A Neoproterozoic carbonate ramp and base-of-slope succession, the Andrée Land Group, Eleonore Bay Supergroup, North-East Greenland: sedimentary facies, stratigraphy and basin evolution
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G E U S

Preface

This Ph.D. thesis is submitted to the University of Copenhagen, Faculty of Science in fulfillment of the Ph.D. degree. The study was carried out at the Department of Geological Mapping, Geological Survey of Denmark and Greenland (GEUS) and was funded by grants from the Danish Natural Science Research Council. The results of the project are presented as three articles published in *Danmark og Grønlands Geologiske Undersøgelse Rapport 1998/28* and *1999/19*, one extended abstract from the International Conference on Arctic Margins held in Celle, Germany in 1998 (which is in press in *Polarforschung*), and five manuscripts. The five manuscripts which are included in this thesis will be submitted to international journals (MS 2, MS 3, MS 4, and MS 5) and to the *Geology of Greenland Survey Bulletin* (MS 1).

The Ph.D. project formed a part of a larger regional geological mapping project in North-East Greenland which included related sedimentological, structural, metamorphic, and geochronological investigations in the Caledonides, and on Palaeozoic to Tertiary sedimentary and volcanic sequences. Field work was carried out during the summers of 1997 and 1998 as a cooperative venture between the Geological Survey of Denmark and Greenland and a series of Danish and foreign research institutes.

During the three years spent on this Ph.D. project, many people have directly or indirectly been of assistance. I am very grateful to all those mentioned below (in random order), and the outcome of the project would not have been the same without them.

I am indebted to Lorraine E. Craig (Royal Geographical Society of London) and Christian B. Skipper (University of Copenhagen) for assistance in the field. I also acknowledge expedition leader Niels "Oscar" Henriksen (GEUS) and the staff at the Survey's base camp in Mestersvig for logistical support during field work, as well as the Sirius Sledge Patrol for hospitality at Dr. Lauge Koch's station "Ørnereden" at Ella Ø, where I enjoyed the unaccustomed, luxurious conditions.

The progress of the scientific work was encouraged by several circumstances. I would like to mention the opportunity I had to discuss various aspects of Precambrian sedimentology during my visit to South Africa in 1997. I acknowledge the help of Martin Sønderholm (GEUS), Pat Eriksson (University of Pretoria), and Nicholas Beukes (Rand Afrikaan University, Johannesburg) for making this possible, as well as for scientific discussions. I also thank Paul Smith (Birmingham University), Ian Fairchild (Keele University), and Michael Hambrey (University of Wales) for discussions on the regional geology of North-East Greenland during my visit to the United Kingdom, as well as for allowing me access to unpublished data, and Jon Ineson (GEUS) and Jesper H. Madsen (University of Copenhagen) for discussions on base-of-slope sedimentation. I am grateful to Anna Siedlecka (Geological Survey of Norway) for suggestions of localities to visit at the now classical Precambrian region of the Varanger Peninsula, Arctic Norway. Of particular importance for the outcome of my project was a four month stay at Queens University, Kingston, Canada. I am indebted to Noel James (Queens University) for stimulating discussions, as well as introducing me to the sedimentology of the Bermuda platform. I also appreciate the fruitful discussions with Anne Sherman (Queens University) on Precambrian carbonate ramps. I am grateful to the staff and research students at Queens University who made my four month stay so successful and enjoyable. Special thanks go to my supervisors Finn Surlyk (University of Copenhagen) and Lars Stemmerik (GEUS) for instructive comments that improved previous drafts of the manuscripts significantly. Finally, I would like to express my thanks to my colleagues on the North-East Greenland expeditions of 1997 and 1998 for discussions, as well as those in the Department of Geological Mapping (scientific, administrative and technical staff) for support. Special thanks go to Tony Higgins for improving my English writing, Helle Zetterwall and Jakob Lautrup for technical assistance, and my room mate Kristine Thrane for good company.

Content

Abstract

The up to 1275 m thick Neoproterozic Andrée Land Group crops out in the central fjord zone in the North-East Greenland Caledonides between latitudes 72ºN and 74º30'N. It consists of limestones, dolomites, and mudstones representing deposition on a storm-dominated, north or north-eastward dipping grain-dominated carbonate ramp and base-of-slope environment. The Andrée Land Group is subdivided into seven formations, which from below are the Skipperdal, Reservatet, Arbenz Kolle, Kap Mohn, Grejsdalen, Munotbjerg, and Waltershausen Gletscher Formations. In the lower five formations, sixteen facies are grouped into three facies associations: (1) microbial ramp, (2) pisolitic ramp, and (3) mid- to outer ramp facies association. Facies association 1 consists predominantly of microbialites which represent microbial reefs formed on an inner- to mid ramp. Facies association 2 consists of micrites, pisolites, peloidal calcarenites, and breccias, that collectively represent pisoid flats and shoals of the inner- to mid ramp. Facies association 3 predominantly consists of storm-produced limestone-mudstone couplets representing the mid- to outer ramp.

A sequence stratigraphic analysis was carried out on the basis of nine measured logs that collectively form a N-S orientated profile west of the Western Fault Zone. Eleven sequences, usually 50-100 m thick, are identified in the lower part of the Andrée Land Group. The sequences reflect the changes in depositional pattern on the ramp during a cycle of relative sea-level change. They are from base to top composed of an early transgressive systems tract dominated by breccias and pisolites or microbialites, a limestone-mudstone couplet-dominated transgressive-to-early highstand systems tract, and a pisolite or microbialite-dominated late highstand systems tract.

The Andrée Land Group includes seven ramp and basin stages: (1) a northward dipping homoclinal mixed siliciclastic-carbonate ramp, (2) a homoclinal carbonate ramp, (3) an aggradational to progradational carbonate ramp, (4) a differentially subsiding carbonate ramp, (5) a flooded carbonate ramp, (6) a drowned ramp, and (7) a re-established carbonate ramp now dipping southwards. Stages 6 and 7 (the Munotbjerg and Waltershausen Gletscher Formations) reveal an episode of rifting probably related to a pre-Vendian opening of the Iapetus Ocean. The Munotbjerg Formation mainly comprises graded carbonate siltstones and black, organic-rich, calcareous siltstones, which represent a base-of-slope environment. Their superposition on carbonate platform sediments reflects the drowning event. The Waltershausen Gletscher Formation mainly consists of pisolitic limestones and limestone-mudstone couplets, which represent a re-established carbonate platform. The drowning event was controlled by accelerated tectonic subsidence, where accumulation of coeval base-of-slope and carbonate platform sequences took place.

The Andrée Land Group carbonate ramp records sedimentological aspects that are characteristic of Neoproterozoic carbonate platforms, including ramp architecture, significant influence of storms, large pisoids, molar-tooth structures, and microbialites containing calcified algae. Sedimentary features such as sea-floor precipitates and tidal flat tufas characteristic of Archaean, Palaeo- and Mesoproterozoic carbonate platforms are absent. The unique feature of the Andrée Land Group ramp compared to other Precambrian and Phanerozoic examples is the presence of a channel facies belt. Inner ramp channels are known from modern carbonate ramps, suggesting that these should also be expected on ancient inner ramps. This study demonstrates that Neoproterozoic carbonates differ significantly from Archaean, Palaeo- and Mesoproterozoic carbonates. Precambrian analogues should therefore be used with the same caution as Phanerozoic and Modern analogues.

Later Palaeozoic tectonic activity related to the Caledonian orogeny and succeeding basin formation has implications for construction of Neoproterozoic palaeogeographical models in North-East Greenland; comparison between eleven measured profiles across the Western Fault Zone demonstrates that the relative positions of Andrée Land Group and the overlying Tillite Group outcrops are changed because of post-depositional sinistral strike-slip movements of 80-90 km along the fault zone. These movements probably took place earlier than the Middle Devonian, and hence the fault zone was not a basin forming feature at least in its early history.

Dansk sammendrag (abstract in Danish)

Den op til 1275 m tykke, neoproterozoiske Andrée Land Gruppe er hovedsageligt blottet i den centrale fjord zone mellem 72°N og 74°30'N i det østgrønlandske kaledoniske foldebælte. Andrée Land Gruppen består af kalksten, dolomitter og kalkmuddersten aflejret på en storm-domineret, nord eller nordøstligt hældende korn-domineret karbonatrampe og i et for-foden-af-skrænten miljø. Gruppen er inddelt i syv formationer, som nedefra er: Skipperdal, Reservatet, Arbenz Kolle, Kap Mohn, Grejsdalen, Munotbjerg, og Waltershausen Gletscher Formationen. I de nederste fem formationer, er 16 facies grupperede i tre facies associationer: (1) mikrobiel rampe, (2) pisolitisk rampe, og (3) midt- til yderrampe facies association. Facies association 1 består hovedsageligt af mikrobialitter, som repræsenterer mikrobielle rev på inder- til midtrampen. Facies association 2 består af mikritsedimenter, pisolitter, peloidale kalkarenitter, og breccier, som hovedsageligt repræsenterer pisoidflader og -banker på inder- til midtrampen. Facies association 3 består hovedsageligt af storm-dannede parvise midt- til yderrampe kalksten og muddersten.

En sekvensstratigrafisk analyse er foretaget på ni profiler, som tilsammen udgør et N-S-orienteret profil vest for "the Western Fault Zone". Der er identificeret elleve sekvenser i den nedre del af Andrée Land Gruppen, der hver er 50-100 m tykke. Sekvenserne udviser ændringer i aflejringsmønstre på rampen under en relativ havniveausvingning. Nedefra og op består sekvenserne af en breccie- og en pisolit- eller mikrobialit-domineret tidlig transgressiv system trakt, en kalksten-muddersten-domineret transgressiv til tidlig højstand system trakt, og en pisolit eller mikrobialit-domineret sen højstand system trakt.

Andrée Land Gruppen repræsenterer syv rampe og bassin stadier; (1) en nordligt hældende homoklinal siliciklastisk-karbonatrampe, (2) en homoklinal karbonatrampe, (3) en aggraderende til progradérende karbonatrampe, (4) en karbonatrampe med differentieret indsynkning, (5) en oversvømmet karbonatrampe, (6) en druknet rampe, og (7) en genetableret karbonatrampe, der nu er sydligt hældende.

Sedimenterne i stadie 6 og 7 (Munotbjerg og Waltershausen Gletscher Formationerne) repræsenterer en rift-episode der sandsynligvis var relateret til en præ-vendisk åbning af Iapetushavet. Munotbjerg Formationen består hovedsageligt af graderede karbonat siltsten og sorte organisk-rige siltsten, som repræsenterer et for-foden-af-skrænten-miljø. Drukningen af rampen er afspejlet ved, at karbonatplatformsedimenter er overlejret af for-foden-af-skrænten-sedimenter. Waltershausen Gletscher Formationen består hovedsageligt af pisolitiske kalksten og parvise kalksten-muddersten, som repræsenterer en genetableret karbonatplatform. Drukningen var styret af accelererende tektonisk indsynkning, hvor akkumulation af samtidige for-foden-af-skrænten- og karbonatplatform-sekvenser fandt sted.

Andrée Land Gruppe karbonatrampen udviser flere kendetegn, der er karakteristiske for neoproterozoiske karbonatplatforme, f.eks rampearkitektur, betydelig stormpåvirkning, store pisoider, molar strukturer, samt mikrobialitter indeholdende kalsifiserede alger. Sedimentære træk som havbundsudfældninger og tidevandsfladetufaer, som er karakteristiske for arkæiske, palæo- og mesoproterozoiske karbonatplatforme, er fraværende. Det mest karakteristiske træk ved Andrée Land Gruppe karbonatrampen i forhold til prækambriske og phanerozoiske analoger er tilstedeværelsen af polymikt breccie facies bælter repræsenterende kanaler på inderrampen. Inderrampekanaler er kendt fra nutidige karbonatramper, hvilket antyder at sådanne kanaler også burde forventes på fortidige inderramper. Dette studie viser at neoproterozoiske karbonater adskiller sig betydeligt fra arkæiske, palæo- og mesoproterozoiske karbonater. Prækambriske analoger bør derfor anvendes med samme forsigtighed som phanerozoiske og nutidige analoger.

Senere palæozoisk tektonisk aktivitet relateret til den kaledoniske orogenese og efterfølgende bassindannelse har stor betydning for opstillelsen af neoproterozoiske palæogeografiske modeller for Østgrønland. Sammenligning mellem elleve profiler på tværs af "the Western Fault Zone" viser at de relative positioner af Andrée Land Gruppen og den overliggende Tillit Gruppe er ændret på grund af sinistrale sideværtsbevægelser på 80-90 km langs forkastningszonen. De sinistrale sideværtsbevægelser skete sandsynligvis tidligere end Midt Devon, og derfor var forkastningszonen ikke en bassin-dannende struktur i dens tidligere faser.

Introduction

Precambrian carbonate rocks record more than three billion years of deposition from the period of first continental accretion to the rise of ecologically diverse carbonate-producing metazoan faunas. This huge time span records chemical, biological and physical evolutionary aspects of past tectonic regimes, environmental change, life, structure of ecosystems, sea-level fluctuations, and changes in composition of sea-water.

Precambrian carbonate rocks differ from their Phanerozoic counterparts in several aspects. What may be relative straight-forward in many Phanerozoic carbonate rock studies, is commonly speculative for Precambrian rocks. Critical factors are relative time control, depositional attributes from fossils and trace fossils, and origin of carbonate particles. Recognition of and distinction between sedimentary facies, carbonate particles, cyclical facies stacking patterns, non-deposition, and platform geometry in Precambrian carbonate successions commonly rely on more sparse data, especially in the case of mud-dominated platforms or carbonate rocks overprinted by metamorphosis. In many cases this may limit the understanding of Precambrian carbonate platforms, even though it has been recognised that they are just as compositionally diverse as Phanerozoic platforms (e.g. Grotzinger & James in press).

Historically, there has been and to some extent there still is a general feeling that Precambrian carbonate successions are poorly preserved, structureless dolostones and dolomitised stromatolites many kilometres thick. The discovery of modern stromatolites in Shark Bay, Western Australia and the succeeding studies carried out by Logan *et al.* (1964, 1974), and Playford & Cockbain (1976) in the 1960s and 70s soon became milestones in Precambrian carbonate sedimentology. Until then research on Precambrian carbonates, primarily stromatolites, was carried out mainly by Russian workers (e.g. Krylov 1963, 1967; Maslov 1960; Makhlaev 1964, 1966; Raaben 1969; Komar 1966; Serebryakov 1968, 1976; Serebryakov *et al.* 1972; Serebryakov & Semikhatov 1974; Semikhatov 1976) who mainly addresed stromatolite taxonomy, morphology and phenety. The following years Precambrian carbonates and stromatolites and modern algal mats received renewed attention that peaked with the book "Stromatolites" edited by Walter (1976). A number of studies during this period (Gebelein 1974; Hoffman 1974; 1976; Serebryakov & Semikhatov 1974; Horodyski 1976, 1977; Beukes 1977; Cecile & Campbell 1978; Siedlecka 1978) shed light on the enigmatic world of the Precambrian carbonate rocks and demonstrated the necessity and potential for additional, more detailed studies. Increasing understanding of carbonate facies, carbonate platform growth and geometry of Phanerozoic carbonate successions (e.g. James 1979; Markello & Read 1981; Read 1982, 1985; Tucker & Wright 1990; Burchette & Wright 1992) was also reflected in the study of Precambrian platforms throughout the world, where the knowledge of facies distribution, platform geometry, and growth styles also increased (e.g. Bertrand-Sarfati & Moussine-Pouchkine 1983; Grey & Thorne 1985; Grotzinger 1986a, 1986b, 1989; Beukes 1987; Southgate 1989; Sami & James 1993, 1994). It soon became clear that facies distribution, platform geometries, and growth styles to a first-order approximation were similar to those present in Phanerozoic and modern carbonates since at least the late Archaean. However, students of Precambrian carbonate rocks also soon realised that a non-actualistic approach commonly was necessary. The study of the Precambrian carbonate rock record thus had to be carried out with careful use of Phanerozoic and Modern analogues, and interpretations and models should be based on their own merits, and not simply as variants of the Phanerozoic. Carbonate facies were described in great detail, and eventually a pattern of time dependence and facies occurrence turned out in many studies. It became clear that many carbonate facies were age-dependent, and carbonates deposited in Archaean, Palaeo-, Meso-, and Neoproterozoic times each are characterised by their own set of facies (Grotzinger 1989; Sami & James 1993, 1994; Grotzinger & James in press; Sherman *et al.* in press). The distinct evolutionary trend in Precambrian carbonates is expressed by platform growth style, modes of carbonate production, and occurrence and distribution of sedimentary facies from Archaean to Neoproterozoic time. Carbonate successions deposited during the Archaean and Palaeoproterozoic time are characterised by the presence of sedimentary features such as iron formations (e.g. Beukes 1987), and sea-floor precipitates such as calcite fans and herringbone calcite (e.g. Grotzinger & Read 1983; Grotzinger 1986a; Sami & James 1996; Sumner & Grotzinger 1996) (Fig. 1). During the Palaeoproterozoic time formation of $CaSO_4$ evaporites and tidal flat tufas became abundant features of carbonate platforms (Grotzinger 1986a; Sami & James 1996), tidal flat tufas, however, declined during the Mesoproterozoic time (Grotzinger & James in press) (Fig. 1). Carbonate successions deposited during Mesoproterozoic to early and mid Neoproterozoic times are characterised by a distinct decline in stromatolites (Awramik 1971; Grotzinger 1990), and presence of abundant carbonate rocks with molar-tooth structures (e.g. James *et al.* 1998) (Fig. 1). Early to mid Neoproterozoic carbonate successions are commonly characterised by large pisoids (Swett & Knoll 1989; Sumner & Grotzinger 1993), and mid to late Neoproterozoic carbonate successions are characterised by thrombolites (e.g. Turner *et al.* 1993), and calcified algae and metazoans (e.g. Turner *et al.* 1993; Grotzinger *et al.* 1995; Grotzinger & James in press) (Fig. 1). Carbonate successions deposited during Neoproterozoic time for unclear reasons show a predominance of ramps over rimmed shelves (Grotzinger & James in press). In spite of the great secular variability in facies, and modes of carbonate production, the architecture of Precambrian carbonate platforms was roughly the same and responded in a similar manner to extrinsic processes as their Phanerozoic counterparts (Grotzinger 1989; Grotzinger & James in press).

Archaean, Palaeo-, Meso-, and Neoproterozoic carbonates are characterised by their own set of facies and modes of carbonate production. As a consequence some sedimentary features may function as very rough time indicators, much like biostratigraphic indicators. The discovery also shows that the Precambrian carbonate record should be examined in discrete intervals and that Precambrian analogues should be used with the same caution as Phanerozoic and modern analogues.

Another important research field is the role of relative sea-level changes on Precambrian carbonate platform growth. There is abundant evidence of major Precambrian plate reorganisations (Dalziel 1997) and glaciations (Harland *et al.* 1965; Hambrey 1983), and it is therefore to be expected that these extrinsic factors have had a major impact on carbonate platform growth during this time interval. Numerous studies of Precambrian carbonate platforms suggest that facies stacking patterns are cyclically arranged in response to relative sea-level fluctuations similarly to their Phanerozoic counterparts (e.g. Grotzinger 1986; Beukes 1987; Sami & James 1993, 1994). The absence of reliable datings has, however, hampered application of sequence stratigraphic concepts on the Precambrian carbonate rock record. Since the understanding of Precambrian carbonate platforms has increased considerably during the last decade it is to be expected that sequence stratigraphic models will be proposed for Precambrian carbonate platforms. Some studies have already addressed this aspect (Tirsgaard 1996; Clough & Goldhammer in press; Sami *et al.* in press).

This thesis contains five manuscripts that collectively describe and interpret the sedimentology and stratigraphy of the thick and widely distributed, Neoproterozoic Andrée Land Group in North-East Greenland. The primary aims are to interpret (1) the sedimentology and stratigraphy of the Andrée Land Group, and (2) place the evolution of the East Greenland basin and its connection to other Neoproterozoic successions, primarily in the present North Atlantic region, in a plate tectonic context.

The Andrée Land Group has been studied throughout its area of distribution allowing the establishment of a lithostratigraphic scheme presented in **manuscript 1**. A sedimentological analysis is presented in **manuscript 2** where depositional processes and environments, and carbonate platform architecture are interpreted and placed within a Precambrian evolutionary context. In **manuscript 3** the platform and basin evolution is interpreted by application of sequence stratigraphic concepts. The upper part of the group differs from the rest of the group in representing a base-of-slope environment. This environmental change coincides with significant changes in tectonical and climatical regimes. In **manuscript 4** the sedimentology and stratigraphy of the upper part of the group is interpreted and a model for the basin evolution is erected. **Manuscript 5** presents the imprints of the Caledonian orogeny on the distribution of the Andrée Land Group. In order to understand the Neoproterozoic basin evolution and palaeogeography a correlation between rocks belonging to the Andrée Land Group and the overlying Tillite Group across a major fault zone has been made.

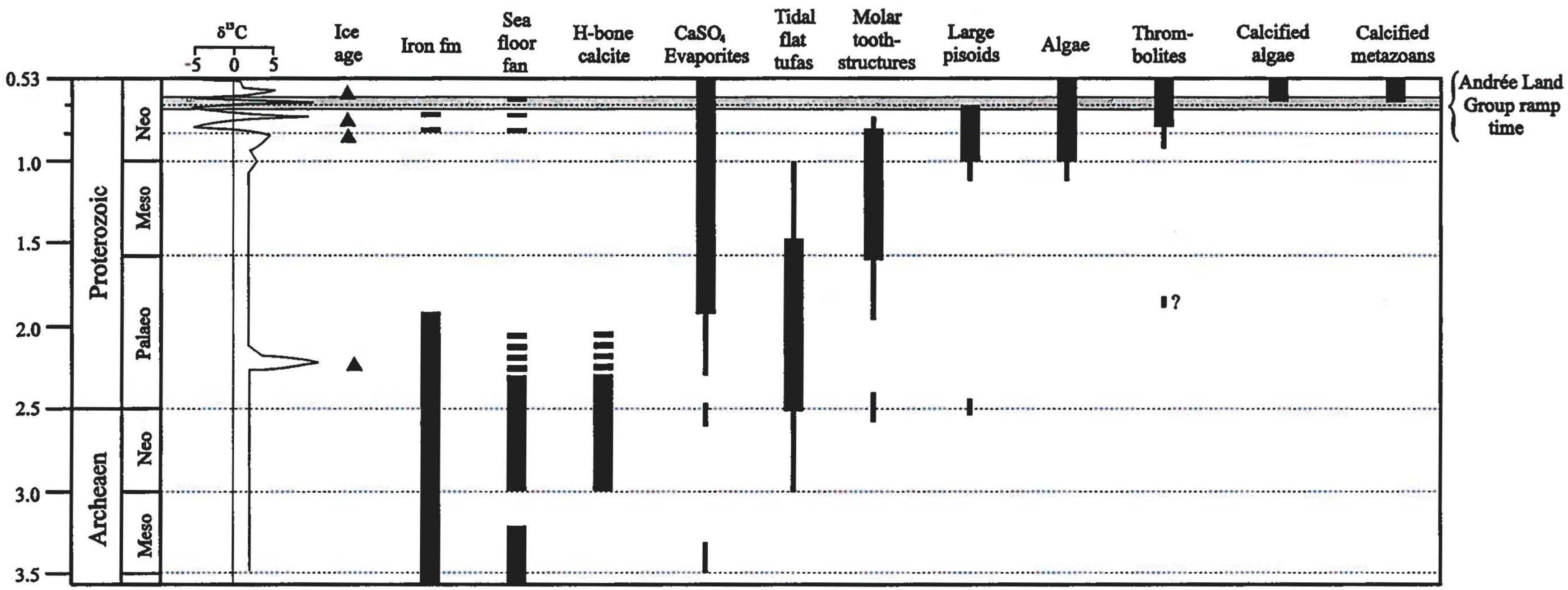

Fig. 1. Evolution of Archaean and Proterozoic carbonate facies, calcium sulfate evaporites, iron formation, known ice ages, and carbon-isotope composition of carbonates. The grey area indicates the approximate position of the Andrée Land Group ramp in the Neoproterozoic Eon (Sturtian, cf. Vidal 1979). Modified from Grotzinger & James (in press).

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Manuscript 1

Lithostratigraphy of a Neoproterozoic carbonate platform and base-of-slope succession, Andrée Land Group, Eleonore Bay Supergroup, North-East Greenland

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Abstract

A lithostratigraphic scheme is presented for the Neoproterozoic (Sturtian) Andrée Land Group, Eleonore Bay Supergroup, North-East Greenland. The group is up to *c.* 1275 m thick and stratigraphically intercalated between the Ymer Ø and Tillite Groups. It crops out in the central fjord zone in northern Scoresby Land, Lyell Land, Ella Ø, Suess Land, Ymer Ø, Andrée Land, Strindberg Land, Ole Rømer Land, Steno Land and Hudson Land, and in outlyers in Canning Land and Payer Land.

The Andrée Land Group is subdivided into seven revised formations. From below they are formed by limestones (Skipperdal Formation, up to 280 m thick), dolomites (Reservatet Formation, up to 90 m thick), limestones (Arbenz Kolle Formation, up to 170 m thick), dolomites (Kap Mohn Formation, up to 130 m thick), mixed dolomites and limestones (Grejsdalen Formation, up to 620 m thick), shales (Munotbjerg Formation, up to 210 m thick), and limestones (Waltershausen Gletscher Formation, up to 240 m thick). In addition, seven new members are defined: The Karlenes Ø and Linné Gletscher Members of the Skipperdal Fomation, the Niviarsiat, Nanortalikdal and Bjørneø Members of the Grejsdalen Formation, the Noa Dal Member of the Munotbjerg Formation and the Aasesøen Member of the Waltershausen Gletscher Formation.

The Andrée Land Group records deposition on a north- or north-east-ward dipping, storm-dominated, low-gradient grainy carbonate ramp with regionally extensive facies belts (the Skipperdal, Reservatet, Arbenz Kolle, Kap Mohn, Grejsdalen, and Waltershausen Gletscher Formations), and in a base-of-slope environment (The Munotbjerg Formation). Carbonate ramp subenvironments mainly include subaerially exposed inner ramp flats, channels, and pisoid shoals and flats, low-energy lagoons, shallow-marine microbial reefs of the inner- to mid ramp, and outer ramp environments. Base-of slope subenvironments include turbidite and debris flow fed or sediment starved environments.

Introduction

This paper describes the largely unmetamorphosed late Neoproterozoic strata of the Andrée Land Group in the central fjord zone in the North-East Greenland Caledonides between latitudes 71°30'N-74°30'N (Fig. 1). A lithostratigraphical scheme for the Andrée Land Group is presented including seven formations.

The group comprising limestones, dolomites and shales, forms the uppermost part of the 14.5 km thick Eleonore Bay Supergroup (Fig. 2). From below the Eleanore Bay Supergroup comprises the siliciclastic Nathorst Land and Petermann Bjerg Groups, up to *c.* 11 km thick (Smith & Robertson 1999), the siliciclastic Lyell Land, up to 2.8 km thick (Tirsgaard & Sønderholm 1997), the mixed siliciclastic-carbonate Ymer Ø Group, up to 1 km thick (Sønderholm & Tirsgaard 1993) and the carbonate-dominated Andrée Land Group. The Andrée Land Group is overlain by the 800 m thick Tillite Group which consists mainly of glacial diamictites, sandstones, mudstones and carbonates (e.g. Hambrey & Spencer 1987). The Tillite Group is overlain by the 4.5 km thick carbonate dominated Cambrian-Ordovician Kong Oscar Fjord Group (Smith *et al.* in press). Together the Eleonore Bay Supergroup, Tillite Group and Kong Oscar Fjord Group constitute a relatively continuous record of deposition covering the period from *c.* 940-950 MA (Steiger *et al.* 1979; Kalsbeek *et al.* in press) to *c.* 480 MA (Smith *et al.* in press). The Nathorst Land, Petermann Bjerg, Lyell Land, and Ymer Ø Groups and the lower Andrée Land Group record shelf and ramp sedimentation on a steadily subsiding passive continental margin (e.g. Harland & Gayer 1972; Caby & Bertrand-Sarfati 1988; Sønderholm & Tirsgaard 1993; Tirsgaard & Sønderholm 1997; Frederiksen MS3; MS4). The upper Andrée Land Group and parts of the Tillite Group record terrestrial, shallow and relative deep marine sedimentation associated with the disintegration of the supercontinent Rodinia and the formation of the Iapetus Ocean (Frederiksen MS3; MS4). The Cambrian-Ordovician Kong Oscar Fjord Group records shallow-water sedimentation along the passive margin of the Iapetus Ocean prior to its clossure during the Caledonian orogeny (Smith *et al.* in press).

Field work

Field work was carried out in the central fjord zone between Scoresby Land and Payer Land in 1997 and 1998 organised by the Geological Survey of Denmark and Greenland (GEUS). Sedimentological and stratigraphical data of the Andrée Land Group were collected during 1:200 scaled logging at 16 localities together with general helicopter-supported reconnaissance work (Fig. 1 and Table 1). The choice of localities in this study was mainly based on the geological maps of Koch & Haller (1971) and Bengaard (1992). In contrast to previous field work carried out mainly in the 1930's and 1950's during Dr. Lauge Kochs Greenland expeditions, and in the 1970's and 1980's by mainly Harvard and Cambridge University geologists, the use of helicopters in the present study allowed access to areas previously not visited. In addition, the use of helicopters provided an opportunity to study the regional distribution of units within the

Andrée Land Group. This was of great importance in the poorly investigated region in Ole Rømer Land, Steno Land and Hudson Land between Waltershausen Gletscher and Wordie Gletscher (Fig. 1).

Physiography and exposures

The Andrée Land Group mainly crops out in the central fjord zone, where it forms a significant proportion of the surface rocks. The group is an easily recognisable rock unit which is well preserved in the synclinal and anticlinal folds of the North-East Greenland Caledonides in the central fjord zone. It is easily spotted by its three distinct decametre thick white, cream or yellow-coloured dolomite units interbedded with grey, blue or black-coloured limestones situated above the multicoloured interval of carbonates, mudstones and sandstones of the Ymer Ø Group. The stratigraphic interval of the uppermost part of the Ymer Ø Group and the lowermost part of the Andrée Land Group is a distinct rock unit mostly forming subvertical cliffs, which at some localities were inaccessible for detailed inspection. The limestones of the remaining part of the Andrée Land Group are usually recessive and sections are most complete in river gullies or smaller cliff-forming ridges, 10-20 m high, situated on smoothly shaped mountain scree slopes.

Primary sedimentary structures are only sporadically preserved in the limestones and dolomites. At some localities, the cliff-forming dolomite units is so strongly dolomitised, that the original sedimentary structures are obliterated, e.g. at Kap Mohn at Ymer Ø (Fig. 14A). At other localities it picks out the original sedimentary structures by variable surface crust weathering, e.g. at Munotbjerg at Ymer Ø, or colouring e.g. in Scoresby Land. The calcareous and dolomitic shales near the top of the group are well-exposed in steep cliffs at most localities, e.g. at Kap Mohn and Munotbjerg at Ymer Ø, at Kap Weber and Månesletten in Andrée Land, and in Nanortalikdal in Suess Land (Figs 5, and 23A, B and C). These shale outcrops commonly contain larger gaps due to scree, lake, or grass cover (Fig. 23C). The boundary to the overlying Tillite Group is with a few exceptions, e.g. at Kap Weber in Andrée Land and near Brogetdal in Strindberg Land, always very well exposed in steep cliffs near mountain peaks (Figs 5D and 23A). The Andrée Land Group is only to a minor degree affected by Caledonian metamorphosis. In Payer Land close to the pre-Neoproterozoic crystalline basement, and at Nanortalikdal in Suess Land and Månesletten in Andrée Land close to the fjord region detachment, the group is slightly metamorphosed or heavily jointed, and sandstones appear as white to greyish metapsammites, while laminated mudstones appear as greenish chlorite slates. The absence of biotite within the chlorite slates suggests that the metamorphic grade, however, never exceeded chlorite grade (very low grade).

Investigations of the Andrée Land Group (from 1930 and onwards)

The knowledge of the Andrée Land Group prior to this study is mainly based on the geological mapping carried out by geologists on the Greenland expeditions during the 1920's, 1930's, and 1950's under the leadership of Dr. Lauge Koch. Extensive geological field mapping, data sampling, and regional descriptions resulted in a geological map of high quality, in spite of limited logistical support, covering the North-East Greenland Caledonides (Koch & Haller 1971). Geological data from the Andrée Land Group, which at that time were referred to as the "Limestone-Dolomite Series", were collected by Schaub (1950) at Ella Ø, Katz (1952) in Strindberg Land, Eha (1953) at Ymer Ø, Ella Ø, and Suess Land, Fränkl (1953a; 1953b) in Andrée Land and Scoresby Land, Cowie & Adams (1957) in Steno Land and Hudson Land, and by Sommer (1957a) in Lyell Land. These studies mainly included lithological descriptions of the stratigraphy, regional distribution of the Andrée Land Group units and the large-scale Caledonian structures in which they formed.

Studies of the Neoproterozoic rock succession in North-East Greenland had their primary focus on the Varangian glaciation and not on pre-, inter-, or postglacial depositional aspects. Studies of the Andrée Land Group were mainly focused on the relationship between the carbonates and the glacial diamictites and their relationship to other Neoproterozoic successions (e.g. at Svalbard), while the sedimentary and basinal evolution of the Andrée Land Group has received less attention. The Andrée Land Group has been subject to micropalaeontological work and new chemostratigraphical methods have been tested. Microfossils, mainly archritarcs, suggested a Sturtian age, and were correlated with the Visingsö Beds in southern Sweden (Vidal 1976; 1979). This suggested an approximate age of 700-610 MA of the Andrée Land Group. Micropalaeontological studies of the Andrée Land Group were carried out in the1980's in order to achieve a better general understanding of early evolution of life (Green *et al.* 1987; 1988; 1989). Various microfossils from pisolites and microbialites of the Andrée Land Group and were compared with populations from correlative rock units of Svalbard. In addition, taxonomic studies of microbialites from Canning Land mapped during the early 1970's (Caby 1972; 1976) suggested a Vendian age (Bertrand-Sarfati & Caby 1976). Chemostratigraphic studies were carried out in the 1980's in order to test stratigraphic isotope variations prior to the initial global radiation of metazoans, or in connection with studies of the Sr-isotope variations in the Proterozoic ocean (e.g. Knoll *et al.* 1986 and Derry *et al.* 1989).

The sedimentology of the Tillite Group is quite well understood due to extensive research in the 1980's (Hambrey 1983; Hambrey & Spencer1987; Moncrieff 1989; 1988; Moncrieff & Hambrey 1988; 1990; Fairchild & Hambrey 1995). Regional mapping of the various Tillite Group units, their geometry, sedimentary features, and relations to the underlying Andrée Land Group resulted in more scientific interest in the Andrée Land Group. The most detailed sedimentological studies of the Andrée Land Group were carried out on what in the old lithostratigraphical nomenclature was referred to as bed-groups 18-20 or AL5-7 at Kap Weber in Andrée Land and at Ella Ø (Herrington 1989; Herrington & Fairchild 1989). Although the regional control on basin evolution was reduced these studies were the first to infer the possibility that bed-group 19 or AL6 records a significant episode of rift-related subsidence. Petrographic studies of pisolites from Kirschdalen in Lyell Land, Kap Weber in Andrée Land, and at Ella Ø were presented by Swett & Knoll (1989).

In connection with investigations during the late 1980's of the underlying Lyell Land and Ymer Ø Groups a lithostratigraphic scheme of the Eleonore Bay Group was erected by Sønderholm & Tirsgaard (1993), in which the Eleonore Bay Group was promoted to supergroup rank and the "Limestone-Dolomite Series" was named to Andrée Land Group. In this paper the subdivisions of the Andrée Land Group are formally described.

Lithostratigraphy

Andrée Land Group

History. The Andrée Land Group was initially defined by Teichert (1933) as "Die Kalk-Dolomit Serie"or "Limestone-Dolomite Series", and subdivided into a number of bed-groups (Fig. 3). The subdivision was later refined and completed by Katz (1952) and Eha (1953), who established seven "bed-groups 14-20". Except for an attempt to erect a formation status of the Limestone-Dolomite Series as the Nøkkefossen Formation (Katz 1961), the informal bed-group subdivision became the standard reference nomenclature during succeeding work on the upper part of the Eleonore Bay Supergroup (e.g. Fränkl 1953a, Haller 1953, Cowie & Adams 1957, Sommer 1957a, Hambrey & Spencer 1987, Herrington & Fairchild 1989, Swett & Knoll 1989, Fairchild & Hambrey 1995) (Fig. 3). In an attemp to undertake an intrabasinal correlation between Andrée Land and Ella Ø, Herrington & Fairchild (1989) informally named correlative units within bed-groups 18-20 as bed-groups 18.1-18.16, 19.1-19.7 and 20.1-20.3 (Fig. 3). Sønderholm & Tirsgaard (1993) gave the Limestone-Dolomite Series group status as the "Andrée Land Group", and renamed the bed-groups 14-20 as "AL1-7" (Fig. 3).

Name. From Andrée Land.

Type locality. The eastern tip of Andrée Land between Kap Weber and Grejsdalen (Fig. 1). The group is well exposed and developed, and easily accessible except for the very basal part. Good sections occur throughout the region, especially just east of Skipperdal in Scoresby Land, at the southern part of Ymer Ø, at Månesletten in Andrée Land, at Waltershausen Gletscher in Ole Rømer Land and at Albert Heim Bjerge in Steno Land (Fig. 1).

Thickness. At the type locality the Andrée Land Group attains a maximum thickness of 1175 m, however, this does not include the basal part. At Månesletten in Andrée Land, *c.* 30 km SW of the type locality a thickness of 1130 m has been measured. Although the thickness at this locality is uncertain as the section contains a stratigraphic gap around the transition between the Grejsdalen and Munotbjerg Formations, the Andrée Land Group has a relative uniform thickness in Andrée Land. A composite section of the two localities is 1275 m thick (Fig. 4A). The Andrée Land Group shows a general thinning to the south. Between Ymer Ø and Scoresby Land it is 900-1000 m thick (Fig. 4B). To the north in Strindberg Land and just north-east of Waltershausen Gletscher in Ole Rømer Land it is 1000 and 630 m thick (Fig. 4C), respectively, and in the Hudson Land and Steno Land regions thicknesses between 450-650 m have been recorded. Thicknesses in the excess of 1500 m as reported by Haller (1971) and Sønderholm *et al.* (1989) from these regions are here considered highly exaggerated. A minimum thickness of 900 m was reported from Canning Land by Caby (1972).

Distribution. The Andrée Land Group is intercalated between the mixed siliciclastic and carbonate sediments of the Elisabeth Bjerg Formation of the Ymer Ø Group and sandstones or diamictites of the Ulvesø Formation of the Tillite Group. It crops out in the central fjord zone in northern Scoresby Land, Lyell Land, Ella Ø, Suess Land, Ymer Ø, Andrée Land, Strindberg Land, Ole Rømer Land, Steno Land and Hudson Land (Fig. 1). Parts of the group are also found in outliers in Canning Land (Caby 1972) and Payer Land (Frederiksen *et al.* 1999) (Fig. 1). Small outcrops of carbonates on southern Hochstetter Forland reported by Sommer (1957b) was reinterpreted by Sønderholm *et al.* (1989) as belonging to the Ymer Ø Group, and carbonates from the C. H. Ostenfeld Nunatak in the Wordie Gletscher reported by e.g. Teichert (1933), Haller (1971), Koch & Haller (1971), and Frykman (1979) belong to the Tillite and Kong Oscar Fjord Groups (Hambrey *et al.* 1989).

Lithology. The Andrée Land Group consists of various grey, bluish, or black limestones, white, grey, or yellowish dolomites, black, grey, buff-coloured, green, red, purple, or brown shales, and minor black chert (Figs 4 and 5). Sediments include dissolution collapse, polymict, and carbonate or quartzose stromaclast breccias, microbialites, micrites, pisolites, limestone-mudstone couplets, carbonate shales, cross-bedded and wavy bedded calcarenites.

Depositional environments. The Andrée Land Group records deposition on a north- or north-east-ward dipping, storm-dominated low-gradient, grainy carbonate ramp with regionally extensive facies belts, and in a base-of-slope environment (Frederiksen MS2; MS4).

Morphologically diverse microbialites (horizontally and wavy laminated, domal, columnar, and bulbous stromatolites) and stromaclast breccias represent shallow-marine microbial reefs formed on an inner- to mid ramp. Laminated mudstones, mostly associated with microbialites, represent low-energy lagoons behind the microbial reefs. Micrites, commonly showing dessication cracks, were deposited on inner ramp flats where subaerial exposure was common. Dissolution collapse breccias are products of subaerial exposure and evaporation, dissolution, and collapse on the inner ramp. Pisolites were formed in environments with semi-permanent shallow-water wave agitation such as pisoid shoals and flats on the inner- to mid ramp. Pisolites with abundant oncoid particles probably record more sheltered environments such as semi-protected lagoons. Polymict breccias were deposited in channels that crossed inner ramp flats and shoals. Trough cross-bedded calcarenites were deposited seawards of pisoid shoals in shoreface environments. Limestone-mudstone couplets, horizontally and wavy laminated, cross-laminated, climbing ripple laminated, and hummocky cross-stratified calcarenites represent deposition on the outer ramp.

In the upper part the Andrée Land Group records a major drowning event with establishment of depositional environments such as turbidite and debris flow fed or sediment starved base-of-slope environments.

Fauna and geological age. Microfossils, cyanobacteria, procaryotes and acritarchs, suggest a Sturtian age of approximately 650-700 Ma (Vidal 1976; 1979). Taxonomic studies of stromatolites suggest a Vendian age (Bertrand-Sarfati & Caby 1976). The faunas are described below.

Boundaries. The lower boundary to the Ymer Ø Group is sharp and is placed at the transition from red, purple, or greenish grey recessive weathering siliciclastic shale to cliff-forming yellow-weathering dolomite (Sønderholm and Tirsgaard 1993) (Fig. 6). The dolomite is predominantly made up by microbial mounds or biostromes, and subordinately by stromaclast breccias. The boundary was placed slightly higher by Katz (1952), as the "grey band" and the "stripey yellow band" were included in the bed-group 13 of the Ymer Ø Group instead of bed-group 14.

The nature of the upper boundary varies. It is placed at the transition from dark grey limestones of the Grejsdalen and Waltershausen Gletscher Formation or shales of the Munotbjerg Formation to diamictites, conglomerates or sandstones of the Ulvesø Formations (Figs 5A, 5B, 23B, and 23E). In Ole Rømer Land, Strindberg Land, Andrée Land, and at parts of Ymer Ø the boundary is a transitional, or sharp and irregular contact from limestones to diamictites, conglomerates or sandstones. In Canning Land and Payer Land it is a sharp, but irregular contact where limestones or dolomites of the Grejsdalen Formation is overlain by diamictites of the Ulvesø Formation. In Hudson Land and Steno Land it is a sharp, but irregular contact where the Munotbjerg Formation is overlain by diamictites or conglomerates of the Ulvesø Formation. At Ella Ø and parts of Ymer Ø, in Suess Land, and Lyell Land it is a transitional or sharp, but regular contact between shales of the Munotbjerg Formation and diamictites of the Ulvesø Formation.

Subdivisions. The Andrée Land Group is subdivided into seven formations, which from the base to the top are: the Skipperdal, Reservatet, Arbenz Kolle, Kap Mohn, Grejsdalen, Munotbjerg, and Waltershausen Gletscher Formations (Fig. 4). They correspond to the bed-groups 14-20 of the Limestone-Dolomite Series of Katz (1952), Eha (1953), Fränkl (1953a), and Haller (1953), and AL1-7 formations of Sønderholm & Tirsgaard (1993) (Fig. 3).

Skipperdal Formation

New formation

History. The Skipperdal Formation corresponds to bed-group 14 of e.g. Katz (1952), Eha (1953), Fränkl (1953a), and Haller (1953), and the AL1 formation of Sønderholm & Tirsgaard (1993) (Fig. 3).

Name. From the NW-SE trending valley located in northern Scoresby Land (Fig. 1).

Type locality. The type locality contains a very well exposed section parallel to the southern shore of Segelsällskabets Fjord north-east of Skipperdal (Fig. 1). Well exposed sections are located at Munotbjerg at Ymer Ø, the southern coast of Ymer Ø facing the Antarctic Sund, slopes north of Brogetdal in Strindberg Land, and at Hjørnebjerget west of Krumme Langsø in Hudson Land (Fig. 1).

Thickness. The thickness varies strongly. At the type locality in Scoresby Land it has a maximum thickness of 280 m (Fig. 7). The thickness decreases towards north and east (Fig. 4). In the Kejser Franz Joseph Fjord region around Månesletten in Andrée Land it is *c.* 160 m thick, and in the region around Albert Heim Bjerge and Promenadedal in Steno Land and Hudson Land it is *c.* 70 m thick. In Canning Land, it is *c.* 200 m thick (Bertrand-Sarfati & Caby 1976).

Distribution. The formation is usually a cliff-forming unit of limestone containing a few minor dolomitic units (Figs 6, 7, and 8). The formation overlies the Elisabeth Bjerg Formation of the Ymer Ø Group, and is overlain by the Reservatet Formation. It crops out between northern Scoresby Land in south and Wordie Gletscher to the north, where the Andrée Land Group overlies the Elisabeth Bjerg Formation conformably.

Lithology. The formation consists of a wide range of lithologies spanning from white, light grey, and yellow dolomites, grey or bluish limestones, to subordinate brown or purple quartzose breccias (Figs 6, 7, and 8). It is predominantly formed by polymict and carbonate or quartzose stromaclast breccias, microbialites, pisolites, limestone-mudstone couplets, carbonate shales, cross-bedded and wavy bedded calcarenites. At the type locality the lowermost *c.* 20 m are made up by dolomitic mound-forming microbialites and quartzose stromaclast breccias (Fig. 7 and 8A) that grade upward into pisolitic limestones and calcareous stromaclast breccias, *c.* 30 m thick. This interval is overlain by dolomitic mound-forming microbialites, *c.* 20 m thick. Above these *c.* 80 m of limestone-mudstone couplets occurs, which are overlain by *c.* 100 m of interbedded, commonly cross-bedded, carbonate stromaclast and polymict breccias, and cross-bedded calcarenites. The uppermost part of the formation is composed of up to 35 m of limestone-mudstone couplets and structureless limestones.

Depositional environments. The formation records depositional environments ranging from shallow-marine inner- to mid ramp low-energy lagoons, microbial reefs, pisoid shoals and flats, channels, and shoreface to outer ramp environments (Frederiksen MS2).

Fauna and geological age. Acritarchs, probably of sturtian age, include *Trachysphaeridium levis* Vidal, *Trachysphaeridum timofeevi* Vidal, and *Chuaria circularis* (Vidal 1979). Stromatolites in dolomites from Canning Land mainly include *Jurusania*-type forms (Bertrand-Sarfati & Caby 1976).

Boundaries. The lower boundary to the Elisabeth Bjerg Formation coincides with the boundary between the Andrée Land Group and Ymer Ø Groups, and is described above.

The upper boundary is placed at the base of white or cream coloured dolomite of the Reservatet Formation above dark grey limestones of the Skipperdal Formation. The nature of the boundary varies. At the type locality of the Skipperdal Formation, it is sharp, and very irregular with a relief up to 1 m, and marked by a shift from dark grey limestone-mudstone couplets to white structureless dolomites. At Munotbjerg at Ymer Ø the upper boundary is sharp and regular and marked by a shift from dark grey, calcareous, structureless or cross-bedded stromaclast breccias to white dolomitic stromaclast breccias that rapidly grades into white dolomitic microbialites. At the type locality in Scoresby Land and in Suess Land it is transitional over 3-10 m from dark grey structureless limestone to white-coloured, cross-bedded, microbial, or structureless dolomite.

Subdivisions. Two members have been defined in the lowermost part of the Skipperdal Formation, the Karlenes Ø Member and Linné Gletscher Member (Fig. 7). They form two distinct and mappable units due to their colour, lithology and sedimentary structures.

Karlenes Ø Member

New member

Name. After the island Karlenes Ø at the joining of the Segelsällskapets Fjord and Kong Oscars Fjord (Fig. 1).

Type locality. The same as the Skipperdal Formation.

Thickness. The thickness ranges from 15 m at the type section to 2 m in Albert Heim Bjerge in Steno Land (Fig. 7).

Distribution. The member forms the lowermost part of the Skipperdal Formation. It occurs as a laterally continuous unit throughout the studied region from northern Scoresby Land in south to the Wordie Gletscher in north. The presence of the member in Canning Land should be expected, but the descriptions of the Skipperdal Formation by Caby (1976), Bertrand-Sarfati & Caby (1976), and Caby & Bertrand-Sarfati (1988) are not sufficiently detailed to verify this.

Lithology. The member mainly consists of yellow domitic microbialites and/or red brownish coloured dolomitic or quartzose stromaclast breccias (Figs 7 and 8A). Only at the northeastern side of Waltershausen Gletscher in Ole Rømer Land the member contain no microbialites, but is composed of stromaclast breccias.

Depositional environments. The member represents a larger microbial reef with smaller channels and lagoons (Frederiksen MS2).

Boundaries. The lower boundary coincides with the lower boundary of the Andrée Land Group as described above. The upper boundary is transitional, and at the type section marked by a shift from yellow and red brownish coloured, dolomitic and quartzose stromaclast breccias to dark grey calcareous stromaclast breccias.

Linné Gletscher Member

New member

Name. From the Linné Gletscher in the northern Scoresby Land (Fig. 1).

Type locality. The same as the Skipperdal Formation.

Thickness. At the type section it is 24 m thick (Fig. 7). In Lyell Land it is 25 m thick at Berzelius Bjerg and 3 m thick at Kap Alfred (Sommer 1957a).

Distribution. The member is a cliff-forming dolomite in the lower part of Skipperdal Formation. It occurs in north Scoresby Land and throughout Lyell Land as a wedge-shaped rock body. It probably also occurs in Canning Land, however, the descriptions of the Skipperdal Formation by Caby (1976), Bertrand-Sarfati & Caby (1976), and Caby & Bertrand-Sarfati (1988) do not allow this to be ascertained.

Lithology. The member consists of yellow and light grey to light bluish coloured dolomite (Figs. 7 and 8B). At the type section it is predominantly formed by cyclic horizontally to wavy laminated, domal, columnar, and bulbous microbialites with occurrences of carbonate stromaclast breccias between stromatolite forms. The microbialites are arranged in mounds (Fig. 8B). Dolomitic oolites occur at Berzelius Bjerg in Lyell Land (Sommer 1957a).

Depositional environments. The member mainly represents a microbial reef (Frederiksen MS2).

Boundaries. At the type section the lower boundary is marked by a gradational transition from dark grey, cross-laminated pisolitic, dolomitic limestone to yellow, and grey to light bluish coloured, heavily dolomitised polymict breccia that rapidly grades into dolomitic microbialites (Fig. 8B). The upper boundary is sharp and marked by the change from dolomitic stromaclast breccias to wavy-laminated dolomitic limestones.

Reservatet Formation

New fomation

History. The Reservatet Formation corresponds to Bed-group 15 of Katz (1952), Eha (1953), Fränkl (1953a), and Haller (1953), and AL2 formation of Sønderholm & Tirsgaard (1993) (Fig. 3).

Name. From the mountain Reservatet in Steno Land south-east of Wordie Gletscher (Fig. 1).

Type locality. The type locality is at the western mountain slopes of Reservatet and Albert Heim Bjerge in Steno Land (Fig. 1). Other good sections are located parallel to the southern shore of Segelsällskabets Fjord north-east of Skipperdal, north Scoresby Land, and at Munotbjerg at Ymer Ø, the southern coast of Ymer Ø facing the Antarctic Sund, and at Hjørnebjerget west of Krumme Langsø in Hudson Land (Fig. 1).

Thickness. At the type locality the formation reaches a maximum thickness of 90 m (Fig. 9). A similar thickness was measured at Hjørnebjerget in Hudson Land. The thickness shows a general decrease towards west with thicknesses between 15 and 30 m in Ole Rømer Land and Andrée Land. Further south in Suess Land it is up to 75 m thick. In the Kong Oscar Fjord region around north Scoresby Land the formation is *c.* 50 m thick. At the southwestern coast of Strindberg Land it is *c.* 80 m thick (Katz 1952). Stratigraphic studies in this region is hampered by the inaccessiblity and poor exposures (Katz 1952, Frederiksen & Craig 1998, Frederiksen *et al.* 1999), and the estimate of Katz (1952) is appears to be exaggerated. In Canning Land, it is *c.* 60 m thick (Bertrand-Sarfati & Caby 1976).

Distribution. The Reservatet Formation is a dolomitic cliff-forming unit intercalated between the Skipperdal and Arbenz Kolle Formations (Figs 5C, 6C, and 12). It crops out throughout the studied region between north Scoresby Land in the south to Wordie Gletscher in the north.

Lithology. The formation consists of white dolomites and subordinate interbedded grey limestones (Figs 12, 13, and 14). At some localities e.g. at Rytterknægten in Lyell Land the limestones are not completely dolomitised and the predominant lithology is then dolomitic limestone. Preservation of primary textures and structures in the dolomites varies from good to poor due to heavy dolomitisation (Fig. 14A) . Sediments include polymict, stromaclast, and dissolution collapse breccias, microbialites, and in more rare cases cross-bedded and wavy bedded dolomites. At the type locality the lowermost 10-20 m interval are made up by structureless white coloured dolomite which grades into an interval, 4 m thick, of dark grey structureless limestone (Fig. 9). The limestone is overlain by a unit, 45 m thick, of coarse-grained dissolution collapse and polymict breccias containing pebble to cobble-sized clasts of pisolitic dolomite. The uppermost 10 m of the formation, above the collapse breccias, consists of dark grey calcareous stromaclast breccias and structureless limestones overlain by dolomitic microbialites. In northern Scoresby Land the formation consists of a basal interval of structureless dolomites, 5-10 m thick, overlain by coarse-grained dolomitic stromaclast breccias. The breccias contain lenses of massive chert and fine-grained cross-bedded stromaclast breccias (Fig. 14B). At Munotbjerg at Ymer Ø the formation consists of interbedded white dolomitic stromaclast and polymict breccias, and wavy, domal and columnar microbialites. The microbialites form smaller flat, oblate mounds up to 15 cm high and 90 cm wide.

Depositional environments. The formation was deposited in shallow-marine inner- to mid ramp environments such as channel flats, subarially exposed flats, and microbial reefs (Frederiksen MS2).

Fauna and geological age. Microfossils, cyanobacteria and procaryotes, identified in microbialites reach a number of 15 taxa (Green *et al.* 1989). The microfossil assemblage includes the mat builders and dwellers: *Eomycetopsis robusta, Siphonophycus capitaneum, Siphonophycus inornatum, Siphonphycus kestron, Tenuofilum septatum, Eoentophysalis belcherensis, Eoentophysalis medius, Gloeodiniopsis lamellosa, Gloeodiniopsis mikros, Myxococcoides ovata, Myxococcoides stragulescens, Myxococcoides* sp. B and C (see Knoll 1982), *Polybessurus bipartitus, Scissilispaera gradata,*and *Sphaereophycus medium.*

Acritarchs, probably of sturtian age, include the taxa *Chuaria circularis, P. densicoronata* Vidal, *Stictosphaeridium* sp., and *Trachysphaeridium levis* (Vidal 1979).

Stromatolite forms identified in dolomites from Canning Land mainly include *Tungussida* (Bertrand-Sarfati & Caby 1976).

Boundaries. The lower boundary of the formation is placed where the white or cream coloured dolomite overlies dark grey limestones of the Skipperdal Formation. The nature of the boundary is described under the upper boundary of the Skipperdal Formation.

The upper boundary to the Arbenz Kolle Formation is placed at the transition from dolomite to limestone (Fig. 12). At some localities e.g. Munotbjerg at Ymer Ø, it is transitional over 5-10 m from white structureless dolomite grading into dark grey wavy-bedded limestone by a transitional interval predominantly formed by dolomitic limestone.

Arbenz Kolle Formation

New formation

History. The Arbenz Kolle Formation corresponds to bed-group 16 of Katz (1952), Eha (1953), Fränkl (1953a), and Haller (1953), and the AL3 formation of Sønderholm & Tirsgaard (1993) (Fig. 3).

Name. From the mountain Arbenz Kolle located in Lyell Land (Fig. 1).

Type locality. The type locality is located on the slopes of Rytterknægten in Lyell Land facing Narhvalsund (Fig. 1). Good sections are located at Kap Weber in Andre Land, north of Brogetdal in Strindberg Land, at Munotbjerg at Ymer Ø, and the southern coast of Ymer Ø facing the Antarctic Sund (Fig. 1).

Thickness. At the type locality the formation is *c.* 80 m thick (Fig. 10). To the south in Scoresby Land it reaches a thickness of 170 m, and northwards at Ymer Ø and in Andrée Land it is between 110 and 130 m thick. Further north on the north-eastern side of Waltershausen Gletscher in Ole Rømer Land the thickness is 35 m. In Hudson Land and Steno Land the thickness varies between 20 and 190 m. In Canning Land, a thickness of *c.* 110 m was reported by Bertrand-Sarfati & Caby (1976).

Distribution. The formation is intercalated between the Reservatet and Kap Mohn Formations (Figs 5C, 6C, 10, 12, and 15). It crops out in the entire studied region between north Scoresby Land in the south and Wordie Gletscher in the north.

Lithology. The formation mostly consists of grey or bluish limestones, but white, light grey, or yellowish dolomites may also be present. Sediments primarily include pisolites, limestone-mudstone couplets, trough-cross bedded calcarenites, but also polymict and carbonate stromaclast breccias, microbialites, and laminated calcareous mudstones occur. At the type locality a basal interval, *c.* 15 m thick, is made up by limestone-mudstone couplets that grade upwards into a distinct unit, 6 m thick, consisting of mixed dolomitic polymict breccias, limestone-marlstone couplets and dolomitic microbial mounds with stromaclast breccias. This unit is overlain by an interval, 25 m thick, dominated by limestone-mudstone couplets with a few interbeds of pisolites or stromaclast breccias. Above this an interval, *c.* 40 m thick, dominated by cross-bedded pisolites of limestone or dolomitic limestone, and limestone-mudstone couplets occur.

Depositional environments. The formation was mainly deposited in inner- to mid ramp pisoid shoals and flats and outer ramp environments , but evidence of microbial reefs, channel, lagoonal, and shoreface environments are also present (Frederiksen MS2).

Fauna and geological age. Acritarchs, probably of sturtian age, found in grey limestones include *Kildinella hyperboreica* Timofeev, *Kildinella sinica*, *P. densicoronata* Vidal, and *Turuchanica* sp. (Vidal 1979). Stromatolite forms identified in limestones from Canning Land include *Tungussida* (Bertrand-Sarfati & Caby 1976).

Boundaries. The lower boundary is placed at the base of first occurrence of limestone (Figs 15). The nature of the boundary varies. At the type locality it is sharp, planar, and marked by a shift from light grey polymict breccias to dark grey limestone-mudstone couplets. At other localities it is transitional (see description of the upper boundary of the Reservatet Formation).

The upper boundary to the Kap Mohn Formation is placed at the transition from limestone to dolomite. At the type section of the Formation it is sharp and marked by a shift from limestone-mudstone couplets to structureless dolomites. At some localities, e.g. in Albert Heim Bjerge in Steno Land, the boundary is transitional over 3-4 m, where grey pisolitic limestones grade into white structureless or pisolitic dolomites over an interval of predominantly interbedded pisolitic and structureless dolomites and limestones.

Kap Mohn Formation

New formation

History. The Kap Mohn Formation corresponds to bed-group 17 of Katz (1952), Eha (1953), Fränkl (1953a), and Haller (1953), and the AL4 formation of Sønderholm & Tirsgaard (1993) (Fig. 3).

Name. From the westernmost point of Ymer Ø (Fig. 1).

Type locality. The type section is well exposed between Kap Mohn and Margerie Dal at the southern coast of Ymer Ø (Fig. 1). good sections are located at Rytterknægten in Lyell Land, at Hjørnebjerget in Hudson Land, and east of Skipperdal in North Scoresby Land (Fig. 1).

Thickness. At the type locality the formation is 110 m thick (Fig. 11). In the Kong Oscar Fjord region at Rytterknægten in Lyell Land, and around Skipperdal in north Scoresby Land it is 70 to 130 m thick. Northwards in Andrée Land it is *c.* 30 m, at Hjørnebjerget and in Albert Heim Bjerge in Hudson Land and Steno Land it is *c.* 30 m and 55 m, respectively. In Canning Land, it is *c.* 70 m thick (Bertrand-Sarfati & Caby 1976).

Distribution. The formation is a dolomitic cliff-forming unit intercalated between the Arbenz Kolle and the Grejsdalen Formations (Figs 12). It crops out throughout the studied region between north Scoresby Land in the south to Wordie Gletscher in the north.

Lithology. The formation consists mainly of white dolomites, and subordinate of interbedded grey limestones especially at the base (Fig. 16). At some localities e.g. Nanortalikdal in Suess Land and Brogetdal in Strindberg Land, the limestones are not completely dolomitised and the predominant lithology is then dolomitic limestone. Preservation of primary textures and structures in the dolomite varies from good to poor due to heavy dolomitisation. Sediments include polymict, stromaclast, and dissolution collapse breccias, pisolites, and microbialites. At the type locality a basal interval, 25 m thick, is made up by white dolomites and grey dolomitic limestone breccias which grade into an interval, 15 m thick, of white dolomitic pisolites. This interval is overlain by a unit, 15 m thick, of white dolomitic polymict and stromaclast breccias, and pisolites, which is followed by a unit, 55 m thick, of white dolomitic polymict and stromaclast breccias and microbialites. At Kap Weber in Andrée Land the formation is composed of interbedded white dolomites and dark grey limestones, composed of mainly microbialites and polymict breccias. At Hjørnebjerget in Hudson Land, the formation is composed exclusively of white dolomitic, stromaclast breccias. In northern Scoresby Land the formation consists of a basal interval, 20 m thick, of structureless dolomites overlain by grey pisolitic limestones and polymict limestone breccias, 15 m thick. The uppermost 10 m of the formation consists of dolomitic polymict breccias (Fig. 16B).

Depositional environments. The Kap Mohn Formation was deposited in shallow-marine inner- to mid ramp environments such as channel flats, subarially exposed flats, and microbial reefs.

Fauna and geological age. Microfossils, cyanobacteria and procaryotes, in microbialites reach a number of 13 taxa (Green *et al.* 1989). The microfossil assemblage includes the mat builders and dwellers: *Eomycetopsis robusta, Siphonophycus inornatum, Siphonophycus kestron, Tenuofilum septatum, Clonophycus vulgaris, Eoentophysalis belcherensis Eosynechococcus amadeus Gloeodiniopsis lamellosa, Myxococcoides cantabrigiensis, Myxococcoides ovata, Myxococcoides* sp. B and C (see Knoll 1982), and *Sphaereophycus parvum.*

Boundaries. The lower boundary is defined as the base of the white or pale grey dolomite or dolomitic limestone unit overlying dark grey limestones of the Arbenz Kolle Formation. The nature of the boundary varies. At the type locality it is transitional from dark grey, structureless limestones to white, dolomitic polymict and stromaclast breccias with a transitional interval, 8 m thick, composed of mainly polymict breccias. At Hjørnebjerget in Hudson Land the lower boundary is sharp and marked by the change from dark grey fine-grained limestones to white dolomite stromaclast breccias. At Kap Weber in Andrée Land the lower boundary is poorly defined, but appears as a transition from dark grey microbial limestones to interbedded microbial or brecciated dolomites and limestones of white and dark grey colours, respectively.

The upper boundary to the Grejsdalen Formation is usually sharp and placed at the change from white dolomite to dark grey fine-grained limestone or pisolitic limestone.

Grejsdalen Formation

New formation

History. The Grejsdalen Formation corresponds to bed-group 18 of Katz (1952), Eha (1953), Fränkl (1953a), Haller (1953), Herrington & Fairchild (1989), and the AL5 formation of Sønderholm & Tirsgaard (1993) (Fig. 3). Herrington & Fairchild (1989) subdivided the formation into 16 informal members corresponding to the smallest units that lithostratigraphically could be correlated between Kap Weber in Andrée Land and Ella

Ø (Fig. 3). There has been some debate where the upper boundary of the Grejsdalen Formation should be placed (see below).

Name. From the large SE-NW and E-W trending valley Grejsdalen that dissects Andrée Land (Fig. 1).

Type locality. The type locality is located at the western mountain slopes of Mørkebjerg at Kap Weber in Andrée Land (Fig. 1). Good sections are located at Kap Oswald at Ella Ø, in Albert Heim Bjerge in Steno Land, and at Hjørnebjerget west of Krumme Langsø in Hudson Land (Fig. 1).

Thickness. The thickness of the formation is highly variable. At the type locality it is 590 m thick (Fig. 17), and 620 m thick further north around Brogetdal in Strindberg Land. At the northeastern side of the Waltershausen Gletscher in Ole Rømer Land it reaches its minimum thickness of 135 m. In Hudson Land and Steno Land it is between 190 and 280 m thick. In the Kong Oscars Fjord region it is 340 m thick around Munotbjerg at Ymer Ø, at least 640 m thick at Ella Ø, and 285 m thick in north Scoresby Land. In Canning Land it is *c.* 425 m thick (Bertrand-Sarfati & Caby 1976).

Distribution. The formation consists of limestone that commonly forms recessive outcrops with a number of dolomitic cliff-forming units (Figs 5A, 5B, 17, and 18). The formation is intercalated between the Kap Mohn and Munotbjerg Formations. It crops out throughout the studied region between northern Scoresby Land in the south to Wordie Gletscher in the north. In addition, a smaller part of the formation is exposed in Payer Land on the northeastern side of Wordie Gletscher. The sections at Ella Ø were mistakenly correlated with the Reservatet Formation by Schaub (1950).

Lithology. The formation consists of lithologies such as grey, bluish or black limestones and white, light grey, and yellow dolomites occasionally with lenses or interlayers of chert (Figs 5A, 5B, 17, and 18). Sediments include limestone-mudstone couplets, microbialites, pisolites, polymict, dissolution collapse and carbonate stromaclast breccias, and carbonate shales. At the type locality the basal *c.* 135 m are composed of pisolitic limestones occasionally interbedded with units of limestone-mudstone couplets. The pisolitic limestones grade into an interval, *c.* 40 m thick, of dolomitic microbialites mainly consisting of domal or columnar biostromes. Above these, an interval, *c.* 300 m thick, of limestone-mudstone couplets occurs. It contains a few interbedded units of pisolites and subhorizontally, wavy, and domal microbialites. It is overlain by an interval, *c.* 90 m thick, of interbedded dolomitised dissolution collapse breccias and microbialites. The upper *c.* 60 m of the formation is structureless due to heavy dolomitisation.

Depositional environments. The formation was deposited in shallow-marine inner- to mid ramp environments such as subaerially exposed flats, lagoons, microbial reefs, pisoid shoals and flats, and channel flats to outer ramp environments (Frederiksen MS2).

Fauna and geological age. Microfossils, cyanobacteria and procaryotes, in microbialites reach a number of 15 taxa (Green *et al.* 1989). The microfossil assemblage includes mat buiders and dwellers: *Eomycetopsis robusta, Siphonophycus capitaneum, Siphonophycus inornatum, Siphonophycus kestron, Tenuofilum septatum, Clonophycus vulgaris, Eoentophysalis belcherensis, Eosynechococcus amadeus, Gloeodiniopsis lamellosa, Gloeodiniopsis mikros, Myxococcoides cantabrigiensis, Myxococoides inornatum, Myxococcoides ovata, Myxococcoides stragulescens, Myxococcoides* sp. B and C (see Knoll 1982), *Scissilisphaera gradata, Sphaerophycus medium,* and *Sphaereophycus parvum.*

Microfossils, cyanobacteria, in coated particles, primaryly ooids and small pisoids, within pisolites reach a number of 13 taxa (Green *et al.* 1988). Apart from some of the species identified in microbialites, the microfossil assemblage in the pisolites includes: *Cunicularius halleri* sp., *Eoentophysalis dismallakesensis, Eohyella rectoclada* sp., *Eohyella endoatracta* sp., *Eohyella dichotoma* sp., *Glenobotrydion* sp., *Graviglomus incrustus* sp., *Parenchymodiscus endolithicus* sp., *Perulagranum obovatum,* ?*Perulagranum* sp., and *Thylacocausticus globorum* sp..

Stromatolite forms in limestones and dolomites from Canning Land mainly include *Tungussida* (Bertrand-Sarfati & Caby 1976).

Boundaries. The lower boundary of the formation is placed at the base of first occurrence of limestone. It is usually sharp planar, and marked by a shift from light grey or white dolomites to dark grey limestones. At the type locality it is marked by a shift from light to dark grey microbialites to limestone-mudstone couplets.

The upper boundary to the Munotbjerg Formation is placed at the change from limestone or dolomite to black calcareous organic-rich shales or dolomitic shales. At the type section it is sharp and associated with an iron-stained unit, 1-2 m thick.

Subdivisions. Three members are defined within the formation: the Niviarsiat Member, Nanortalikdal Member, and the Bjørneø Member (Fig. 17). The Niviarsiat and Nanortalikdal Members are present within the lower part and the Bjørneø Member in the uppermost part of the Grejsdalen Formation. The members are mappable in most of the region between north Scoresby Land and Ole Rømer Land due to their distinct colour, lithology, and sedimentary structures.

Niviarsiat Member

New member

History. Niviarsiat Member corresponds to member 18.3 and possibly also 18.5 of Herrington & Fairchild (1989) (Fig. 3).

Name. From the mountain Niviarsiat at the north coast of Suess Land (Fig. 1).

Type locality. The type locality of the member is at the south coast of Ymer Ø between Kap Mohn and Margerie Dal (Fig. 1). Other good sections are located at Kap Weber in Andrée Land, in Nanortalikdal in Suess Land, at Ella Ø, and at Rytterknægten in Lyell Land (Fig. 1).

Thickness. At the type locality the member is *c.* 100 m thick (Fig. 17). In Andrée Land and Strindberg Land in the north it is 70 m and 120 m thick, respectively, and to the south in northern Scoresby Land it is 15 m thick. In Hudson Land it is up to 35 m thick, and in Canning Land it is *c.* 45 m thick (Bertrand-Sarfati & Caby 1976).

Distribution. The member is composed of mainly pisolitic limestone (Fig. 19). The exact stratigraphic position of the member varies between the localities, but it always forms a unit within the the lower part of the Grejsdalen Formation. At some localities the member is situated at the base of the Grejsdalen Formation directly on the top of the Kap Mohn Formation and at other localities above a minor interval of various unspecified limestones belonging to the Grejsdalen Formation. At some localities, e.g. at Kap Weber in Andrée Land, it is overlain by the Nanortalikdal Member, and at other localities, e.g. in Nanortalikdal in Suess Land, it is overlain by unspecified limestones of the Grejsdalen Formation. It crops out in the studied region between northern Scoresby Land in the south to Strindberg Land in the north, in the north-eastern region of Hudson Land and Steno Land, and in the south-eastern outlier in Canning Land (Bertrand-Sarfati & Caby 1976). It is absent in Ole Rømer Land around Waltershausen Gletscher.

Lithology. The member is composed mainly of pisolitic limestones made up by oncoids, ooids, and pisoids that reach extraordinary large sizes up to 14 mm (Fig. 19). Such sizes have only been reported in a few other studies of pisolites (Gutstadt 1968; Singh 1987; Swett & Knoll 1989; Sumner & Grotzinger 1993, Frederiksen MS2). Subordinate lithologies include limestone-mudstone couplets and pisolitic dolomites.

Depositional environments. The member was deposited on the inner-to mid ramp such as semi-protected lagoons and pisoid shoals and flats, and on the mid- to outer ramp (Frederiksen MS2).

Boundaries. The lower boundary is placed at the base of the first occurrence of pisolitic limestone. It is usually sharp, planar, and marked by a shift from light grey or white dolomites or grey structureless limestones to dark grey pisolitic limestones. At the type locality it is marked by a shift from grey structureless limestones to grey pisolitic limestones.

The upper boundary is placed at the transition from pisolitic limestones to non-pisolitic limestones or dolomites. At the type locality it is gradual and marked by transition over *c.* 20 m from grey pisolitic limestones to limestone-mudstone couplets, pisolitic dolomitic limestones or microbial limestones or dolomitic limestones.

Nanortalikdal Member

New member

History. The Nanortalikdal Member corresponds to members 18.6-18.8 of Herrington & Fairchild (1989) (Fig. 3).

Name. From the N-S trending valley in Suess Land (Fig. 1).

Type locality. The type locality is on the slope of Trugbjerg just east of Nanortalikdal in northern Suess Land (Fig. 1). Other good sections are located at Kap Weber in Andrée Land, in Promenadedal in Hudson Land, in Albert Heim Bjerge in Steno Land, at Munotbjerg at Ymer Ø, and at Ella Ø (Fig. 1).

Thickness. At the type locality the member is 80 m thick (Figs 5A, 5B, and 17). In Andrée Land, Strindberg Land and in Ole Rømer Land at Waltershausen Gletscher in the north it is 50 m, 7 m, and 2 m thick, respectively, and to the south at Ella Ø it is 70 m thick. In Hudson Land it is up to 30 m thick. In Canning Land it is *c.* 100 m thick (Bertrand-Sarfati & Caby 1976).

Distribution. The member is mainly composed of dolomitic microbialite (Fig. 20). The exact stratigraphic position of the member varies between the localities, but it always forms a unit within the lower part of the Grejsdalen Formation. At some localities the member lies directly on the top of Niviarsiat Member and at other localities a shorter interval of various unspecified sediments belonging to the Grejsdalen Formation is intercalated between the Niviarsiat and Nanortalikdal Members (see above). The member crops out in the studied region between Lyell Land in south and Ole Rømer Land in north, in the north-eastern region of Hudson Land and Steno Land, and in the south-eastern outlier of Canning Land (Bertrand-Sarfati & Caby 1976). It is not present in north Scoresby Land.

Lithology. The member is predominantly composed of dolomitic microbialites and associated carbonate stromaclast breccias (Fig. 20). Subordinary lithologies include limestone-mudstone couplets, pisolitic dolomites, and carbonate shales. At the type locality the basal 20 m of the member are composed of interbedded dolomitic microbialites and carbonate stromaclast breccias. This interval is overlain by 60 m of dolomitic microbialites with a few interbedded limestone-mudstone or microbial limestone intervals up to *c.* 5 m thick.

Depositional environments. The Nanortalikdal Member was deposited in shallow-marine inner- to mid ramp microbial reefs and low-energy lagoons (Frederiksen MS2).

Boundaries. The lower boundary is placed at the base of the first occurrence of dolomitic microbialites or stromaclast breccias (Figs 6A, 6B, and 17). It is sharp and planar, or transitional over about 5 m. It is usually marked by a shift from grey pisolitic or structureless limestone to dolomitic microbialites or stromaclast breccias. At the type locality it is marked by a shift from grey laminated limestones to white dolomitic stromaclast breccias over 4 m structureless dolomite.

The upper boundary is placed at the transition from dolomitic microbialites or stromaclast breccias to grey limestones, commonly limestone-mudstone couplets (Figs 6A, 6B, and 17). The boundary is not exposed at the type locality, but at the reference section at Kap Weber in Andrée Land it is gradual with a transition over *c.* 3 m from white dolomitic microbialites to light grey calcareous microbialites to dark grey limestone-mudstone couplets (Figs 6A and B).

Bjørneø Member

New member

History. Bjørneø Member corresponds to member 18.14 of Herrington & Fairchild (1989) (see discussion below) (Fig. 3).

Name. From the island Bjørneø in Geologfjord between Andrée Land and Strindberg Land (Fig. 1).

Type locality. The same as the Grejsdalen Formation. Other good sections are located at Hjørnebjerget in Hudson Land and in Albert Heim Bjerge in Steno Land (Fig. 1).

Thickness. At the type locality the member reaches its maximum thickness of 90 m (Fig. 5A, 5B, and 17). In the northern part of the Kong Oscars Fjord region it is between 20 and 35 m thick, and to the south in Scoresby Land only 10 m thick. In Steno Land, Hudson Land and Payer Land thicknesses are between 15 and 40 m. At many localities the thickness recorded represent a minimum thickness as the upper boundary of the member is covered by scree or vegetation due to the recessive nature of overlying shales of the Munotbjerg Formation. In Canning Land it is *c.* 130 m thick (Bertrand-Sarfati & Caby 1976).

Distribution. The member is composed of dolomite which is mostly structureless, or forms dissolution collapse breccias or microbialites (Fig. 21). Stratigraphically, the member is positioned within the uppermost part of the Grejsdalen Formation. At some localities the member is directly overlain by the Munotbjerg Formation while at other localities an interval, 10-20 m thick, of unspecified sediments of the Grejsdalen Formation separates the Bjørneø Member from the Munotbjerg Formation. It crops out in the studied region between Scoresby Land in south to Andrée Land in north, in the north-eastern region of Hudson Land, Steno Land, and Payer Land, and from the south-eastern outlier in Canning Land (Bertrand-Sarfati & Caby 1976). It is not found in Strindberg Land and Ole Rømer Land.

Lithology. The member is predominantly composed of white-coloured structureless dolomite, dolomitic microbialites or dissolution collapse breccias. In the northern part of the region in Hudson Land, Steno Land and Payer Land dissolution collapse breccias are the most common facies. At the type locality the lowermost 30 m are composed of interbedded dolomitic microbialites and dissolution collapse breccias. This interval is overlain by *c.* 60 m of structureless dolomites.

Depositional environments. The member was deposited in shallow-marine inner- to mid ramp environments such as channel flats, subarially exposed flats, and microbial reefs (Frederiksen MS2).

Boundaries. The lower boundary is placed at the base of the first occurrence of dolomite. It is always sharp and planar, and is usually marked by a shift from grey limestone to white dolomitic dissolution collapse breccias or microbialites (Fig. 21).

The upper boundary is placed at the shift from white structureless dolomite, dolomitic dissolution collapse breccias or microbialites to limestone-mudstone couplets, normally graded limestones, or black shales. At the type locality the boundary is sharp and planar and marked by a shift from white structureless dolomite to fissile, black shales of the Noa Dal Member, Munotbjerg Formation.

Munotbjerg Formation

New member

History. The Munotbjerg Formation corresponds to bed-group 19 of Katz (1952), Eha (1953), Fränkl (1953a), Haller (1953), Hambrey & Spencer (1987), Herrington & Fairchild (1989), and the AL6 formation of Sønderholm & Tirsgaard (1993) (Fig. 3). Herrington & Fairchild (1989) subdivided the formation into seven informal members corresponding to the smallest units that lithostratigraphically could be correlated between Kap Weber in Andrée Land and Ella Ø (fig. 3). Schaub (1950, 1955), Eha (1953), Hambrey & Spencer (1987), and Herrington & Fairchild (1989) placed the boundary between the Grejsdalen and Munotbjerg Formations *c.* 50 m higher in the succession than in this study, and consequently the Noa Dal Member and another unspecified unit stratigraphically above the Noa Dal Member (member 18.16 of Herrington & Fairchild 1989) was described as members of the Grejsdalen Formation. Fränkl (1953a) placed the boundary at the top of Bjørneø Member (member 18.14 of Herrington & Fairchild 1989) which is correct for east Andrée Land (the study area of Fränkl 1953), but as a general marker horizon for the boundary between the Grejsdalen and Munotbjerg Formations it is wrong. Herrington & Fairchild (1989) rejected Fränkl's (1953a) placement of the boundary as they argued that the Bjørneø Member was a dolomite body that cuts across the "layer-cake" and owes its distinct character to diagenetic dissolution. The statement of Herrington & Fairchild (1989) is true, but as the dolomite bodies comprising the Reservatet and Kap Mohn Formations also cut across the "layer-cake" and partly owe their distinct character to diagenetic dissolution the present author finds the member status of the Bjørneø Member and the position of the boundary between the Grejsdalen and Munotbjerg Formations justified. The boundary is here placed between the Grejsdalen and Munotbjerg Formations at the lithological shift from white dolomite or grey limestone to black shales of the Noa Dal Member (where present) or to mainly light grey or buff-coloured dolomitic shales.

Name. From the mountain Munotbjerg east of Margerie Dal at Ymer Ø (Fig. 1).

Type locality. The type locality is just north of the mountain Munotbjerg in the southern part of Ymer Ø (Fig. 1). Other good sections are located at Kap Weber and Månesletten in Andrée Land, at Arenaen at Ymer Ø, the southern coast of Ymer Ø facing the Antarctic Sund, the western mountain slope of Trugbjerg in Suess Land, and at Ella Ø just east of Kap Oswald (Fig. 1).

Thickness. Maximum thickness of 160 m to 210 m is measured in the area between Andrée Land and Ella Ø (Fig. 22), around the Waltershausen Gletscher it is only 9 m, and in Hudson Land and Steno Land up to *c.* 5 m.

Distribution. The formation consists of recessive, calcareous and dolomitic shales. It is intercalated between the Grejsdalen and the Waltershausen Gletscher Formations or the Ulvesø Formation of the Tillite Group (Figs 5A, and 23A, B and C). At Hammeren on Ymer Ø a tongue of the formation occurs within the Waltershausen Gletscher Formation. The formation crops out in Lyell Land, Ella Ø, Suess Land, Ymer Ø, Andrée Land, Strindberg Land, and Ole Rømer Land.

Around Sorteelv Gletscher in Scoresby Land, Fränkl (1953b) identified a rock succession, 140-150 m thick, below the Tillite Group as the bed-group 19 (here Munotbjerg Formation). Hambrey & Spencer (1987) and Moncrieff (1988) rejected the observations by Fränkl (1953b) and suggested that the formation is missing in Scoresby Land, and the younger Ulvesø Formation, Tillite Group rests on sediments from the Grejsdalen Formation. This fits well with the general thinning of the formation from Ella Ø and southwards as well as its absence in Canning Land, where the Storeelv Formation (Tillite Group) rests unconformably on rocks probably belonging to the Grejsdalen Formation (Caby 1972; Hambrey & Spencer 1987).

Around the mountains Hjørnebjerget and Snehvide in Hudson Land, and Albert Heim Bjerge in Steno Land only a few metres of the Munotbjerg Formation are measured, and in Promenadedal in Hudson Land and on the northeastern side of the Wordie Gletscher in Payer Land it is absent. The absence or small thickness in Steno Land, Hudson Land, and Payer Land is due to later faulting which probably took place during the Caledonian orogeny.

Lithology. The Munotbjerg Formation is composed of grey, brown, red, purple, green, orange, yellow, black and buff-coloured dolomitic and calcareous shales (Figs 23 and 25). Other lithologies include light brown dolomitic mud conglomerates rich in black limestone clasts, and black calcareous organic-rich shales. At the type locality a basal interval, at least 16 m thick, is composed of black calcareous, organic-rich recessive shales. They are overlain by *c.* 40 m thick grey or buff-coloured, dolomitic and calcareous shales, overlain by two distinct marker units. The lower unit is composed of black normally graded, shaly limestone, *c.* 5 m in thick, and the upper unit is *c.* 8 m thick and composed of grey and buff-coloured dolomitic shale showing climbing ripple lamination. The two units are overlain by mainly green, red and purple dolomitic shales, 35 m thick, Above the dolomitic shales, another distinct marker unit, 5 m thick, containing thin bands of green, red, purple or buff-coloured dolomitic shales with climbing ripple lamination that rapidly grades into grey and yellow-coloured dolomitic shales. The unit is overlain by *c.* 60 m of green, red, orange and purple dolomitic shales with a few beds of calcareous shales that form the top of the Munotbjerg Formation. At some of the reference sections, e.g. at the coastal slopes of Antarctic Sund just east of Kap Mohn at Ymer Ø, characteristic beds, 50 cm thick, of brown carbonate mudstone conglomerates occur within the upper dolomitic shale.

Depositional environments. The Munotbjerg Formation mainly records deposition in base-of-slope environments that were fed by turbidity currents or debris flows, or were sediment starved (Frederiksen MS4).

Fauna and geological age. Well-preserved acritarchs, probably of sturtian age, from dark grey shales include *Kildinella hyperboreica* Timofeev, *Kildinella sinica* Timofeev, *Kildinella vesljanica* Timofeev, *Stictosphaeridium* cf. *sinapticuliferum* Timofeev, *Stictosphaeridum verrucatum* Vidal, *Synsphaeridium* sp., *Protosphaeridium laccatum, Trachysphaeridium laufeldi, Trachysphaeridium laminaritum* and *Chuaria circularis* (Vidal 1976, 1979).

Boundaries. The lower boundary to the Grejsdalen Formation is usually covered by scree due to the commonly recessive nature of the Munotbjerg Formation (Fig. 23C). It is placed at the transition from grey limestone or white dolomite to black organic-rich shales or dolomitic shales. At the type section it is covered by scree. North-east of Waltershausen Gletscher the boundary is sharp and non-erosional, marked by a shift from light grey to buff-coloured dolomite breccias to grey-greenish shales.

The nature of the upper boundary varies as it depends on whether the Munotbjerg Formation is overlain by the Waltershausen Gletscher Formation or the Ulvesø Formation (Tillite Group) (Figs 5A, 5B, 23B, and 23E). North-east of Waltershausen Gletscher in Ole Rømer Land the boundary to Waltershausen Gletscher Formation is irregular, but sharp, erosional and marked by the shift from greenish shales to dark grey limestone breccia. At Månesletten in Andrée Land it is sharp, non-erosional and marked by the shift from grey to buff-coloured dolomitic shales to a heavily dolomite veined, dark grey limestone. At Ymer Ø, just east of Kap Mohn, it is a tectonic contact, marked by the shift from greenish shales to deformed, dark grey pebbly limestone preserved as a 1-2 m thick lensoid slice, belonging to the Tillite Group as it contains deformed down-bended lamination below pebble clasts suggesting a dropstone depositional mode. Pebbles consist of carbonate, quartzite, mudstone, and tillite. Hambrey & Spencer (1987) suggested that the boundary between the formations of the Andrée Land Group and the Tillite Group should be placed at the first occurrence of sandy sediments, and in this case the pebbly limestones is considered as belonging to the Waltershausen Gletscher Formation. In Suess Land the boundary to the Ulvesø Formation is transitional over 10 cm and marked by a shift from buff-cloured dolomitic shales to diamictites representing dropstones laid down in distal glaciomarine environment (Hambrey & Spencer 1987). At Ymer Ø and Ella Ø the boundary to the Ulvesø Formation is planar, sharp and erosional, and marked by a shift from greenish or reddish dolomitic shales to weakly bedded diamictites interpreted as waterlain tillites (see Moncrieff & Hambrey 1988). In Steno Land the Ulvesø is a tectonic contact upon the Munotbjerg Formation.

Subdivisions. One member is defined, the Noa Dal Member, in the lower part of the formation. It is easy mappable due to its black colour and fissile shale lithology.

Noa Dal Member

New member

History. The Noa Dal Member corresponds to Member 18.15 of Herrington & Fairchild (1989) (Fig. 3). The Noa Dal Member to the Grejsdalen Formation, but this is not followed here (see above) (Schaub 1950, 1955; Eha 1953; Hambrey & Spencer 1987; Herrington & Fairchild 1989).

Name. From the valley Noa Dal in the northwestern part of Ymer Ø (Fig. 1).

Type locality. The type locality is at Arenaen in the northern part of Ymer Ø (Fig. 1). Other good sections are located at Kap Weber in Andrée Land and just north of the mountain Munotbjerg in the southern part of Ymer Ø (Fig. 1).

Thickness. The thickness of the member is 12 m at the type locality. At the reference sections the thickness is more difficult to estimate due to the recessive nature and poor quality of the exposures. At Kap Weber in Andrée Land and around Munotbjerg in southern Ymer Ø the member is 16-30 m and at least 16 m thick, respectively.

Distribution. The member is composed of organic-rich black shales (Fig. 25). The stratigraphic position of the member is within the lowermost part of the Munotbjerg Formation. At some localities the member directly overlies the Bjørneø Member or uspecified sediments of the Grejsdalen Formation, and at other localities it overlies unspecified sediments of the Munotbjerg Formation. It crops out in the studied region at Munotbjerg at the southern part of Ymer Ø, at Arenaen and Hammeren on northern Ymer Ø, and at Kap Weber in Andrée Land. Based on a wrong correlation to limestones of the Grejsdalen Formation Herrington & Fairchild (1989) also inferred thee presence of the member at Ella Ø. The member is possibly present on Ella Ø below the scree cover of the Storeelv river plain. Organic-rich black shales probably corresponding to the Noa Dal Member were reported by Sommer (1957a) from Kap Lagerberg in Lyell Land.

Lithology. The member is exclusively made up by a fissile black, organic-rich calcareous shale (Fig. 25). Lenses or nodules of iron-staining are common.

Depositional environments. The member mainly records very low-energy sedimentation in an anaerobic, poorly water-circulated and sediment starved base-of-slope environment (Frederiksen MS4).

Boundaries. The boundaries of the Noa Dal Member are rarely exposed due to the recessive nature except for the type locality (Fig. 25). Both the lower and upper boundary is sharp and planar and without any signs of erosion.

Waltershausen Gletscher Formation

New formation

History. The Waltershausen Gletscher Formation corresponds to bed-group 20 of e.g. Katz (1952), Eha (1953), Fränkl (1953a), Haller (1953), Hambrey & Spencer (1987), Herrington & Fairchild (1989), and the AL7 formation of Sønderholm & Tirsgaard (1993) (Fig. 3). Herrington & Fairchild (1989) further subdivided the formation into three informal members at Kap Weber in Andrée Land (Fig. 3).

Name. From the SE-NW trending glacier between Strindberg Land and Ole Rømer Land (Fig. 1).

Type locality. The type locality is on the north-east of the Waltershausen Gletscher in Ole Rømer Land. Other good sections are present at Månesletten and Kap Weber in Andrée Land, and at Arenaen on Ymer Ø (Fig. 1).

Thickness. At the type locality the formation has its maximum thickness of 240 m (Fig. 24). The thickness shows a marked decrease southwards with thicknesses of 95 m, 85 m, 35 m, and 2 m at Kap Weber and Månesletten in Andrée Land and Arenaen and the south coast at Ymer Ø, respectively (Fig. 4).

Distribution. The Waltershausen Gletscher Formation is made up by a cliff-forming limestone unit, that stratigraphically overlies the Munotbjerg Formation, and forms the top of the Andrée Land Group (Figs 5A and B). It is overlain by the Ulvesø Formation of the Tillite Group, and crops out in Ole Rømer Land, Strindberg Land, Andrée Land, and on Ymer Ø.

Lithology. The formation mostly consists of dark grey or bluish limestones, but rare light grey or buff-coloured dolomites are present at some localities (Figs 5A, 5B and 25). Sediments mainly include limestone-mudstone couplets, turbiditic limestones, pisolitic limestones, and calcareous shales, with subordinate limestone and dolomite stromaclast and polymict breccias. At the type locality the lowest 5 m is composed of buff-coloured dolomitic polymict breccias that rapidly grade into cross-bedded stromaclast breccias. This is overlain by an interval, *c.* 150 m thick, of dark grey limestone-mudstone couplets containing a few lenses or interbeds of dark grey limestone stromaclast breccias. The limestone-mudstone couplets are overlain by a distinct unit, 2 m thick, of light grey dolomite polymict breccia. Above this unit an intervalof poorly exposed limestones, 15 m thick, occur. These are overlain by dark grey turbiditic limestones, *c.* 10 m thick. At the top of the formation a unit of pisolitic limestones, up to 40 m thick, occurs in Ole Rømer Land (Figs 4, and 24). In Strindberg Land and at Hammeren and Arenaen both at Ymer Ø the uppermost 1-10 m thick part is made up of calcareous shales.

Depositional environments. The Waltershausen Gletscher Formation represents a carbonate ramp with depositional environments ranging from pisoid shoals and flats of the inner- to mid ramp to outer ramp environments (Frederiksen MS4).

Fauna and geological age. No fauna have been reported in previous studies.

Boundaries. The lower boundary to the Munotbjerg Formation is placed at the transition from black organic-rich calcareous shales or dolomitic shales to grey limestones (Fig. 25). At the type section the boundary is irregular, but sharp erosional and marked by a shift from greenish dolomitic shales to buff-coloured dolomitic polymict breccia. In Strindberg Land the boundary is planar and erosional boundary marked by a shift from buff-coloured dolomitic shales to dark grey turbiditic limestones. At Månesletten in Andrée Land it is sharp, non-erosional and marked by the shift from grey to buff-coloured dolomitic shales to a heavily dolomite veined limestone.

The upper boundary to the Ulvesø Formation of the Tillite Group is placed at the transition from dark grey limestones, or grey or bluish shales to diamictites, conglomerates or sandstones. At Kap Weber in Andrée Land and at Ymer Ø just east of Kap Mohn aeolian sandstones and glaciomarine diamictites, repectively, of the Ulvesø Formation is in tectonic contact upon the grey limestones of the Waltershausen Gletscher Formation (Moncrieff & Hambrey 1988). At Arenaen at the northern part of Ymer Ø the boundary is transitional over 10 cm and marked by a shift from bluish shale with abundant soft sedimentary deformation structures to diamictite of glaciomarine origin that within 1 m pass into a very coarse-grained, clast-supported conglomerate interpreted as a subglacial drainage deposit from other parts of the Tillite Group (Moncrieff & Hambrey 1990).

Subdivision. A new member is defined, the Aasesøen Member. It forms a distinct and mappable unit.

Aasesøen Member

New member

Name. From the lake in Ole Rømer Land just north-east of the SE-NW trending Waltershausen Gletscher (Fig. 1).

Type locality. At the NW-facing slopes just west of the lake Aasesøen in Ole Rømer Land (Fig. 1).

Thickness. At the type locality the member is *c.* 40 m thick.

Distribution. The member forms the uppermost part of the Waltershausen Gletscher Formation just below the Ulvesø Formation of the Tillite Group. It is only known from Ole Rømer Land.

Lithology. The member is composed of alternating dark grey oolitic and pisolitic limestones.

Depositional environments. The member represents an inner- to mid ramp pisoid shoal and flat environment (Frederiksen MS4).

Boundaries. The lower boundary is placed at the first occurrence of oolitic or pisolitic limestone, and the upper boundary is placed at the first occurrence of non-oolitic or non-pisolitic limestone. The exact nature of the boundaries is not known, as they are not well exposed, but the exposed rocks below the member comprise dark grey or black turbiditic limestones. The rocks above the member are light brown sandstones of the Ulvesø Formation of the Tillite Group.

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Figure captions:

Fig. 1. Sketch map showing the distribution of the Eleonore Bay Supergroup in North-East Greenland with geographical place names used in the text. Abreviations in alphabetic order: AH: Albert Heim Bjerge, AK: Arbenz Kolle, A: Arenaen, BB: Berzelius Bjerg, BØ: Bjørneø, BD: Brogetdal, CHO: C.H. Ostenfeld Nunatak, GD: Grejsdalen, H: Hammeren, HB: Hjørnebjerget, KA: Kap Alfred, KLB: Kap Lagerberg, KM: Kap Mohn, KO: Kap Oswald, KW: Kap Weber, KØ: Karlenes Ø, KD: Kirschdalen, KL: Krumme Langsø, LG: Linné Gletscher, MS: Månesletten, MU: Munotbjerg, MD: Margerie Dal, MØ: Mørkebjerg, ND: Nanortalikdal, NI: Niviarsiat, NO: Noa Dal, PD: Promenadedal, R: Reservatet, RK: Rytterknægten, SD: Skipperdal, SF: Segelsällskapet Fjord, S: Snehvide, SG: Sorteelv Gletscher, TB: Trugbjerg, and AaS: Aasesøen.

Fig. 2. Lithostratigraphic subdivision of Eleonore Bay Supergroup (modified after Sønderholm & Tirsgaard 1993).

Fig. 3. Comparison between the subdivision of the Andrée Land Group in this study and in previous studies.

Fig. 4. Stratigraphic sections of the Andrée Land Group. **(A)** Composite log from the reference section at Månesletten and the type section at Kap Weber in Andrée Land, and the reference sections **(B)** at Ymer Ø, and **(C)** Waltershausen Gletscher in Ole Rømer Land. **(D)** Legend to lithologies, textures and structures used in the stratigraphic sections.

Fig. 5. Views of the Andrée Land Group at the type locality at Kap Weber, Andrée Land (A, B, and C) and at the reference section at Nanortalikdal, Suess Land (D). **(A)** View of the Arbenz Kolle (AK), Kap Mohn (KM), Grejsdalen (GD), Munotbjerg (MB), and Waltershausen Gletscher (WG) Formations, and the sandy Ulvesø (US) Formation of the Tillite Group in the south-facing mountain wall at Kap Weber. Note the prominent cliff-forming white-coloured dolomite unit, the Bjørneø Member (BØ), within the upper part of Grejsdalen Formation overlain by recessive black shales of the Noa Dal Member (ND). The succession from sea-level to the base of the Ulvesø Formation is *c.* 1100 m thick. **(B)** View of the Arbenz Kolle (AK), Kap Mohn (KM), Grejsdalen (GD) including the Niviarsiat (NI), Nanortalikdal (NA) and Bjørneø (BØ) Members, Munotbjerg (MB), and Waltershausen Gletscher (WG) Formations, and the sandy Ulvesø Formation (US) of the Tillite Group on the west-facing mountain slope at Kap Weber perpendicular to the mountain wall of (A). The succession from the river plain and up to the base of the Tillite Group is *c.* 1100 m thick. **(C)** The boundary between the Ymer Ø (YØG) and Andrée Land Groups at the type locality Kap Weber, Andrée Land *c.* 5 km north of (B), showing the Skipperdal (SD), Reservatet (RE) and Arbenz Kolle

(AK) Formations. **(D)** View of the Arbenz Kolle (AK), Kap Mohn (KM), Grejsdalen (GD), and Munotbjerg (MB) Formations, and the diamictic Ulvesø Formation (US) of the Tillite Group at the west-facing mountain slopes of Trugbjerg at Nanortalikdal, Suess Land. Succession between base of photo to base of Tillite Group boundary is *c.* 750 m.

Fig. 6. Views of the Ymer Ø-Andrée Land Group boundary. **(A)** The boundary on the southern coast of Strindberg Land, the steep cliff-forming upper Ymer Ø Group (YØG) and lower Andrée Land Group (ALG) are succeeded by recessive plateau-forming Andrée Land Group rocks. The cliff is *c.* 1 km high. **(B)** The boundary between the Ymer Ø Group (YØG) and Skipperdal Formation (SD) containing the Karlenes Ø (KØ) and Linné Gletscher (LG) Members, just east of Skipperdal, in northern Scoresby Land. Section shown is *c.* 300 m thick. **(C)** The boundary at the southern coast of Suess Land facing Kempe Fjord. The top of the Ymer Ø Group (YØG), Skipperdal (SD), Reservatet (RE), Arbenz Kolle (AK), Kap Mohn (KM), and Grejdalen (GD) Formations are shown. The Reservatet Formation in center of the photo is *c.* 40 m thick. **(D)** Close-up of the boundary just east of Skipperdal, in northern Scoresby Land, placed at the top of the greenish grey recessive weathering siliciclastic shale (S) intercalated between yellow and grey-coloured dolomitic stromaclast breccias (SB) and microbialites (M).

Fig. 7. Stratigraphic section of the calcareous and dolomitic Skipperdal Formation including Karlenes Ø and Linné Gletscher Members at the type locality, just east of Skipperdal, northern Scoresby Land. For legend see Fig. 4D.

Fig. 8. View of the members within the Skipperdal Formation (Karlenes Ø and Linné Gletscher Members) at the type locality in Scoresby Land. **(A)** Yellow-coloured dolomitic microbial mounds of the Karlenes Ø Member and **(B)** white to yellowish-coloured dolomitic microbial mounds of the Linné Gletscher Member overlying unspecified dark grey pisolitic limestones of the Skipperdal Formation.

Fig. 9. Stratigraphic section of the dolomitic Reservatet Formation at the type locality in Albert Heim Bjerge, Steno Land. For legend see Fig. 4D.

Fig. 10. Stratigraphic section of the calcareous Arbenz Kolle Formation at the type locality at Rytterknægten, Lyell Land. For legend see Fig. 4D.

Fig. 11. Stratigraphic section of the dolomitic Kap Mohn Formation at the type locality on the western part of Ymer Ø. For legend see Fig. 4D.

Fig. 12. Dark grey calcareous Skipperdal (SD), white dolomitic Reservatet (RE), dark grey calcareous Arbenz Kolle (AK), white dolomitic Kap Mohn (KM), and the Grejsdalen (GD) Formations on the mountain slopes at Kiledal, Ymer Ø showing why previous workers named the Andrée Land Group the "Limestone-Dolomite Series". Note that the section which is 600-700 m thick, is stratigraphically overturned, with the top to the lower right.

Fig. 13. White dolomitic microbialites of the Reservatet Formation at the type locality in Albert Heim Bjerge in Steno Land. Note the highly irregular lower boundary of the Reservatet Formation (RE) to the Skipperdal Formation (SD). Person for scale.

Fig. 14. **(A)** Strongly dolomitised breccias of the Reservatet Formation at Kap Mohn, Ymer Ø containing stylolites. **(B)** White dolomitic breccias of the Reservatet Formation in the reference section in northern Scoresby Land containing iron-stained chert lenses (CL). Hammer for scale.

Fig. 15. Steeply dipping well-bedded pisolitic limestones of the Arbenz Kolle Formation (AK) at Kap Mohn at Ymer Ø intercalated between the white dolomitic Reservatet (RE) and Kap Mohn (KM) Formations. The Arbenz Kolle Formation is *c.* 110 m thick.

Fig. 16. The Kap Mohn Formation. **(A)** View of the cliff-foming formation (KM) at Munotbjerg, Ymer Ø, overlying recessive limestones of the Arbenz Kolle Formation (AK). **(B)** Dolomitic polymict breccia of the Kap Mohn Formation from the type section at Ymer Ø.

Fig. 17. Stratigraphic section of the dolomitic and calcareous Grejsdalen Formation including pisolitic limestones of the Niviarsiat Member, microbial dolomites of the Nanortalikdal Member, and microbial and brecciated dolomites of the Bjørneø Member, at the type locality of Kap Weber, Andrée Land. For legend see Fig. 4D.

Fig. 18. Cliff-forming limestone-mudstone couplets at the type locality at Kap Weber in Andrée Land commonly form intervals, 100's of metres thick, within the Grejsdalen Formation. Person for scale.

Fig. 19. Pisolitic limestones of the Niviarsiat Member, Grejsdalen Formation, at the type section at Kap Weber, Andrée Land. Lense cap for scale.

Fig. 20. Tightly spaced white, dolomitised microbial mounds of the Nanortalikdal Member, Grejsdalen Formation, **(A)** in vertical cross-section at Ella Ø and **(B)** in plan view at the reference section of Rytterknægten in Lyell Land (rucksack for scale).

Fig. 21. Sharp boundary between unspecified limestone-mudstone couplets of the Grejsdalen Formation (GD) and dolomitic microbialites of the Bjørneø Member (BØ), Grejsdalen Formation at Kap Weber, Andrée Land. Encircled person for scale.

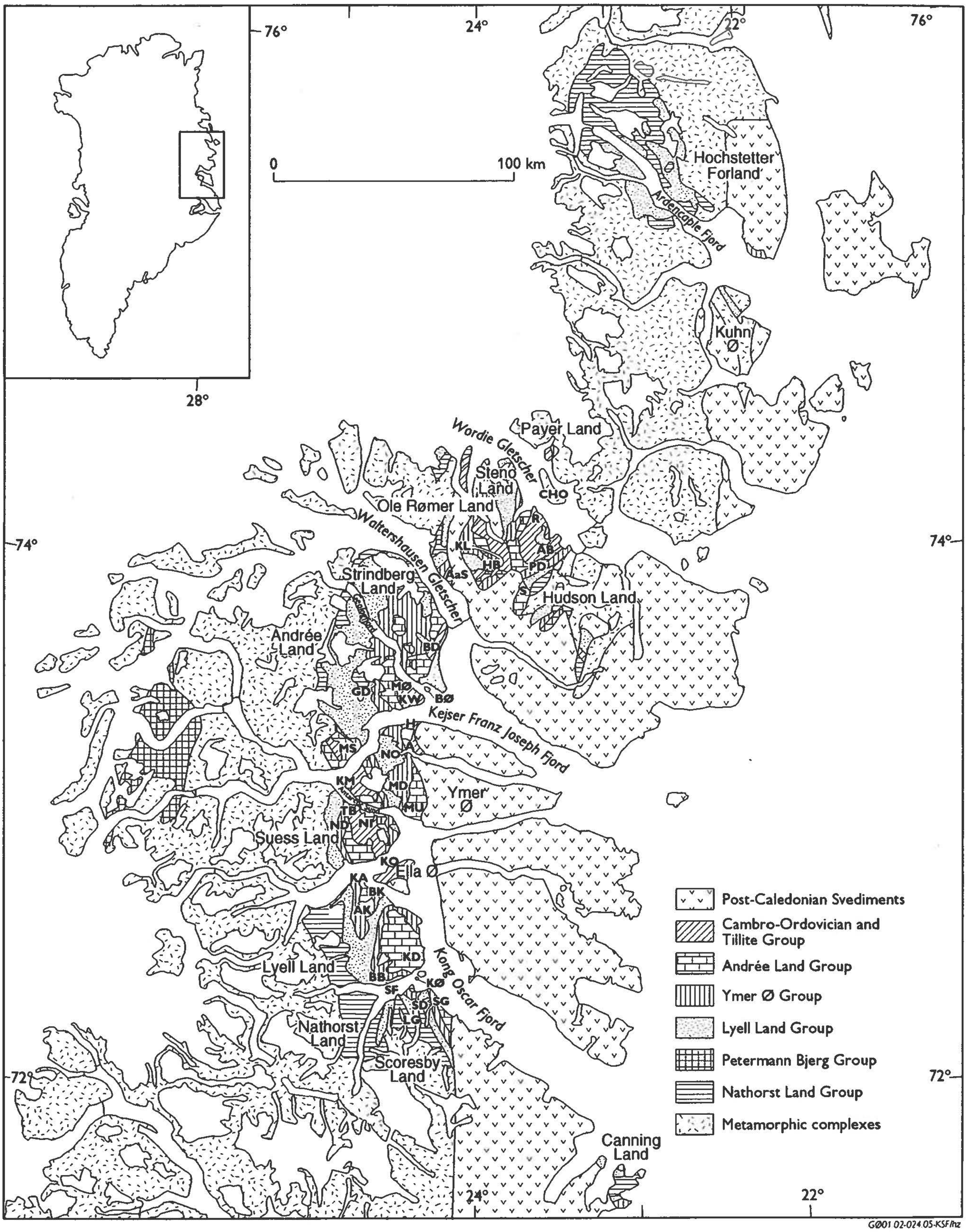
Fig. 22. Stratigraphic section of the shaly Munotbjerg Formation including the Noa Dal Member at the type locality at Ymer Ø. For legend see Fig. 4D.

Fig. 23. Red, green, and cream-coloured, dolomitic and calcareous shales of the Munotbjerg Formation at **(A)** the type section at Munotbjerg, Ymer Ø (mountain slope is *c.* 60 m high). **(B)** Contact between the Munotbjerg Formation (MB) and the Ulvesø Formation (US) at Kap Mohn, Ymer Ø (mountain wall is *c.* 80 m high). **(C)** Red, green, and cream-coloured, dolomitic and calcareous shales of the Munotbjerg Formation at Månesletten, Andrée Land (mountain slope is *c.* 200 m high). **(D)** Thin-bedded, cream-coloured, dolomitic shales of the Munotbjerg Formation deposited by turbidity currents. **(E)** Boundary between the Munotbjerg Formation (MB) and the Ulvesø Formation (US) of the Tillite Group at Munotbjerg, Ymer Ø, where bluish coloured shales are overlain by light brown diamictites containing centimetre-sized clasts.

Fig. 24. Stratigraphic section of the Waltershausen Gletscher Formation including the Aasesøen Member at the type locality in Ole Rømer Land. For legend see Fig. 4D.

Fig. 25. Thick-bedded limestones of the Waltershausen Gletscher Formation (WG) overlying recessive black organic-rich calcareous shales of the Noa Dal Member, Munotbjerg Formation (MB) at the type section of the Noa Dal Member at Arenaen, Ymer Ø (encircled person for scale).

Table 1. Summary of localities and measured sections, lithostratigraphic subdivisions, structural setting, and physiography. Names and interpretations of structural settings are based on Wegman (1935), Bütler (1948), Katz (1952), Eha (1953), Fränkl (1953a; 1953b), Cowie & Adams (1957), and Sommer (1957a).



76°
24°
22°
76°
28°
0
100 km
Hochstetter Forland
Ardencaple Fjord
Kuhn Ø
Payer Land
Wordie Gletscher
Steno Land
CHO
Ole Rømer Land
Waltershausen Gletscher
74°
74°
KL
HB
AB
PD
AaS
Strindberg Land
Hudson Land
Andrée Land
BD
GD
MØ
KW
BØ
Kejser Franz Joseph Fjord
MS
NO
Ymer Ø
KM
MD
TB
MU
ND
NF
Suess Land
KO
Ella Ø
KA
BK
AK
Lyell Land
KD
BB
Kong Oscar Fjord
SF
KØ
SD
SG
LG
Nathorst Land
Scoresby Land
72°
72°
Canning Land
24°
22°
Post-Caledonian Svediments
Cambro-Ordovician and Tillite Group
Andrée Land Group
Ymer Ø Group
Lyell Land Group
Petermann Bjerg Group
Nathorst Land Group
Metamorphic complexes
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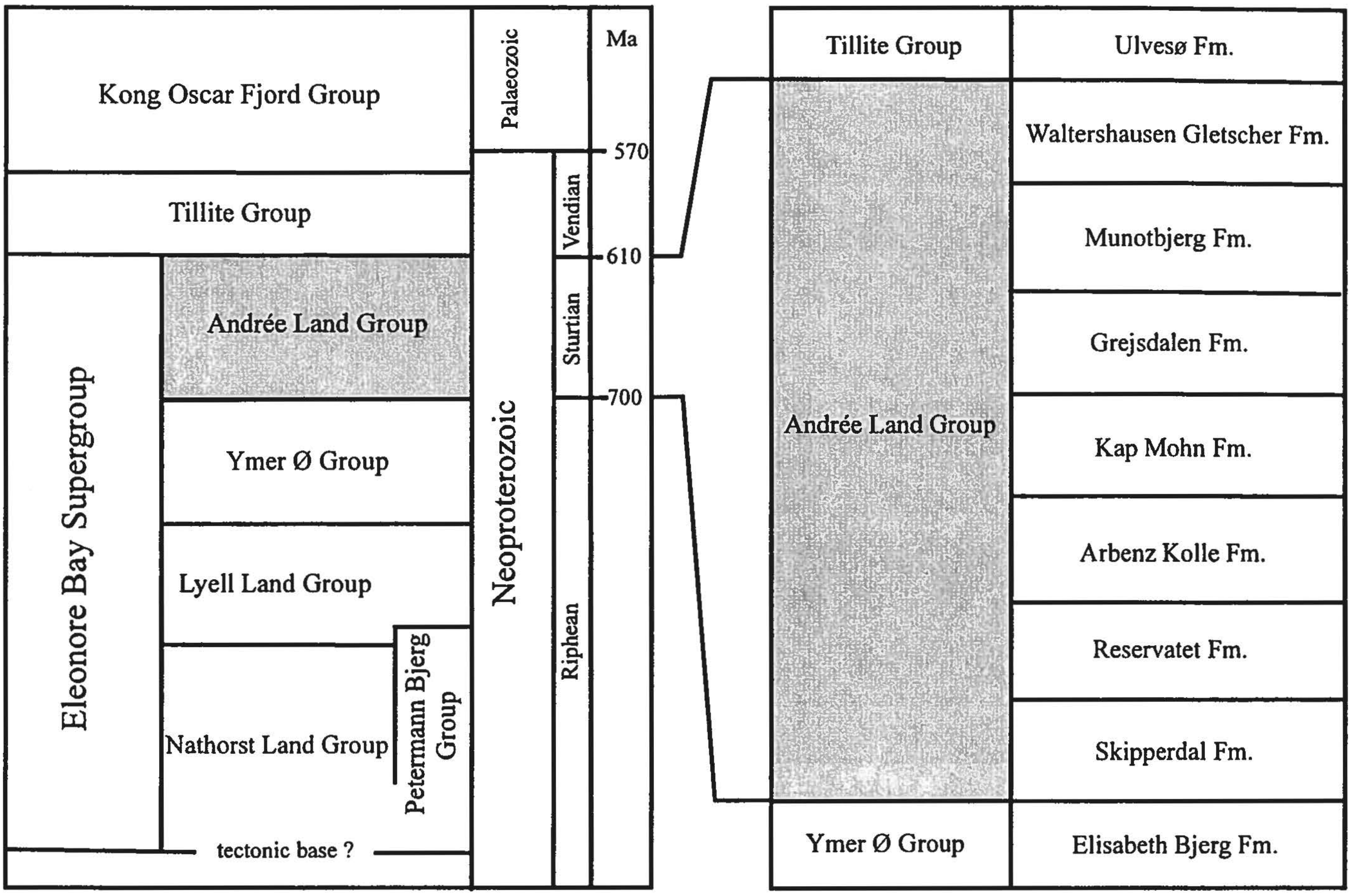
Fig. 1



Kong Oscar Fjord Group
Tillite Group
Andrée Land Group
Ymer Ø Group
Lyell Land Group
Nathorst Land Group
Petermann Bjerg Group
Eleonore Bay Supergroup
tectonic base ?
Palaeozoic
Neoproterozoic
Vendian
Sturtian
Riphean
Ma
570
610
700
Tillite Group
Ulvesø Fm.
Waltershausen Gletscher Fm.
Munotbjerg Fm.
Grejsdalen Fm.
Andrée Land Group
Kap Mohn Fm.
Arbenz Kolle Fm.
Reservatet Fm.
Skipperdal Fm.
Ymer Ø Group
Elisabeth Bjerg Fm.

Fig. 2

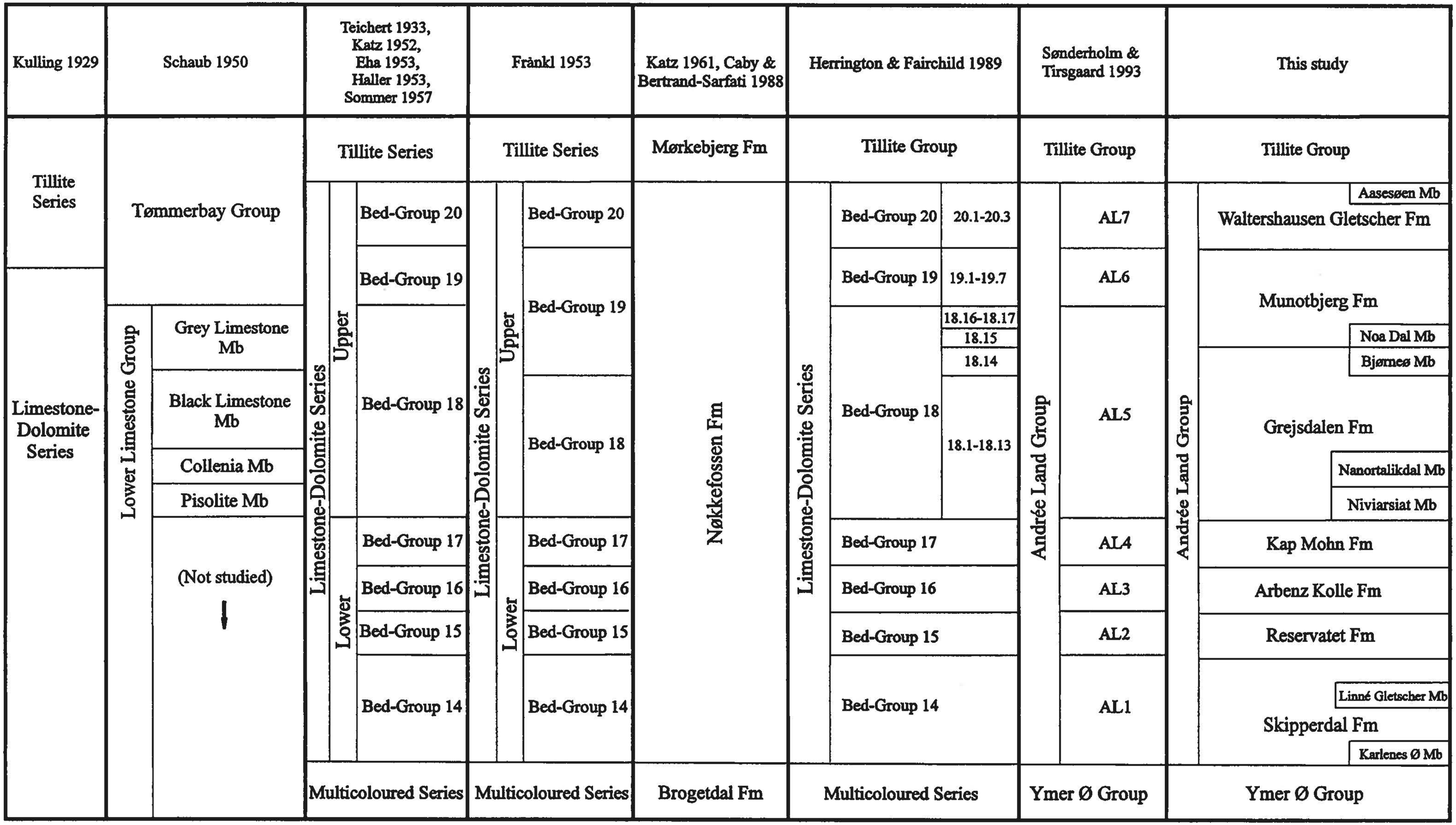

Kulling 1929
Tillite Series
Limestone-Dolomite Series
Schaub 1950
Tømmerbay Group
Lower Limestone Group
Grey Limestone Mb
Black Limestone Mb
Collenia Mb
Pisolite Mb
(Not studied)
Teichert 1933, Katz 1952, Eha 1953, Haller 1953, Sommer 1957
Tillite Series
Limestone-Dolomite Series
Upper
Lower
Bed-Group 20
Bed-Group 19
Bed-Group 18
Bed-Group 17
Bed-Group 16
Bed-Group 15
Bed-Group 14
Multicoloured Series
Frånkl 1953
Tillite Series
Limestone-Dolomite Series
Upper
Lower
Bed-Group 20
Bed-Group 19
Bed-Group 18
Bed-Group 17
Bed-Group 16
Bed-Group 15
Bed-Group 14
Multicoloured Series
Katz 1961, Caby & Bertrand-Sarfati 1988
Mørkebjerg Fm
Nøkkefossen Fm
Brogetdal Fm
Herrington & Fairchild 1989
Tillite Group
Limestone-Dolomite Series
Bed-Group 20
20.1-20.3
Bed-Group 19
19.1-19.7
Bed-Group 18
18.16-18.17
18.15
18.14
18.1-18.13
Bed-Group 17
Bed-Group 16
Bed-Group 15
Bed-Group 14
Multicoloured Series
Sønderholm & Tirsgaard 1993
Tillite Group
Andrée Land Group
AL7
AL6
AL5
AL4
AL3
AL2
AL1
Ymer Ø Group
This study
Tillite Group
Andrée Land Group
Aasesøen Mb
Waltershausen Gletscher Fm
Munotbjerg Fm
Noa Dal Mb
Bjørneø Mb
Grejsdalen Fm
Nanortalikdal Mb
Niviarsiat Mb
Kap Mohn Fm
Arbenz Kolle Fm
Reservatet Fm
Linné Gletscher Mb
Skipperdal Fm
Karlenes Ø Mb
Ymer Ø Group

Fig. 3

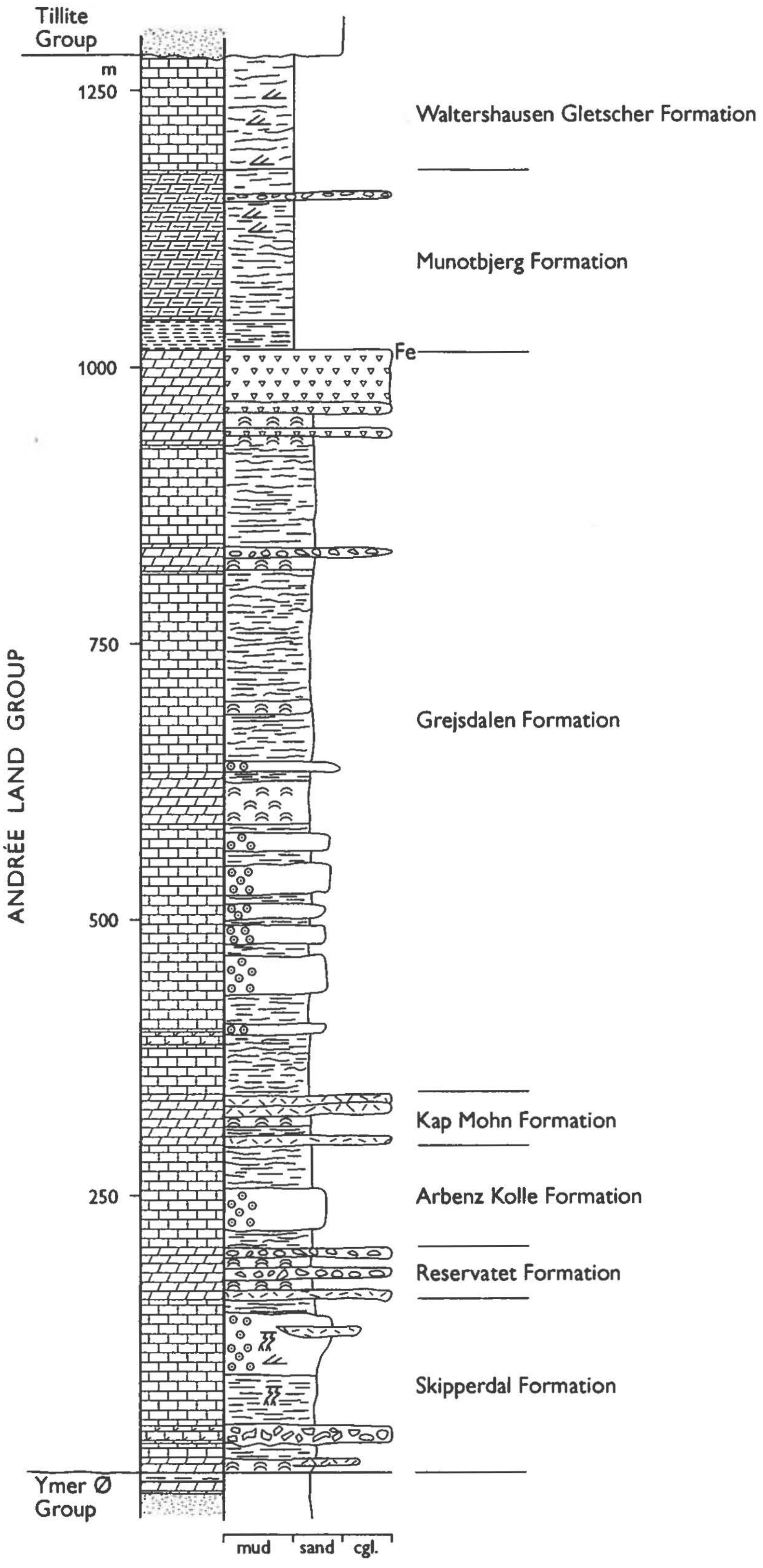

Tillite Group
m
1250
1000
750
500
250
Waltershausen Gletscher Formation
Munotbjerg Formation
Fe
Grejsdalen Formation
Kap Mohn Formation
Arbenz Kolle Formation
Reservatet Formation
Skipperdal Formation
ANDRÉE LAND GROUP
Ymer Ø Group
mud
sand
cgl.

Fig. 4A

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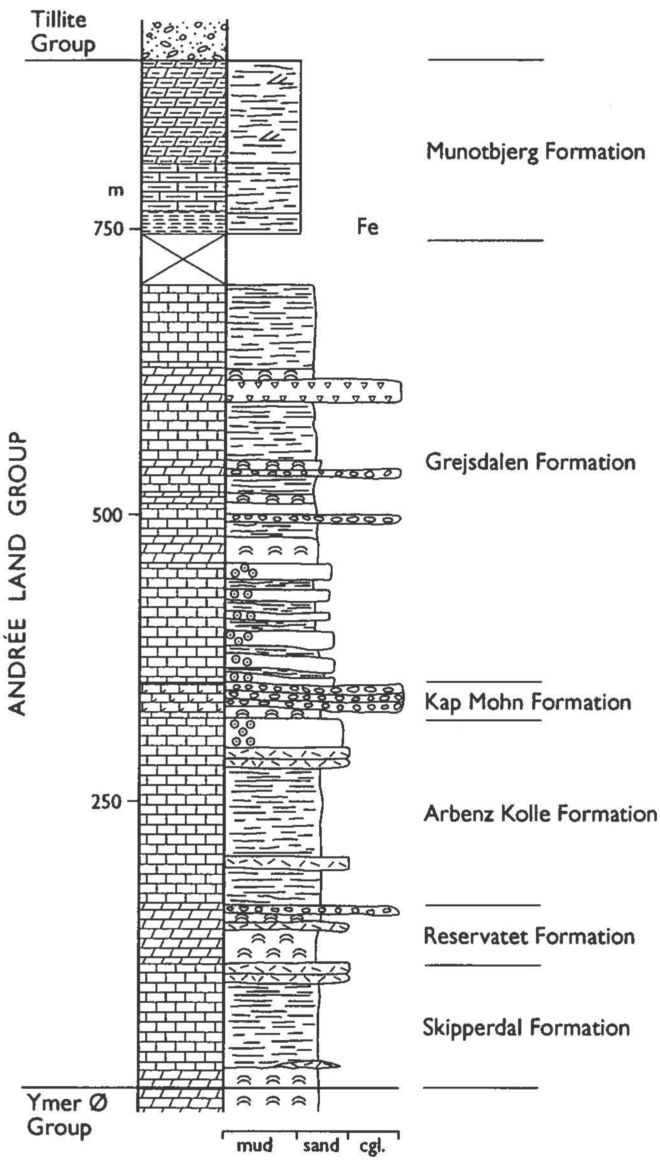

Fig. 4B

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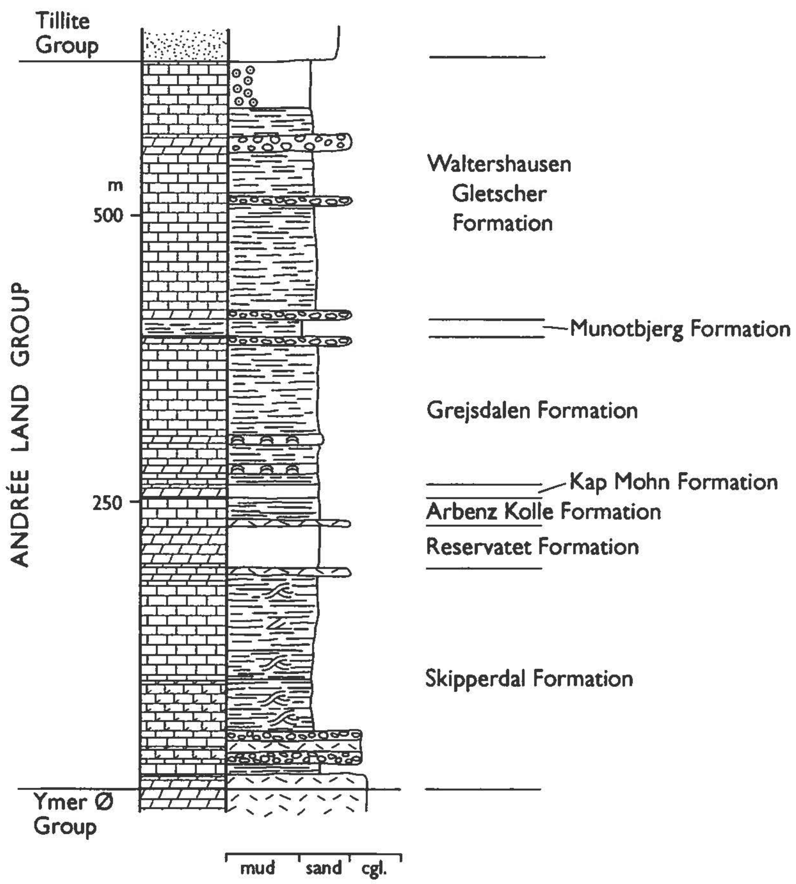

Fig. 4C

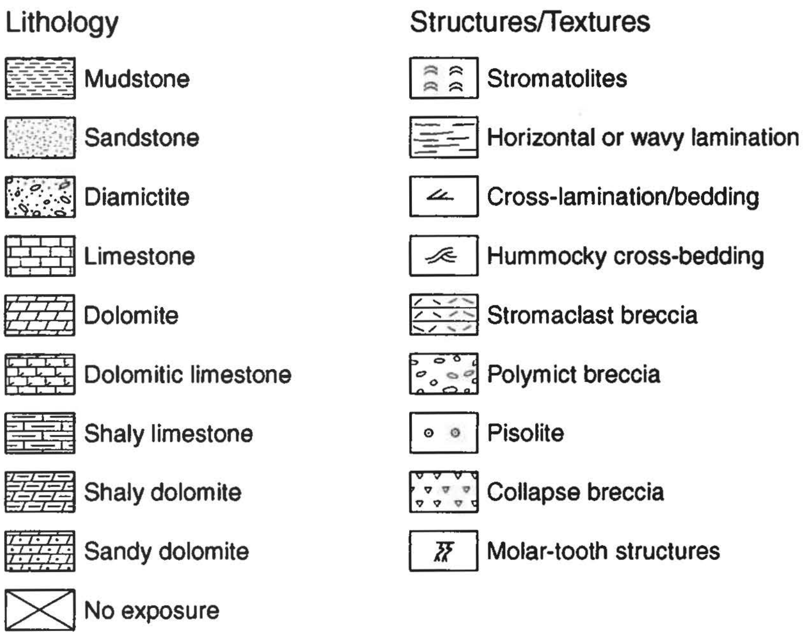

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Fig. 4D

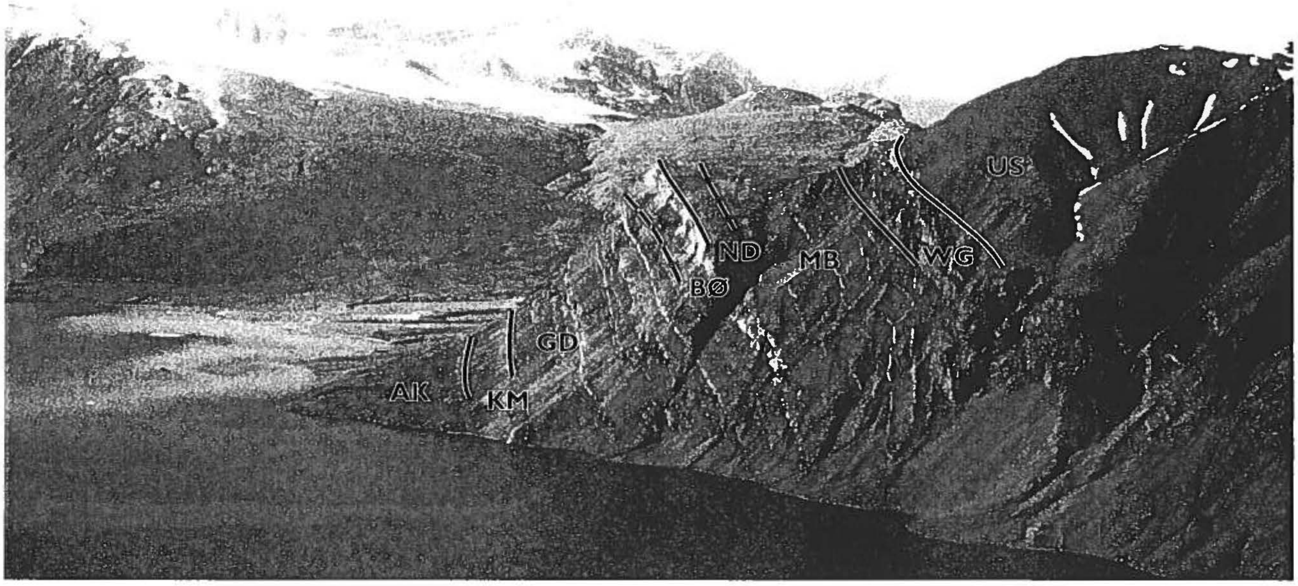

Fig. 5 A

Fig. 5 B

Fig. 5 C

Fig. 5 D

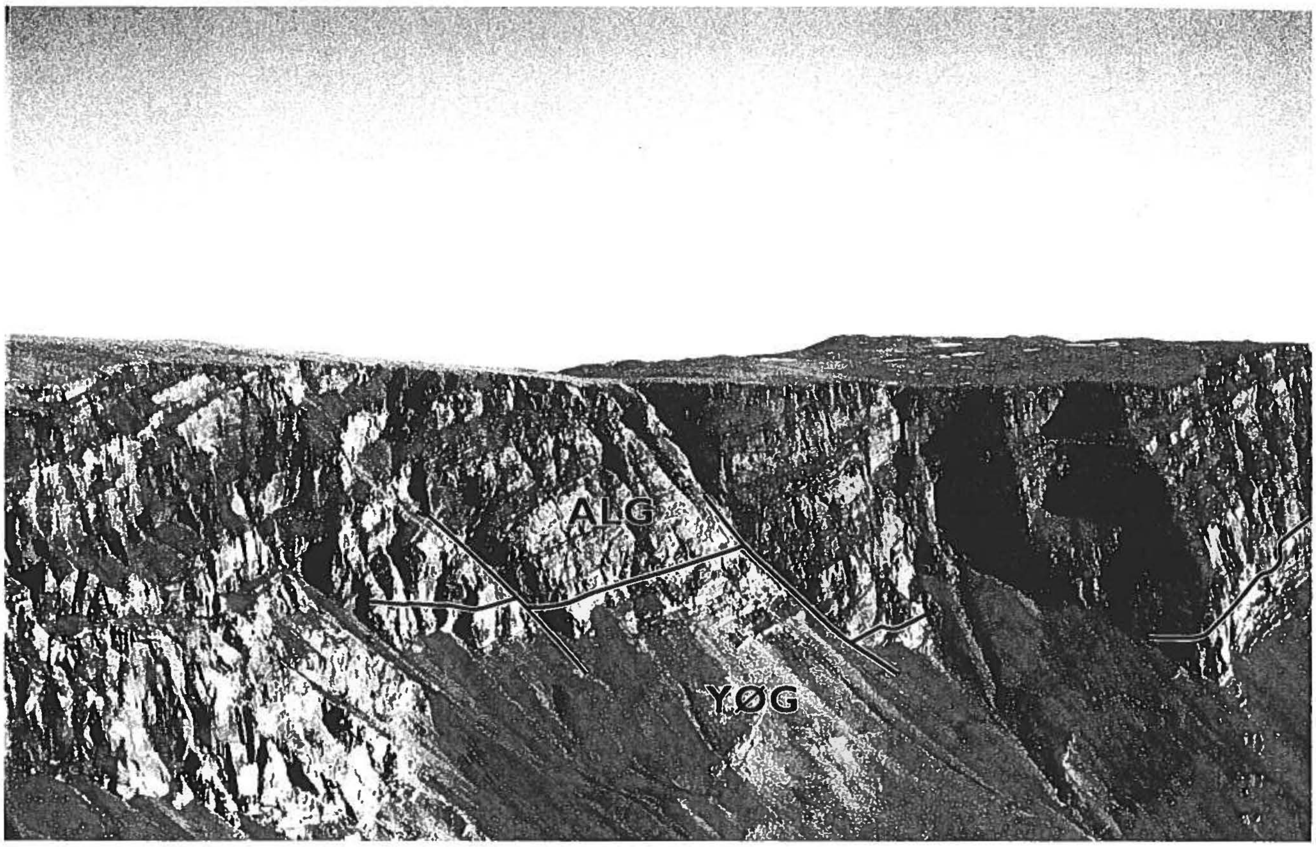

Fig. 6 A

Fig. 6 B

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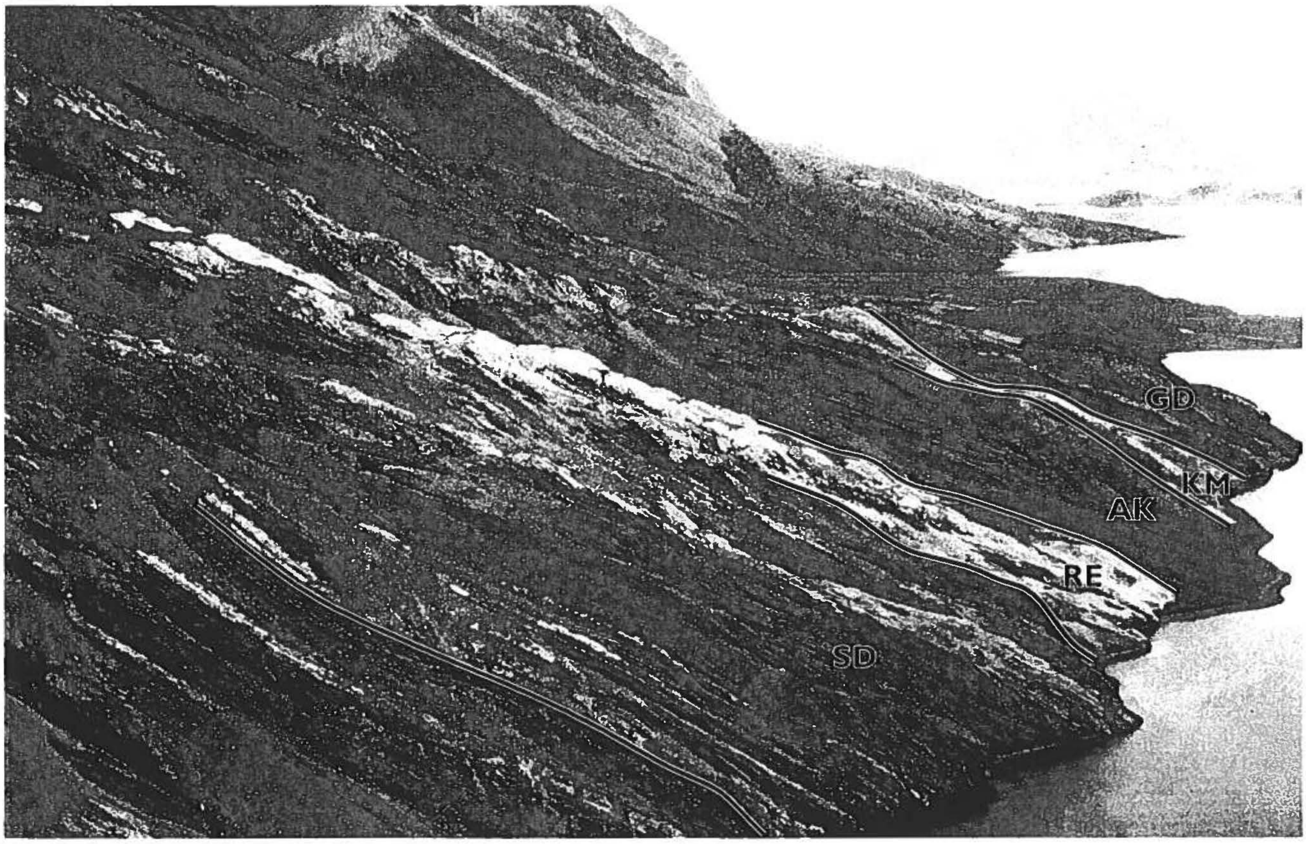

Fig. 6 C

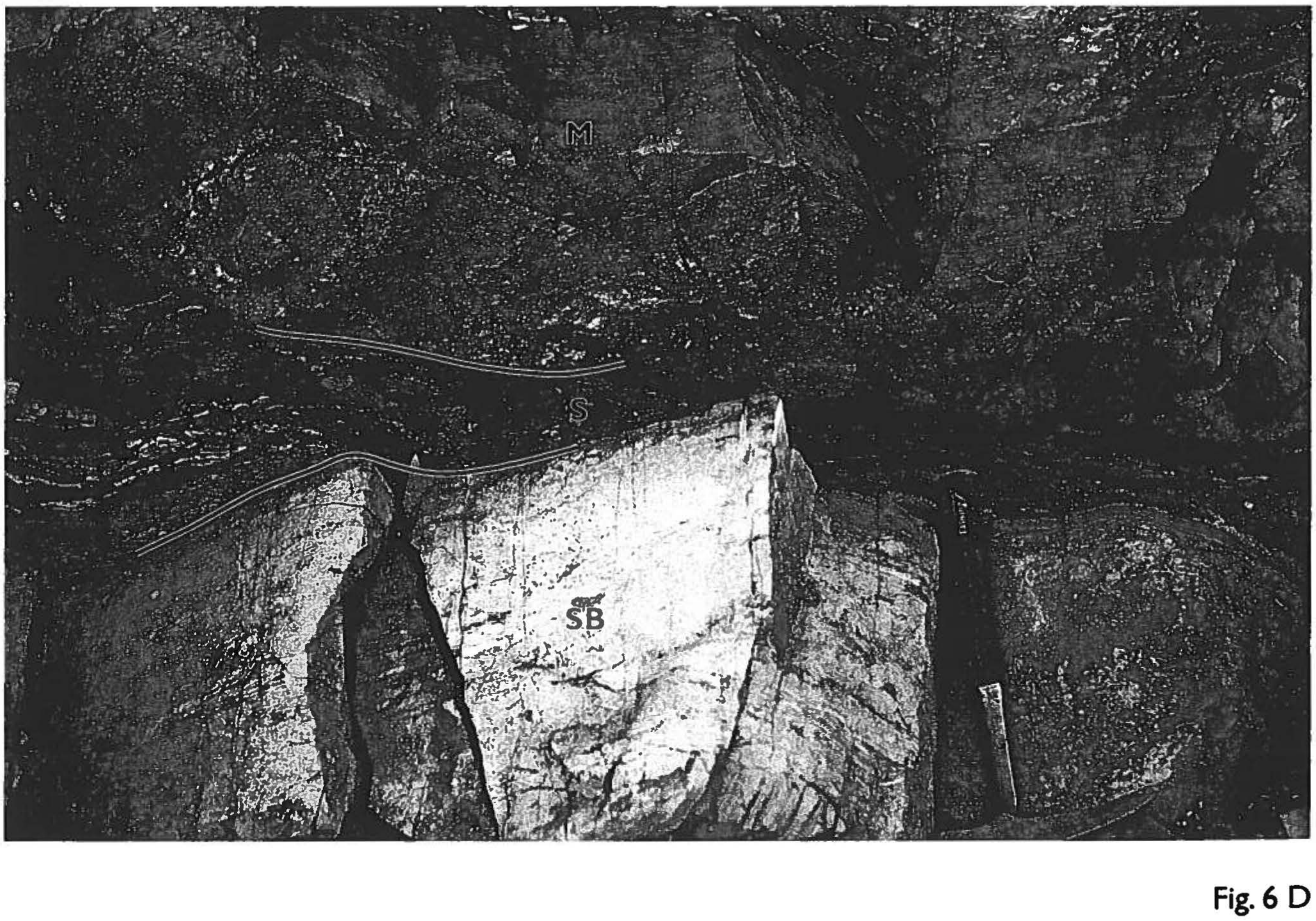

Fig. 6 D

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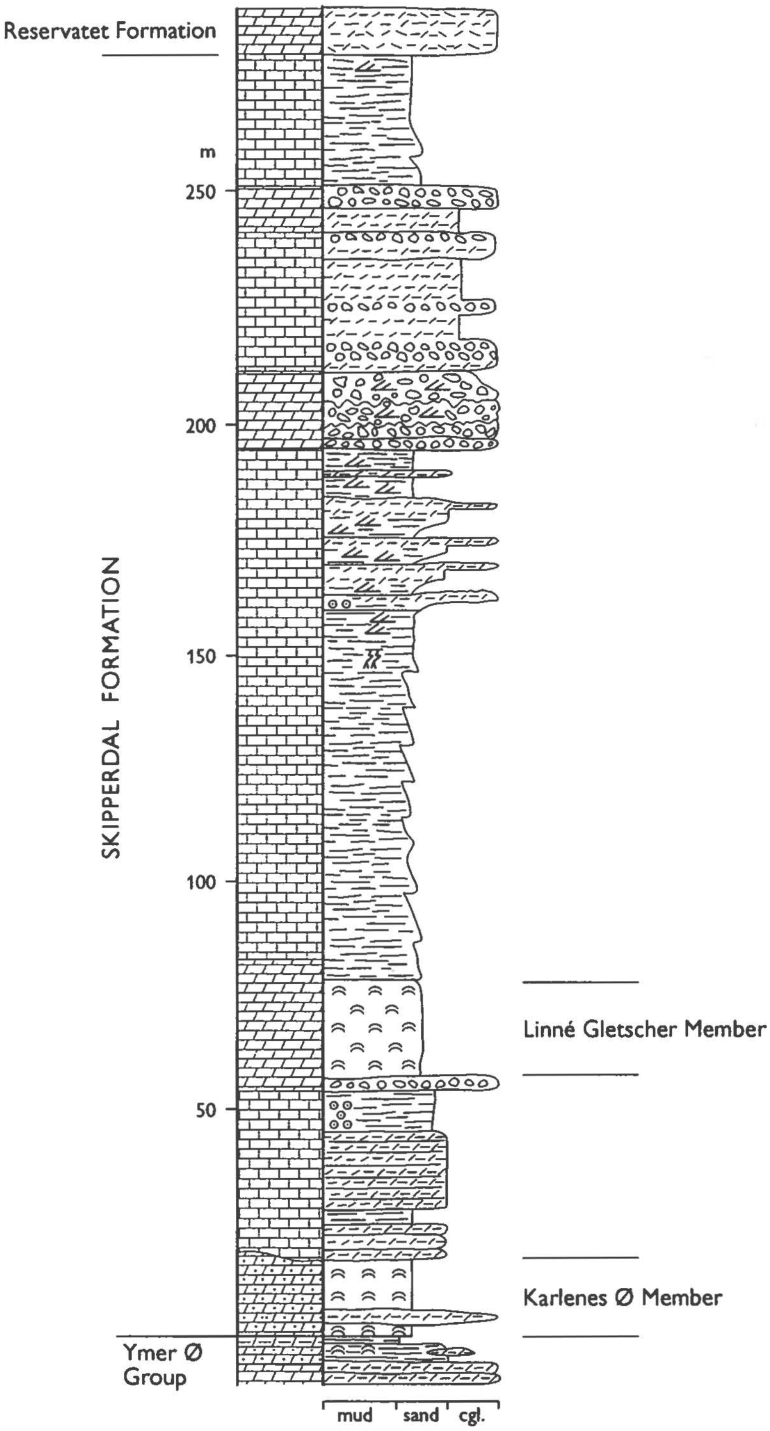

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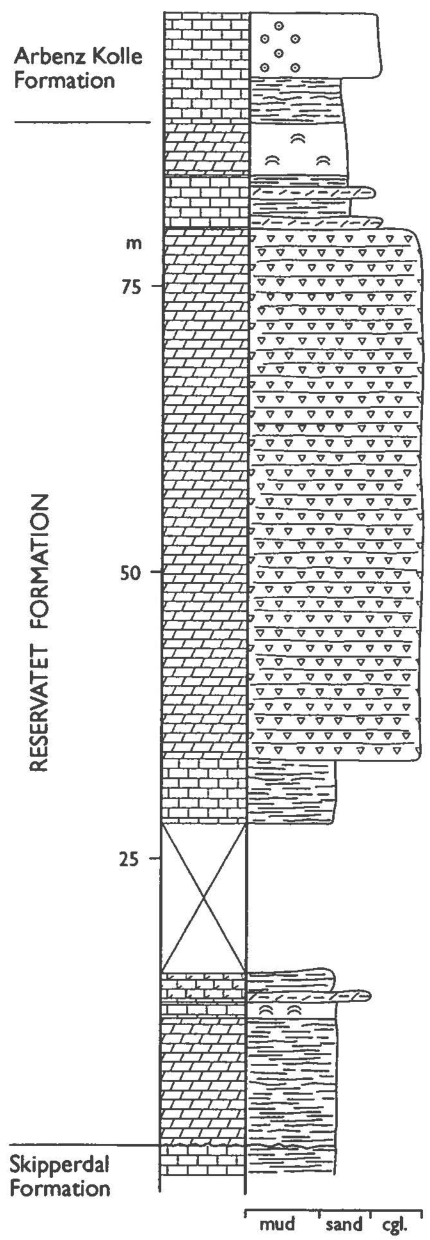
Fig. 7

Fig. 8 A

Fig. 8 B



Arbenz Kolle Formation
m
75
RESERVATET FORMATION
50
25
Skipperdal Formation
mud
sand
cgl.

Fig. 9

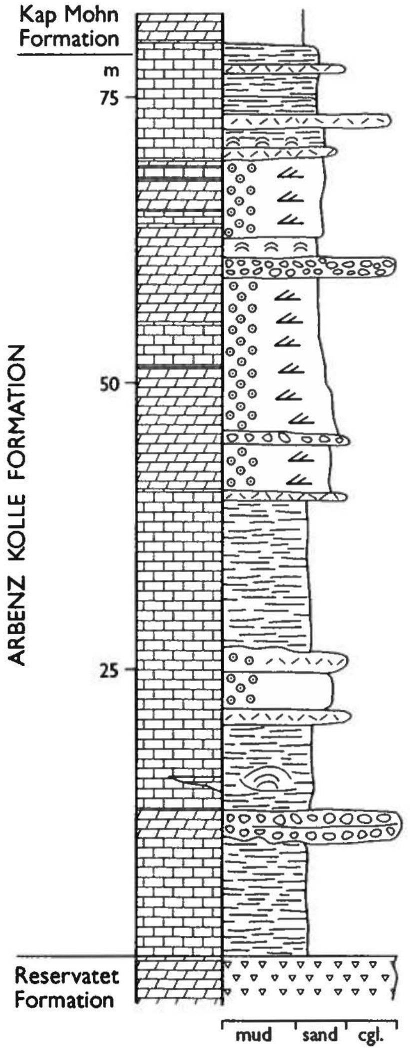

Kap Mohn
Formation
m
75
50
25
ARBENZ KOLLE FORMATION
Reservatet
Formation
mud
sand
cgl.

Fig. 10

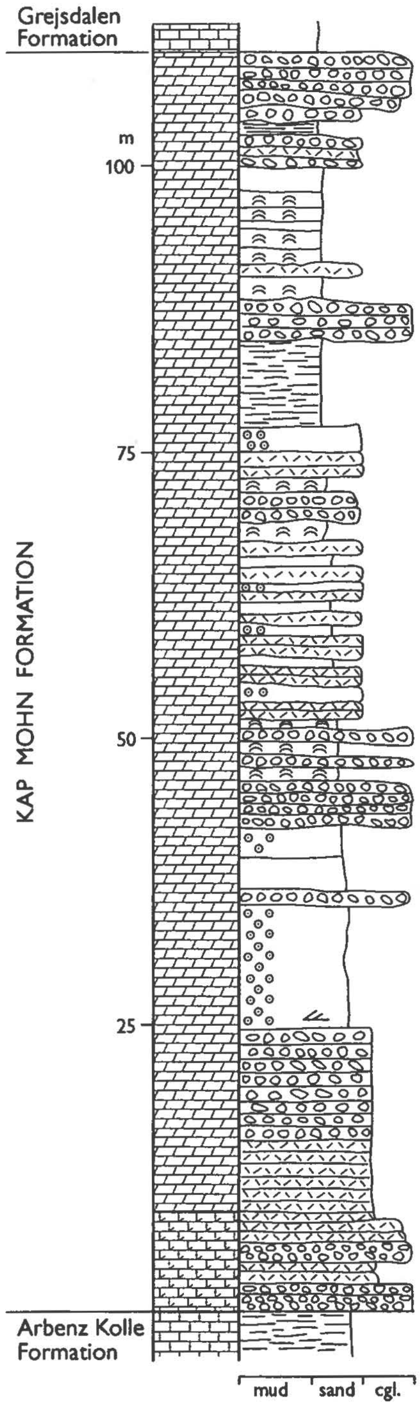

Grejsdalen Formation
m
100
75
50
25
KAP MOHN FORMATION
Arbenz Kolle Formation
mud
sand
cgl.

Fig. 11

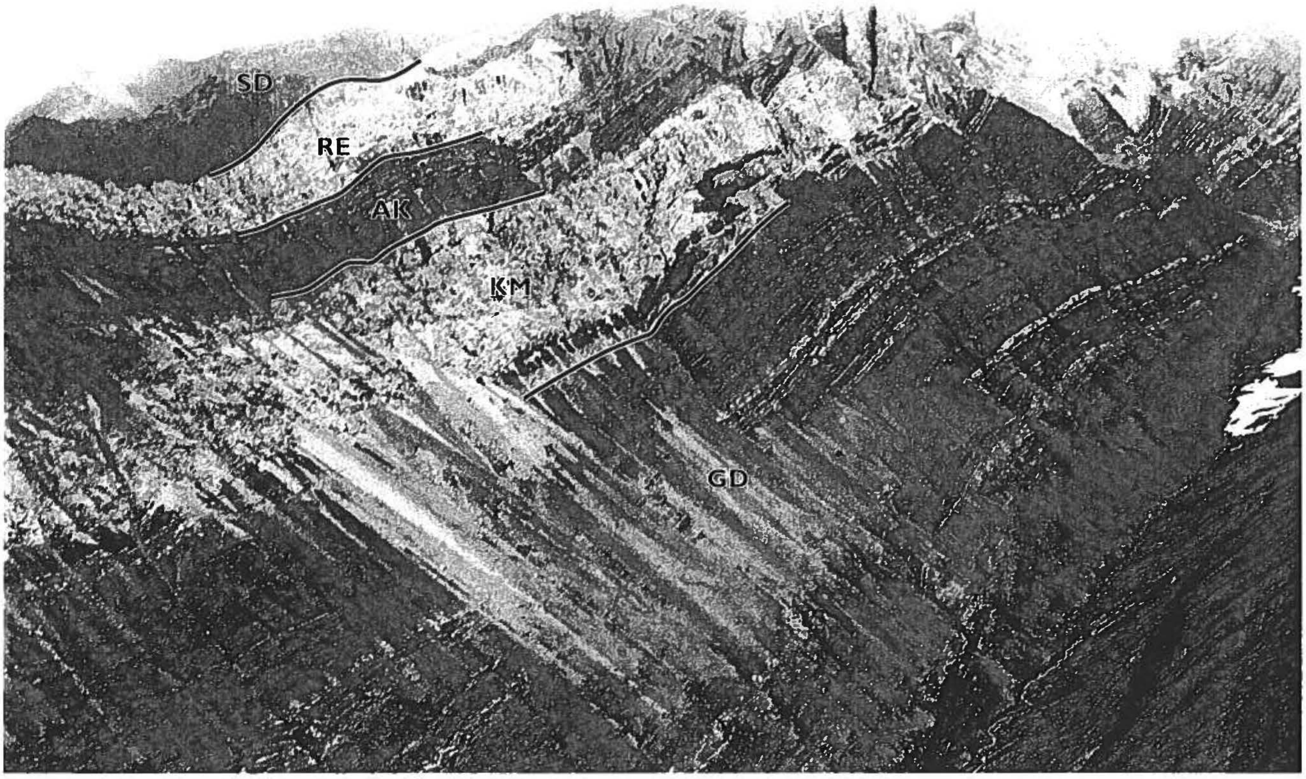


Fig. 12

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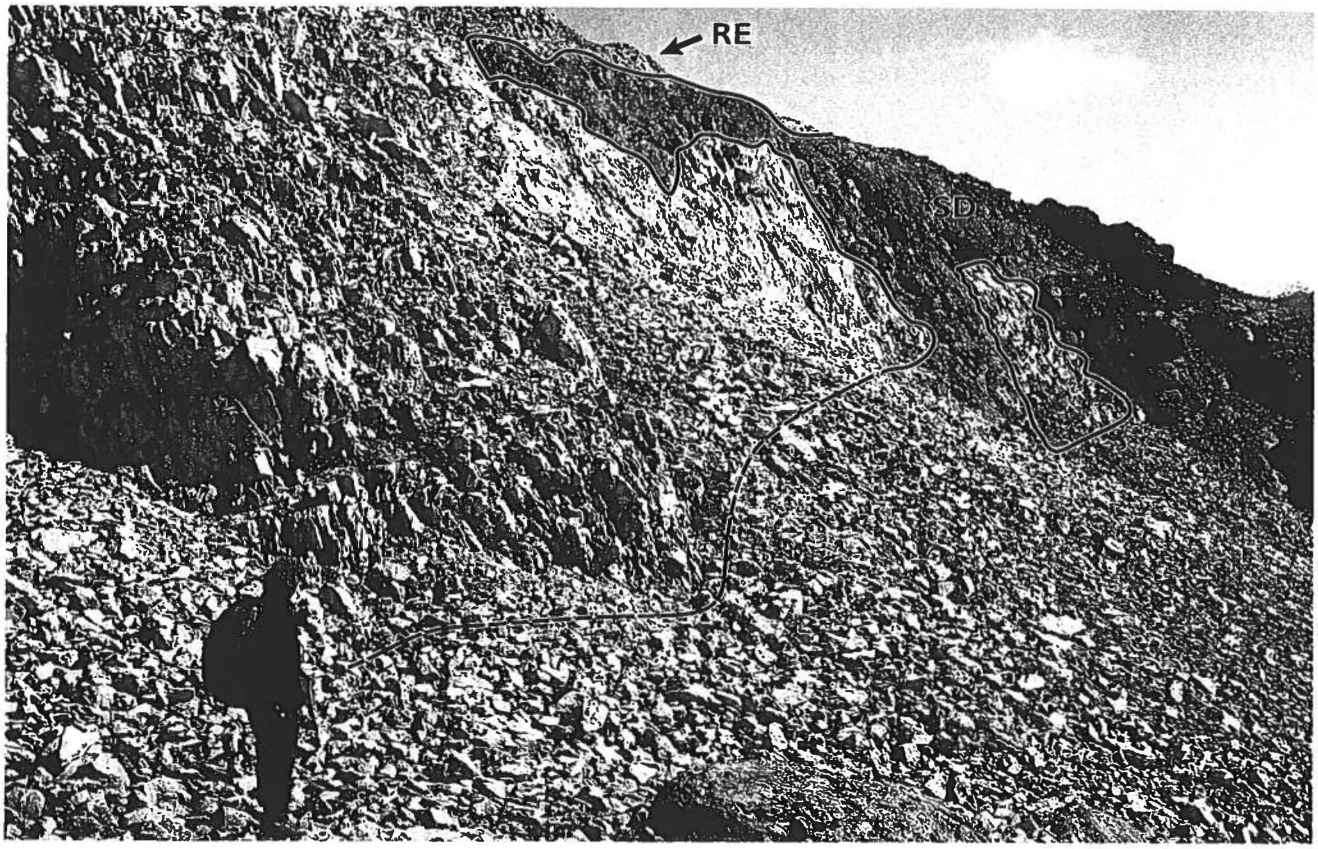

Fig. 13

Fig. 14 A

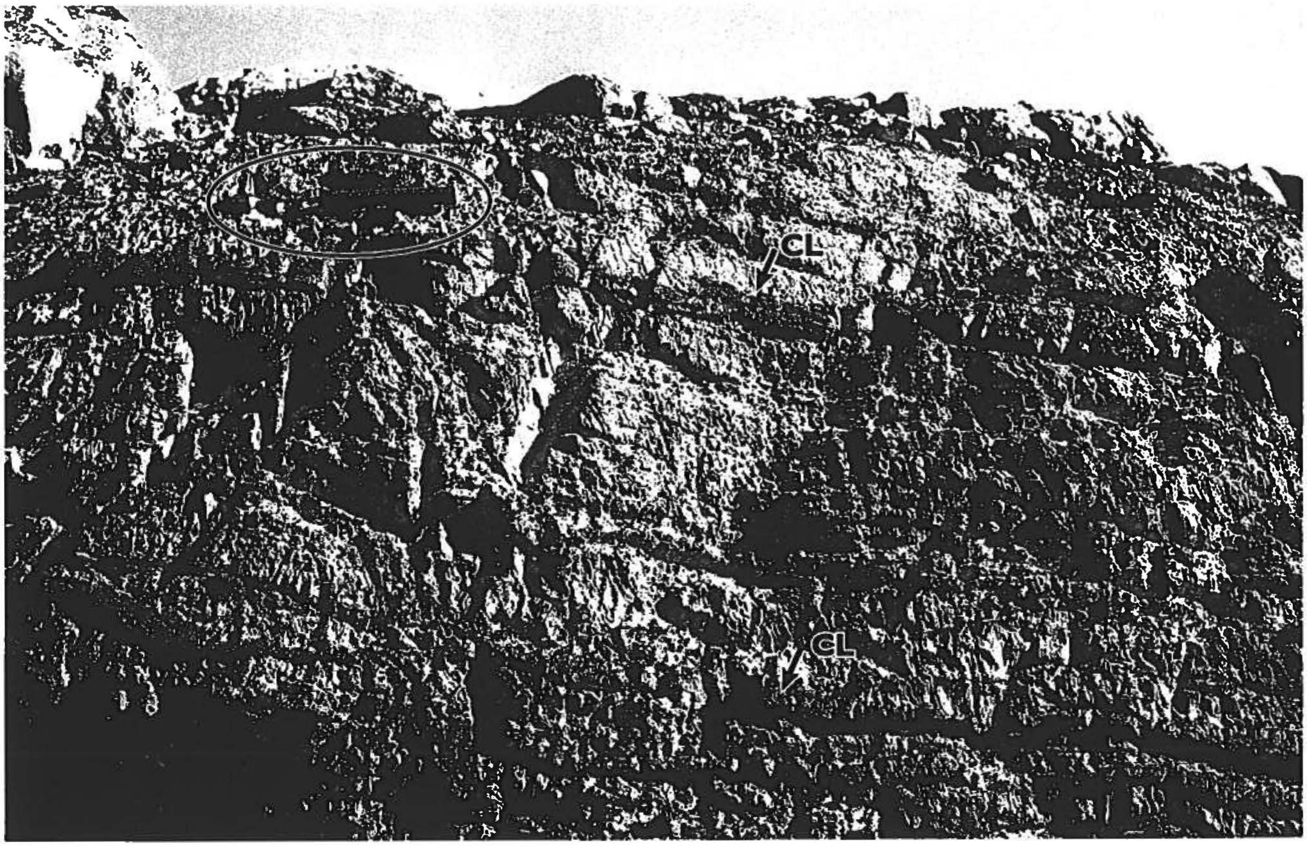

Fig. 14 B

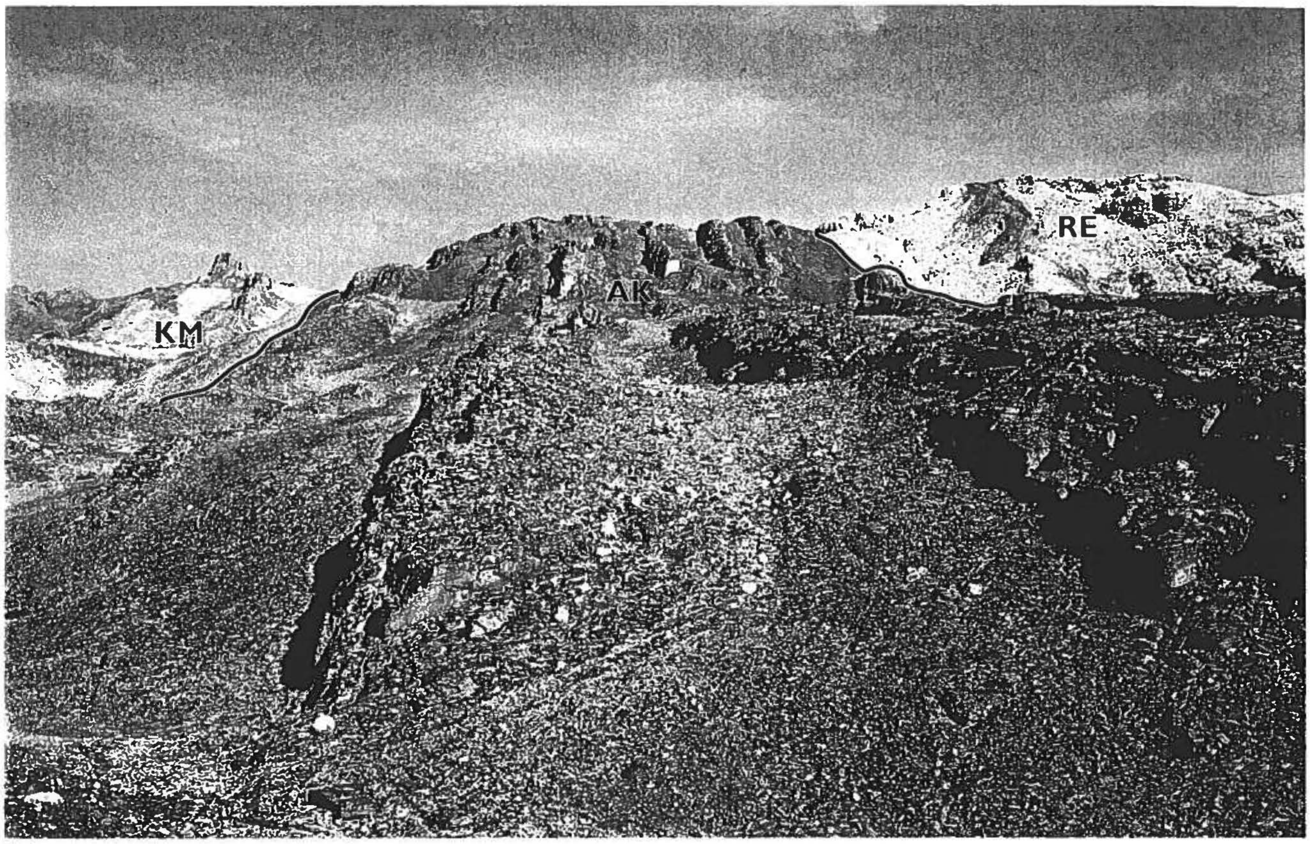

Fig. 15

Fig. 16 A

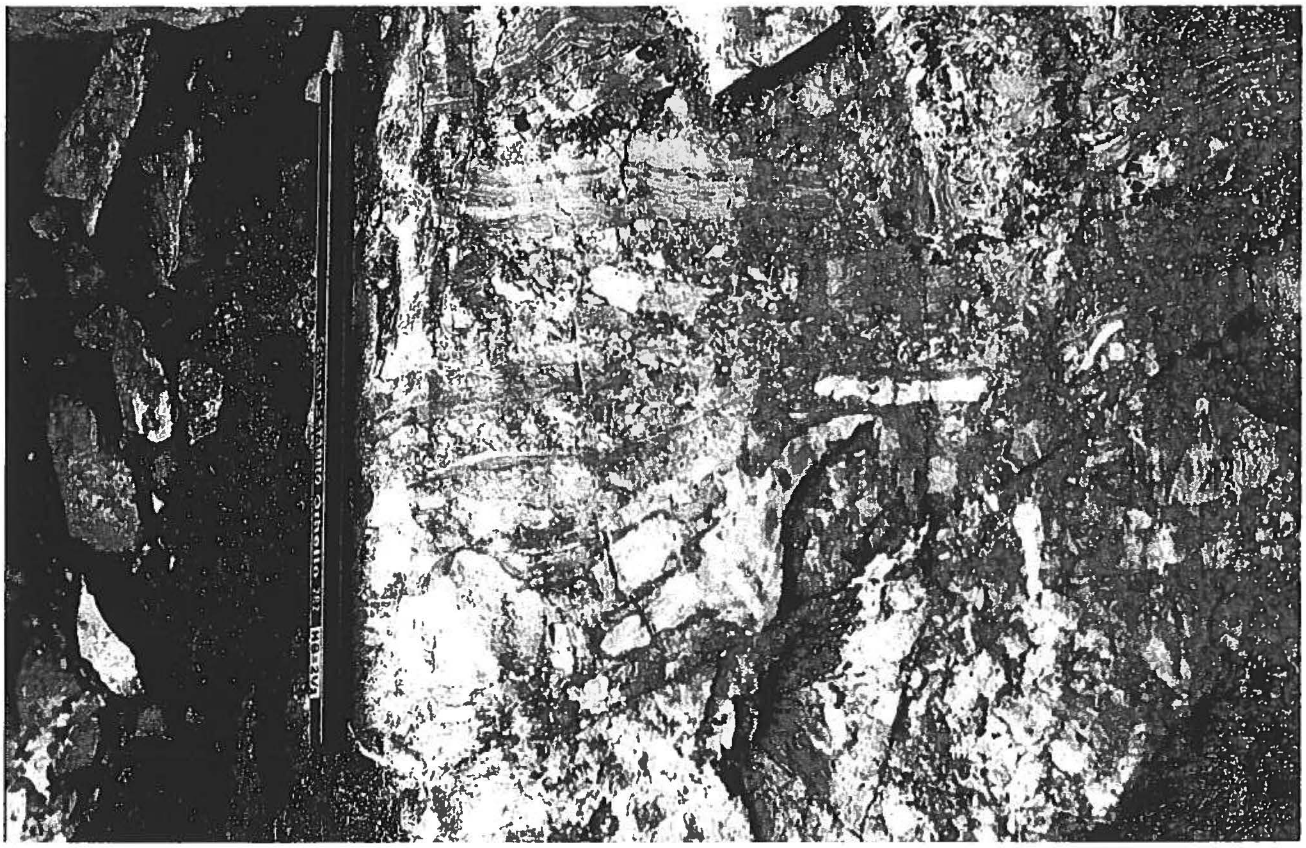

Fig. 16 B

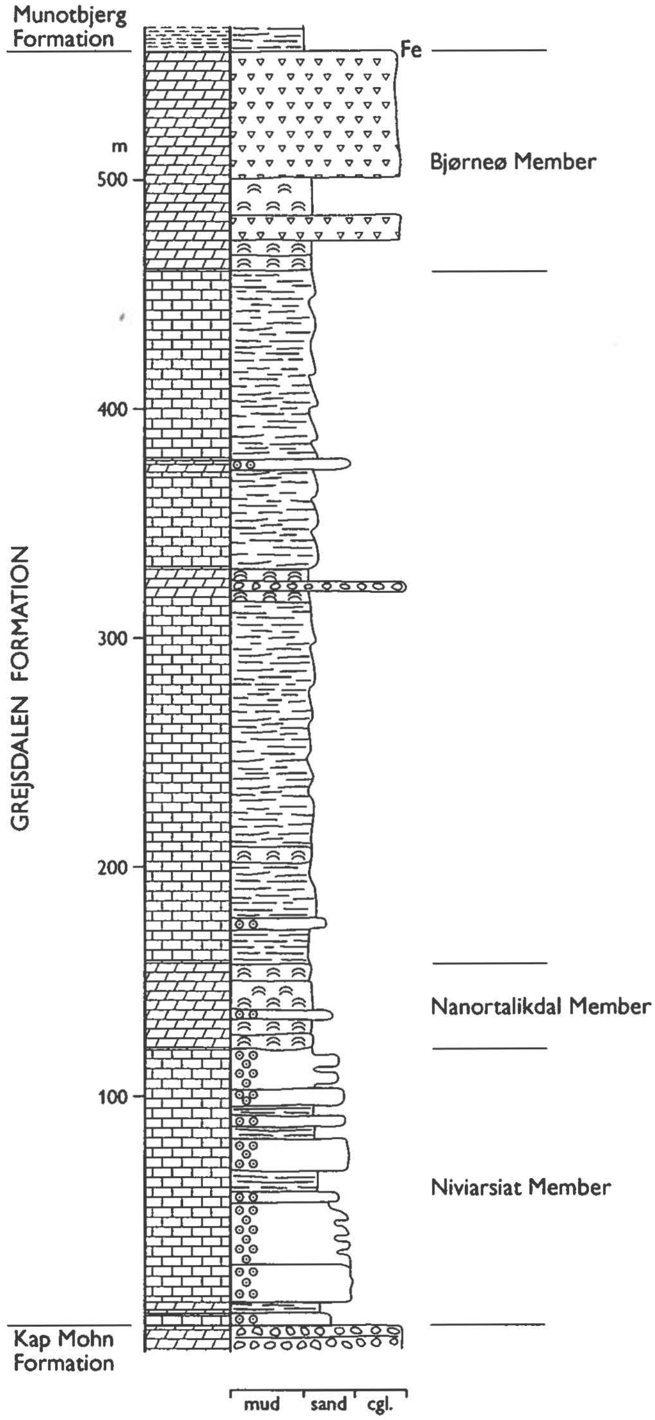

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Fig. 17

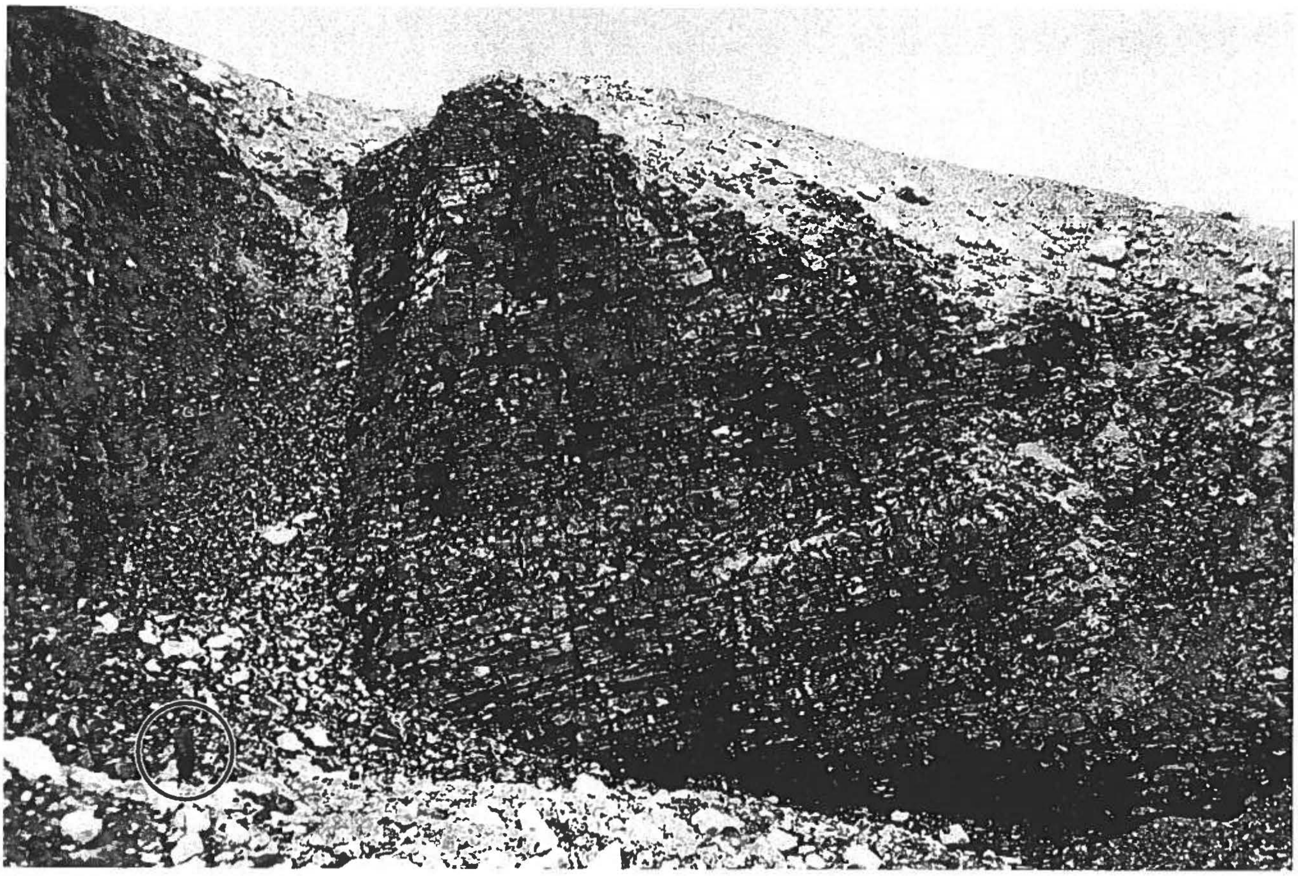

Fig. 18

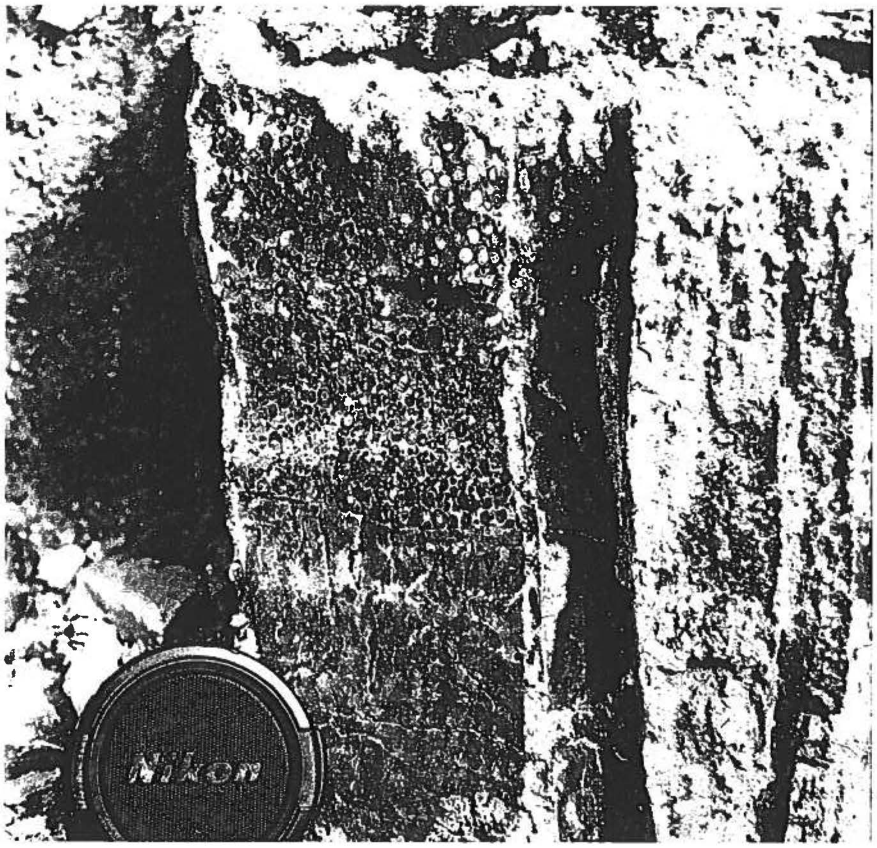

Fig. 19

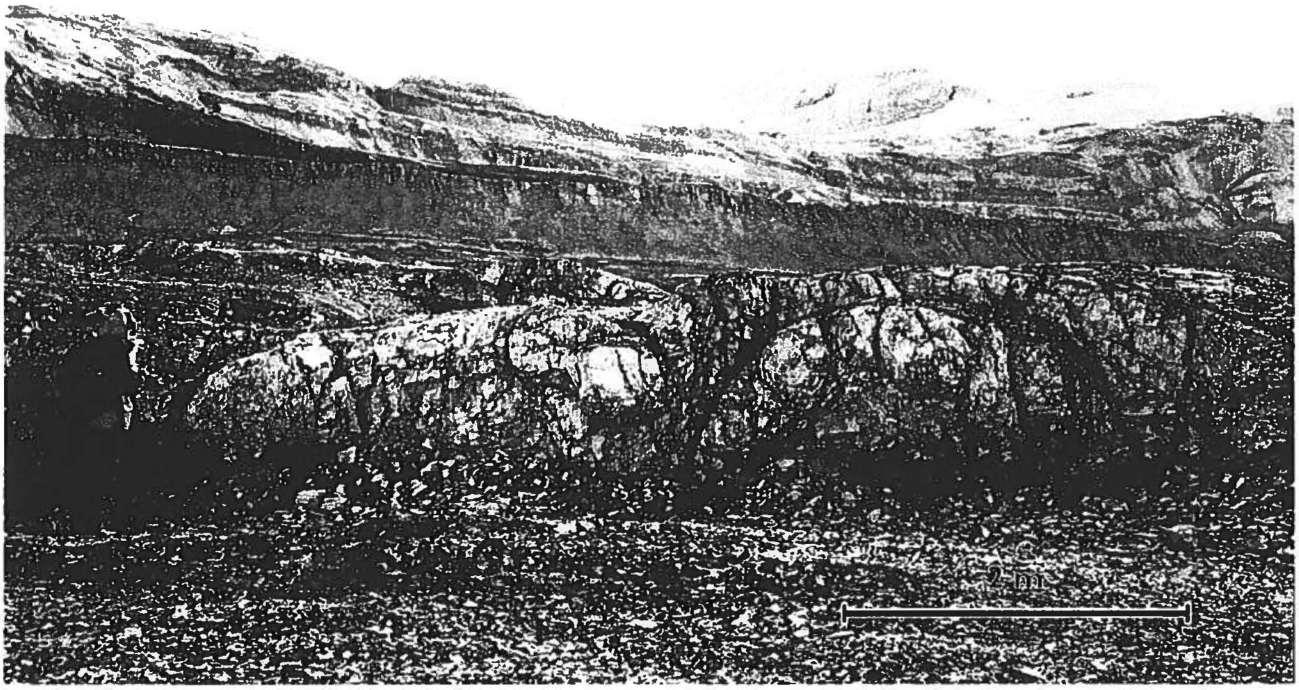

Fig. 20 A

Fig. 20 B

Fig. 21

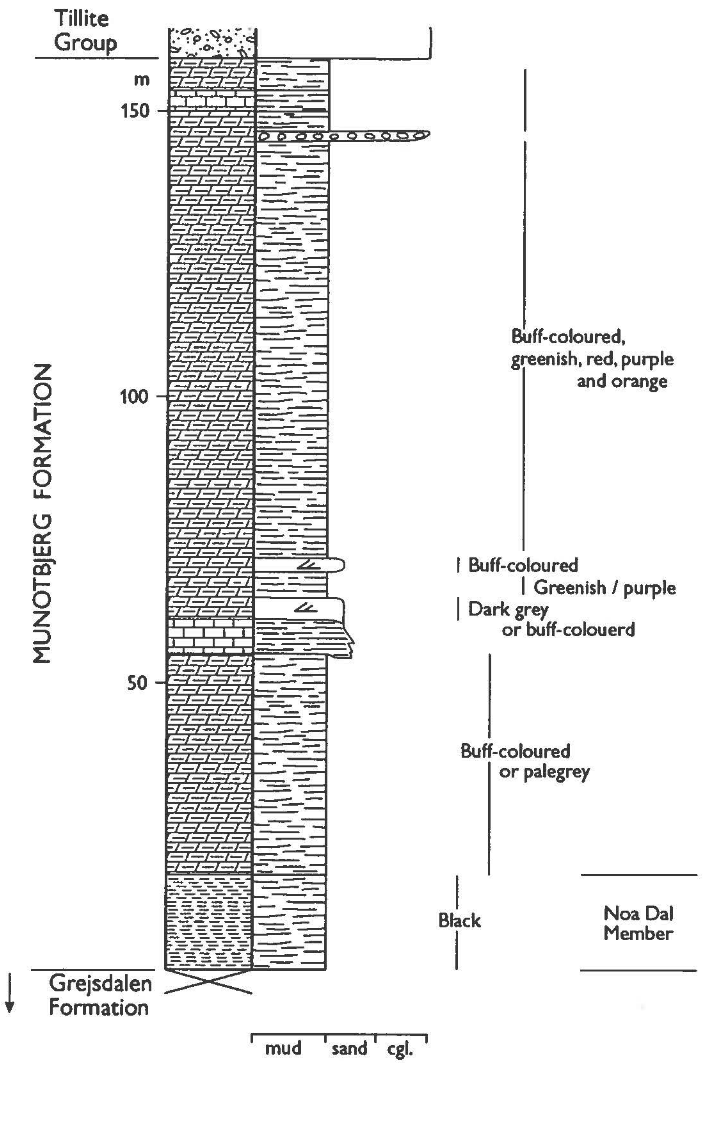

Fig. 22

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Fig. 23 A

Fig. 23 B

Fig. 23 C

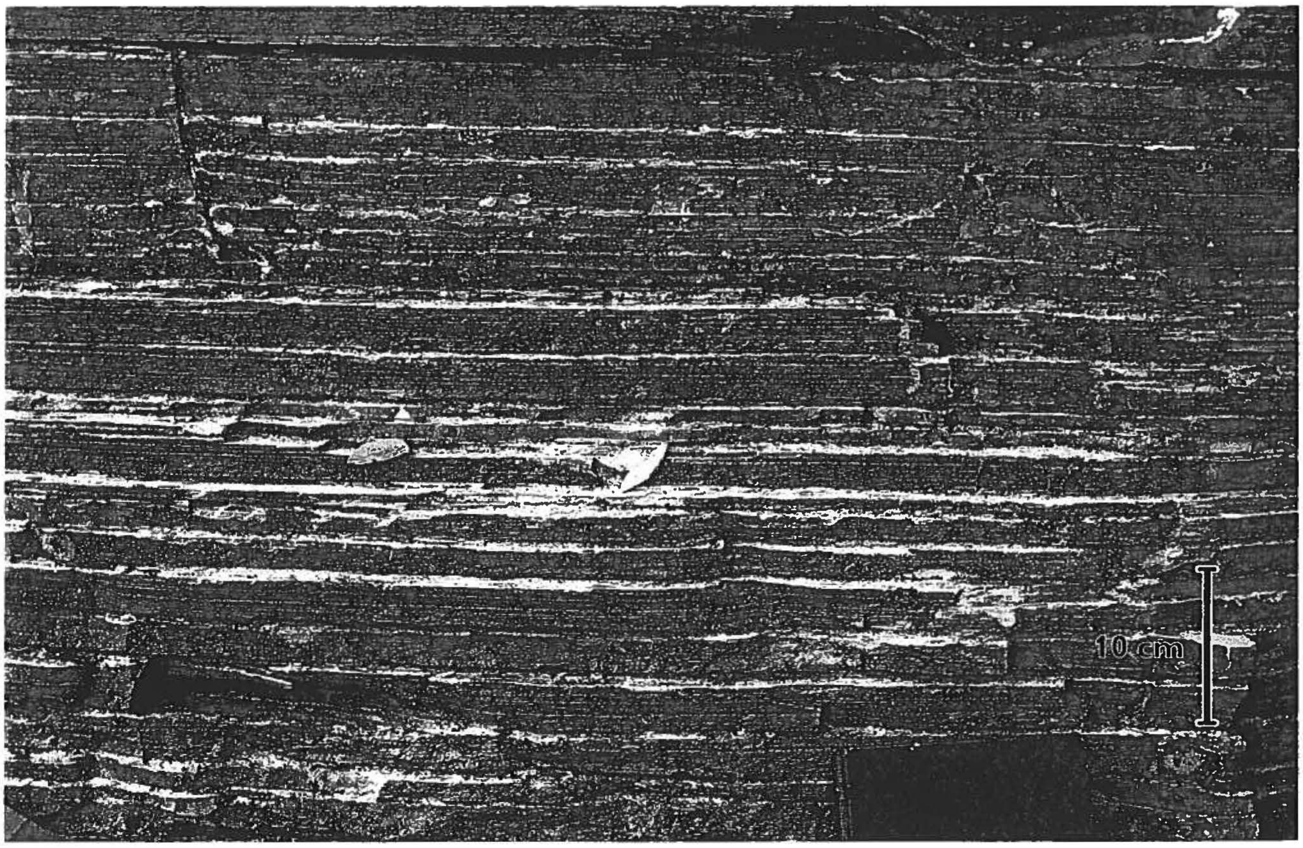

Fig. 23 D

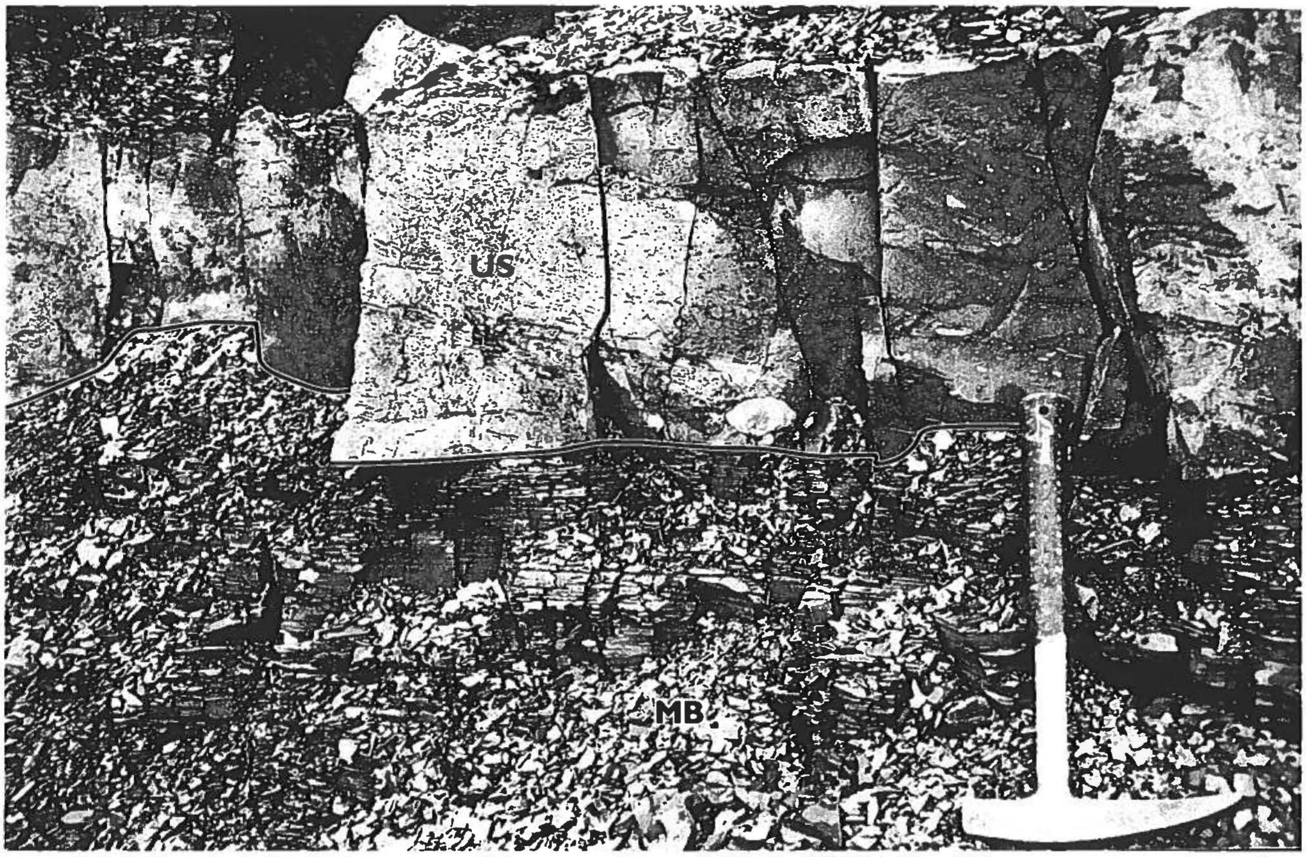

Fig. 23 E

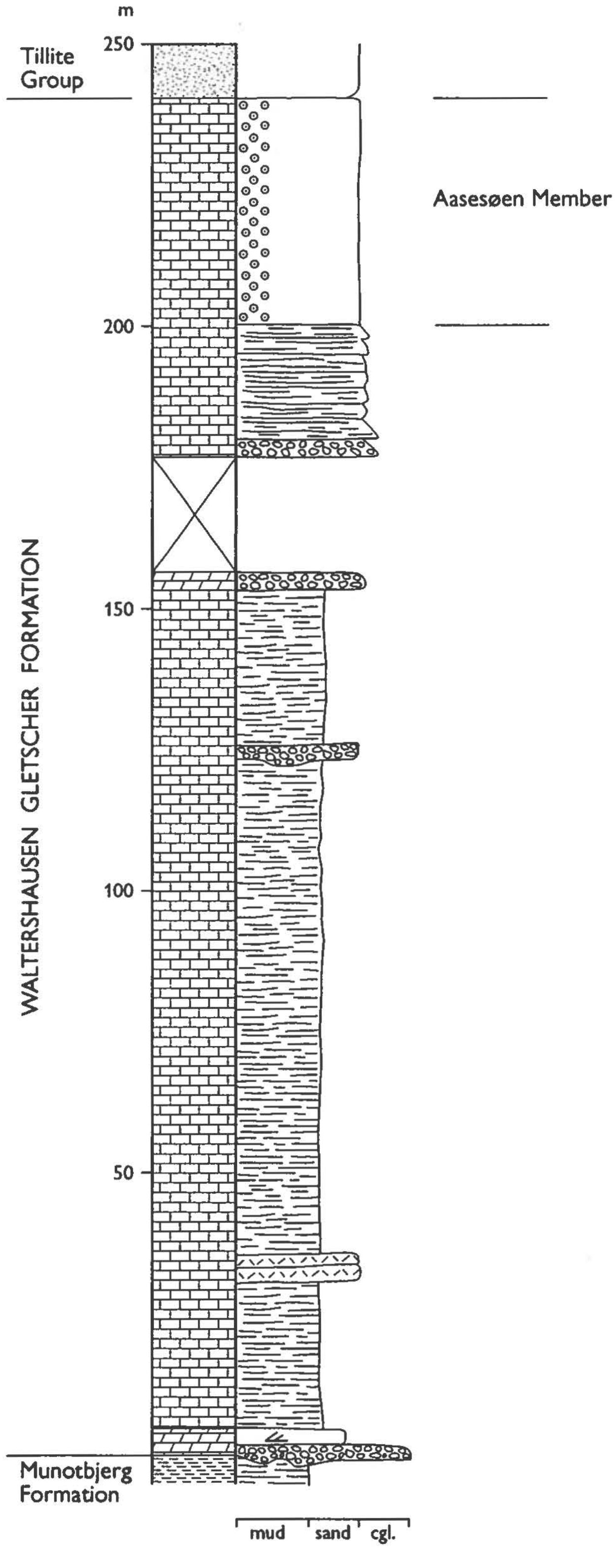

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Fig. 24

Fig. 25

G006.158A KSFR

	Name of locality	Position of locality	Thickness	Formations present in the measured section	Comments on the stratigraphy	Structural setting	Physiography
1.	Kap Weber, Andrée Land	73°29'N, 25°06'W	1175 m	Skipperdal and Reservatet Fms are missing.		In the southern limb of the Kap Weber Syncline	River sections and steep mountain slopes
2.	Brogetdal, Strindberg Land	73°45'N, 24°40'W	1000 m	All present.		In the northern limb of the Brogetdal anticline	Mountain slope ridges
3.	Munotbjerg, Ymer Ø	73°06'N, 24°51'W	900 m	Waltershausen Gletscher Fm is missing.		In the eastern fault-rotated limb of the border anticline	Mountain slope ridges
4.	Nanortalikdal, Suess Land	73°06'N, 25°45'W	1040 m	Waltershausen Gletscher Fm is missing.		In the western limb of the western syncline	Mountain slope ridges
5.	Kap Oswald, Ella Ø	73°53'N, 25°08'W	890 m	Grejsdalen and Munotbjerg Fms are present.		In the core of the border anticline	Mountain slope ridges
6.	Skipperdal, Scoresby Land	72°25'N, 24°51'W	855 m	Munotbjerg and Waltershausen Gletscher Fms are missing.		In the eastern limb of the Skipperdal syncline	Mountain slope ridges
7.	Waltershausen Gletscher, Ole Rømer Land	74°01'N, 24°28'W	630 m	All present		Close to western fault zone	Mountain slope ridges
8.	Albert Heim Bjerge, Steno Land	74°06'N, 23°30'W	465 m	Munotbjerg and Waltershausen Gletscher Fms are missing	Up to 5 m of the Munotbjerg Fm is preserved	In the northern limb of the "Albert Heim" syncline	River sections and mountain slope ridges
9.	Wordie Gletscher, Payer Land	74°26'N, 22°51'W	60 m	Grejdalen Fm is present		At the boundary to the Palaeo-proterozoic crystalline basement	Mountain slope ridges
10.	Promenadedal, Hudson Land	74°01'N, 23°12'W	555 m	Munotbjerg and Waltershausen Gletscher Fms are missing		In the southern limb of the "Albert Heim" syncline	Mountain slope ridges
11.	Snehvide, Hudson Land	73°55'N, 23°26'W	280 m	Grejsdalen Fm is present		In isolated faulted blocks	River sections and mountain slopes
12.	Hjørnebjerget, Hudson Land	74°02'N, 23°50'W	655 m	Waltershausen Gletscher Fm is missing	Up to 10 m of the Munotbjerg Fm is preserved	In the western limb of the "Krumme langsø" syncline	Mountain slope ridges
13.	Månesletten, Andrée Land	73°21'N, 25°53'W	1130 m	All present		In the northern limb of the Månesletten syncline	River sections and steep mountain slopes
14.	Arenaen, Ymer Ø	73°20'N, 24°52'W	65 m	Munotbjerg and Waltershausen Gletscher are present		Between the Barrier and Main Faults in the border anticline	Mountain slope ridges
15.	Kap Mohn, Ymer Ø	73°07'N, 25°14'W	950 m	All present	2 m of the Waltershausen Gletscher Fm is preserved	In the western limb of the border anticline	Mountain slope ridges
16.	Rytterknægten, Lyell Land	72°47'N, 25°75'W	690 m	Waltershausen Gletscher Fm is missing		In the eastern limb of the Arbenz Kolle syncline	Mountain slope ridges

Table 1