast of Varangerfjord (Bjørlykke, 1967) along the boundary between the late Precambrian sediments and the crystalline basement. Its presence there argues against a tectonic (high angle fault) origin of the boundary suggested by Holtedahl (1918, p.310) and supported by Føyn, (1960, p.40). Rather, it indicates that the boundary is the tilted unconformity between the late

Precambrian sediments and the basement (Bjørlykke, 1967, pp. 22 and 36).

Passing westwards along the southern margin of the sediments, an important tectonic boundary, the Gaissa Thrust, develops, reaching a minimum throw of 20 km around Porsangerfjord (Gayer and Roberts, 1971). The transition from autochthonous to allochthonous conditions from east to west has been studied by Føyn (1967). Above the thrust, the Gaissa Nappe includes the Porsanger Sandstone Formation in the lower part and the Børselv Sub-Group in the upper part (White, 1968a; Gayer and Roberts, 1971). The lower unit is believed to be equivalent to the Older Sandstone Series to the east, with the dolomitic Børselv Sub-Group corresponding to the Grasdal Formation at the top of the Older Sandstone Series (Holtedahl, 1918, pp. 179, 222).

Beneath the Gaissa Thrust, and resting unconformably on the crystalline basement are undeformed late Precambrian to Cambrian sediments termed the Dividal Group (Føyn, 1967). These rocks are a condensed equivalent of the Stappogiedde Formation and Lower Brevik Member (Banks, 1971).

The degree to which cleavage and deformation have affected the sedimentary rocks is variable, even within the same area. There is a general increase in the intensity of deformation towards the northwest (Pl. 1), where asymmetrical overturned folds are developed, associated with minor thrust faults (figs. 2 and 3, back cover). Also in this region the rocks may be strongly cleaved with mica flakes and grains (especially in the tillites) orientated parallel to the cleavage. The folding is believed to predate the thrusting of the metamorphic nappes and the Gaissa Nappe (Føyn, 1937). The age of the folding is uncertain but postdates the Tremadocian, the age of the youngest sediments, and apparently occurred during the Caledonian Orogeny, in early Ordovician to late Silurian times.

Rare dolerite dykes intrude the sediments; they apparently postdate the folding (Reading, 1965). Ages of 320-350 m.y. have been obtained using the K:Ar method (R. Beckinsale, Pers. Comm.).

1.3 Geography

Many of the observations recorded in this thesis were made along the coastal fjords of Finnmark, which have a relief of up to 600 m and are steep-sided with excellent exposure. Inland, the topography is gentle, characterised by broad, flat gaissas (mountains), occasionally interrupted by deep, fluvial gorges (e.g. Føyn, 1937, p. 117). Only where contrasting lithologies occur, such as with the tillites around Tanafjord, can continuous observations be made. Most of the area is underlain by loose material of local origin (e.g. Føyn, 1937, p.107), but glacial drift is developed in some places.

Only the coastal areas are inhabited; nomadic Lapps are occasionally encountered in the inland gaissas, as are herds of reindeer. Access to coastal areas must be, in many cases, by boat, and as many of the local people are fishermen, such transport can be easily arranged. A Government-run ferry service connects many points along Tanafjord, and is considerably more economical to use than private boats.

1.4 A Note on the Development of the Study

The original project was to study the Mortensnes tillite and adjacent units, the Nyborg and lower part of the Stappogiedde Formations. It included neither the Smalfjord Tillite, nor the closely related Older Sandstone Series. After the first two field seasons, it was realised that the Mortensnes Tillite was not, by itself, conducive to understanding the pattern of deposition of the different facies. The Smalfjord Tillite was known to be complex, and might therefore show certain relationships more frequently and more clearly than the Mortensnes Tillite. Consequently, time was allocated for the study of the Smalfjord Tillite in Varangerfjord and Smalfjord, and it was in the study of the latter region that the important tillite to siltstone sequence described in Chapter 5 was discovered. The stratigraphy of the Older Sandstone Series was studied in conjunction with the Smalfjord Tillite primarily to determine the morphology of the sub-Smalfjord Tillite unconformity.