An Upper Proterozoic unconformity in northern Wedel Jarlsberg Land, southwest Spitsbergen: Lithostratigraphy and tectonic implications

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Recent field studies of Upper Proterozoic rocks in northern Wedel Jarlsberg Land, southwest Spitsbergen, have shed new light on the pre-Caledonian evolution of the region. A regional angular unconformity divides the greenschist-facies metasedimentary rocks into two distinct tectono-stratigraphic sequenees. The sub-unconformity (Nordbukta) sequence, exposed in the southwestern part of the study area, consists mainly of quartzites, phyllites and dolomites, and may be correlative with Proterozoic rocks exposed east of Recherchebreen (Magnethøgda sequence) and south of Torellbreen (Deilegga sequence). The Nordbukta sequence was affected by large-scale recumbent folding during late (?) Proterozoic tectonism. Strata above the unconformity (Dunderbukta-Recherchefjorden sequence) include conglomerates, dolomites, green and black phyllites, meta-basalts and Vendian (?) diamictites, with laterally complex depositional relationships. The continuation of this sequence south of Torellbreen is the Sofiebogen Group in the Hornsund area. The apparent continuity of both sub- and supra-unconformity Proterozoic rocks across Recherchebreen and Torellbreen is not compatible with the hypothesis that a major late Devonian strike-slip terrane boundary lies beneath these glaciers.

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The Proterozoic succession exposed in northern Wedel Jarlsberg Land, between Bellsund and Torellbreen, southwest Spitsbergen (Fig. 1), consists of greenschist-facies metasedimentary and metavolcanic rocks, including quartzite, phyllite, conglomerate, dolomite, metabasalt, metatuff and diamictite. The total thickness of the succession may be as great as 9,000 m (Bjørnerud 1987). The age of these rocks is poorly constrained but considered to be Upper Proterozoic on the assumption that diamictites at the top of the succession are Vendian glaciogenic deposits (Harland 1964; Hjelle 1969).

Until recently, the Proterozoic succession had been studied only on a reconnaissance basis (Orvin 1940; Winsnes 1965; Hjelle 1969; Flood et al. 1971). Considerable debate has centered on the nature of several clast-bearing units within the succession: congiomerates exposed at Konglomeratfjellet, Orvinfjellet and south of Dunderdalen (Orvin 1940; Winsnes 1965; Hjelle 1969) and the 'Kapp Lyell' diamictite sequence exposed between Dunderdalen and Chamberlindalen (Garwood & Gregory 1898; Hjelle 1969; Harland 1978a; Waddams 1983; Kowallis & Craddock 1984). Resolving the depositional environment and lithostratigraphic position of these units is important for correlations not only with coeval rocks in Svalbard but also with Vendian and Riphean successions throughout the North Atlantic region. This has not been possible without careful and complete mapping, due to the depositional complexity of the Proterozoic rocks and to the effects of polyphase Caledonian deformation. (Although Tertiary tectonism also affected this area, K-Ar age dates and structural relationships indicate that metamorphism and penetrative deformation of the Proterozoic rocks were pre-Tertiary.) Most of northern Wedel Jarlsberg Land (WJL) has now been mapped at a scale of 1:10,000 as part of a University of Wisconsin (U.S.A.) project whose principal objective was to define Caledonian structural features. A by-product of this work is detailed knowledge of the Proterozoic lithostratigraphy and geologic setting of the region. This new information is of particular importance because the Proterozoic rocks in northern WJL occur on both sides of a postulated Caledonian strike-slip terrane boundary to which hundreds of kilometers

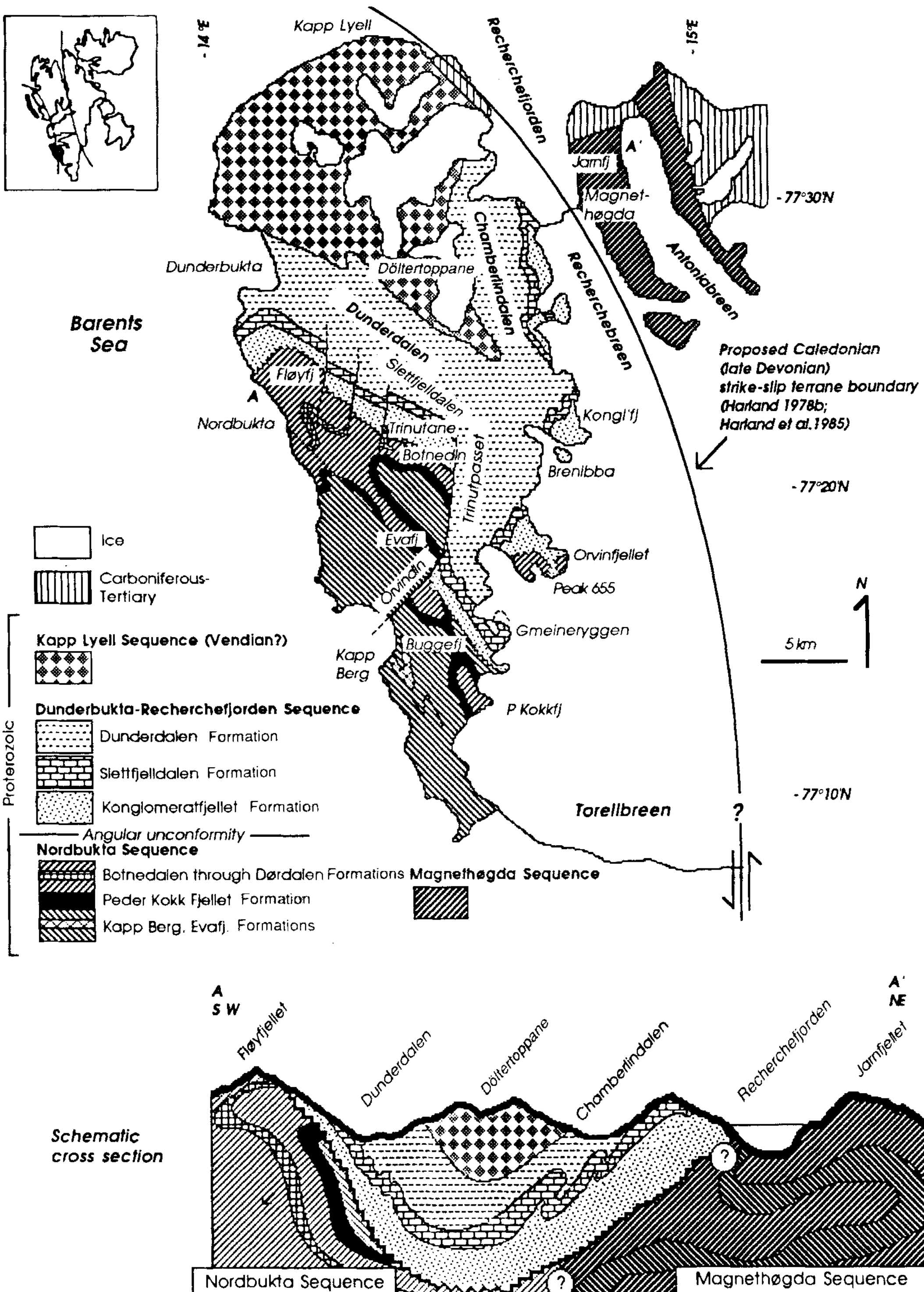

Fig. 1. Simplified geologic map and cross-section of northern Wedel Jarlberg Land. Structure of Nordbukta and Magnethøgda sequences is too complex to depict in detail at this scale (see Dallmann et al. 1990). Inset shows location within Svalbard.

of late Devonian displacement have been attributed (Fig. 1) (Harland 1978b; Harland et al. 1985).

Upper Proterozoic unconformity

The purpose of this report is to describe a well-exposed angular unconformity which divides the Proterozoic succession of northern WJL into two stratigraphically and structurally distinct sequences (Hauser et al. 1983; Cochrane 1984; Bjørnerud 1985; Kalinec 1985). The sub-unconformity rocks, referred to here as the Nordbukta sequence (nomenclature of Dallmann et al. 1990), record a period of intense deformation in Proterozoic time (Bjørnerud 1987; Bjørnerud et al. 1990). The age of this event is constrained only to the extent that the supra-unconformity rocks, which include the Vendian (?) diamictites, bear no evidence of pre-Caledonian deformation. The laterally variable supra-unconformity sequence is divisible into two interlocking geographic parts, here designated the Dunderbukta and Recherchefjorden sequences (Dallmann et al. 1990).

South of Dunderdalen the contact between the Nordbukta and Dunderbukta sequences dips moderately to steeply northeastward as part of a regional Caledonian-age fold (Fig. 1). The discontinuity cuts across an estimated 1,500 m of Nordbukta stratigraphy but is parallel to bedding in the Dunderbukta sequence. The surface itself is well exposed along a 15 km NW-trending trace and it is clearly an angular unconformity rather than a fault. Features which record erosion and deep weathering are common in rocks just below the unconformity. Where the unconformity transects quartzitic units in the Nordbukta sequence, for example, it is typically not a distinct surface but instead a zone of transition from regolith-like, fragmented and iron-stained quartzite upward into quartzite-cobble conglomerates with graded bedding (Nania 1987). Nordbukta sequence carbonate rocks near the trace of the unconformity, moreover, contain sparry solution cavities and apparent collapse breccias which may represent palaeo-karst features formed at the same time as the unconformity (Kalinec 1985). The rocks immediately above the unconformity are also characteristic of an erosional stratigraphic contact. The Dunderbukta sequence begins with a basal conglomerate, containing rounded clasts of Nordbukta rock types locally truncated by the unconformity. The mineralogy of the conglomerate matrix is generally different from that of the clasts, providing further evidence that the conglomerate is not a fault breccia. In addition, many clasts show deformational fabrics not present in the matrix, indicating that the fabrics formed before the clasts were incorporated into the conglomerate. Although the clasts of the basal Dunderbukta beds vary laterally from pebble- to boulder-size, the conglomerate shows an overall upward-fining trend.

The transection of the Nordbukta sequence by the unconformity indicates that the erosional surface developed on a strongly deformed terrane. Contrasting structural styles in the two Proterozoic sequences also point to a deformational episode which preceded deposition of the Dunderbukta sequence. The Nordbukta sequence is characterized by a penetrative linear fabric not developed in the younger rocks. Cross-bedding and graded bedding in Nordbukta rocks show, moreover, that the sub-unconformity rocks were regionally overturned at the time the Dunderbukta sequence was deposited. These and other structural features (recumbent isoclinal folds, sheath folds and zones of intense layer-parallel mylonitization) suggest that the Nordbukta sequence was deformed during a Proterozoic tectonic event, which involved development of a nappe-like fold whose upper limb was largely removed by erosion before

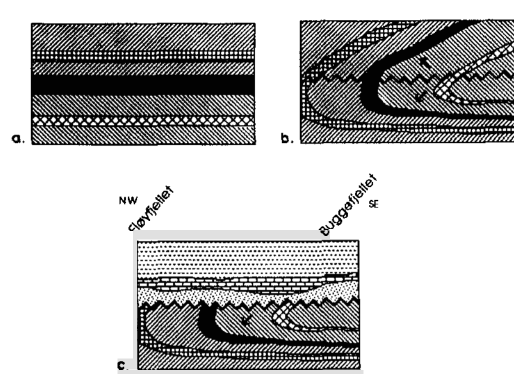

Fig. 2. Schematic portrayal of late Proterozoic events in northern Wedel Jarlsberg Land. Ornamentation as in Fig. 1.
a. Deposition of Nordbukta sequence.
b. Late Proterozoic tectonism involving nappe emplacement. Zig-zag line shows level of future unconformity.
c. Erosion of upper limb of nappe structure, leaving lower limb with inverted stratigraphy. Deposition of Dunderdalen-Recherchefjorden sequence.

the Dunderbukta sequence was laid down (Fig. 2) (Bjørnerud et al. 1990).

Regional structures and distribution of the two Proterozoic sequences

The large-scale distribution of Proterozoic rocks in northern WJL is controlled by macroscopic NW-trending folds of Caledonian age (Flood et al. 1971; Bjørnerud 1987). South of Dunderdalen the unconformity lies on the northeastern limb of an anticlinorium and dips almost homoclinally to the northeast, although its trace is offset about 6 km in a dextral sense along the NNE-trending Orvindalen fault (Fig. 1). Nordbukta sequence rocks are exposed southwest of the unconformity trace, in the core of the anticlinorium, while Dunderbukta sequence rocks lie on the NE-dipping limb of the antiform and in the succeeding synclinorium, which is cored by the Kapp Lyell diamictites. In the eastern part of the study area (Fig. 1) the northeastern limb of this synclinorium is partly obscured by the glacier Recherchebreen, with a possible continuation of the Proterozoic unconformity on this SW-dipping limb, beneath the glacier. This inference is supported by the fact that the lowest stratigraphic units of the Recherchefjorden sequence occur immediately west of Recherchebreen (McCord 1978; Hauser 1982). The Proterozoic Magnethøgda sequence (formerly 'Antoniabreen Succession'; Hauser 1982; Craddock et al. 1985) is exposed in a broad antiformal arch east of Recherchebreen. The Magnethøgda sequence is the possible continuation of the sub-unconformity Nordbukta sequence south of Dunderdalen; evidence for and implications of this correlation are discussed below.

Sub-unconformity lithostratigraphy

Nordbukta sequence

Because the rocks of the Nordbukta sequence have experienced at least two periods of penetrative deformation (Proterozoic and Caledonian), it is impractical to subdivide them according to stratigraphic rules developed for undeformed rocks. The lithostratigraphic divisions presented in this paper, therefore, are necessarily informal. Table 1 summarizes the lithostratigraphy of the Nordbukta sequence south of Dunderdalen. (Formation names proposed here are the same as those which appear in the Norsk Polarinstitutt 1:100,000 geologic map of Van Keulenfjorden (Dallmann et al. 1990).)

As mentioned, younging-direction indicators including cross-bedding and graded-bedding show that Nordbukta strata are overturned on a regional scale (Bjørnerud 1985; Kalinec 1985). These 'way up' indicators also show that progressively younger Nordbukta rocks are preserved along the trace of the unconformity from Peder Kokkfjellet northwestward to Fløyfjellet (Figs. 1, 2). The rocks of the Nordbukta sequence fall into two broad divisions which suggest a general upward-shallowing trend. The upper division (Peder Kokkfjellet Formation through Dørdalen Formation; Table 1) is characterized by an abundance of dolomites and limestones, while the lower division (Evafjellet and Kapp Berg Formations) consists of quartzites and phyllites.

The lower division occurs mainly as shattered outcrops on the strandflat, and it lacks distinctive marker beds for regional correlation. Massive white, pink and green quartzites, locally cross-bedded, alternate with beds of black phyllite across the width of the strandflat from Olafsonbukta to Kapp Borthen (Fig. 1) (Cheng 1984; Cochrane 1984; Wills 1984; Kalinec 1985; Phillips 1986). It is not clear whether the widely scattered occurrence of these quartzites represents stratigraphic or tectonic repetition (perhaps both). The Kapp Berg Formation has a greater proportion of phyllitic strata than the overlying Evafjellet Formation, but the boundary between the two units is not sharply defined. The bottom of the Kapp Berg Formation is not exposed. The intercalation of quartzite and phyllite in the two formations suggests that they may represent shelf-edge density-flow deposits, with the Evafjellet Formation more proximal to the sediment source than the Kapp Berg Formation. However, tectonic obliteration of sedimentary structures makes it difficult to establish the depositional setting of the rocks.

Good exposures and the presence of several marker horizons allow the lithostratigraphy of the upper Nordbukta division to be resolved in detail (Bjørnerud 1985; Bray 1985; Kalinec 1985). The estimated total thickness of the upper division

Table 1. Lithostratigraphy of the sub-unconformity Proterozoic sequences, northern Wedel Jarlsberg Land, SW Spitsbergen.

Unit		Estimated thickness (m)			
NORDBUKTA SEQUENCE					MAGNETHØGDA SEQUENCE
Fløyfjellet to Peder Kokkfjellet (Bjørnerud 1987)			*Orvinfjellet area* (Rogers 1985)		*Antoniabreen area* (Hauser 1982)
8	Dørdalen Formation Heterogeneous dolomite & phyllite	150+	O-8 (Hl*): Limestone/white marble	?	M-8 (Hbd*): Banded dolomite/white marble
7	Thiisdalen Formation Red-brown phyllite & quartzite	200	O-7 (Hpm): Maroon phyllite	?	M-7 (Hdp): Dark phyllite
6	Trinutane Formation c) Ferroan dolomite/pink marble	150	O-6c (Hdo): Orange dolomite	?	M-6c (Hyd): Yellow dolomite
	b) Resinous phyllite	30	O-6b (Hpw): Waxy phyllite	?	M-6b (Hgq): Grey-green quartzite
	c) Pink, cross-bedded quartzite	200		?	M-6a (Hfq): Feldspathic quartzite augen mylonite
5	Seljehaugfjellet Formation b) Grey dolomite	150	O-5b (Hdfl): Grey dolomite floatstone	?	M-5b (Hgd): Grey dolomite w/hematite
	a) Black Limestone	50			
4	Botnedalen Formation Platy limestone, dolomite and phyllite	300	O-4 (Hlsp): Limestone & phyllite		
3	Peder Kokkfjellet Formation Sandy dolomite	60		?	
2	Evafjellet Formation Quartzite & phyllite	1,000?		?	M-2 (Hlq): Layered quartzite
1	Kapp Berg Formation Phyllite & quartzite	1,000?			

* Symbols used by Rogers (1985) and Hauser (1982).

is in the order of 1,500 m. The first distinctive unit above the monotonous quartzites is an orange-weathering dolomite which is sandy (locally cross-bedded and oolitic) in the north and rich in white mica in the south. This unit is named for Peder Kokkfjellet (Fig. 1), where it is exposed in the core of a large east-closing recumbent fold. The Peder Kokkfjellet Formation is also well exposed on Evafjellet and Grisryggen. It grades upward into a platy, micaceous limestone-phyllite-dolomite unit, named the Botnedalen Formation. Sedimentary structures (including bedding) are difficult to discern in this unit, which apparently sustained intense shear strain during Proterozoic tectonism. The Botnedalen Formation grades into black, thinly-bedded, locally oolitic limestone and laminated, stromatolitic (?) grey dolomite (Seljehaugfjellet Formation). The succeeding unit, the Trinutane Formation, includes three rock types which define a distinctive stratigraphic package. The formation begins with pink- to orange-weathering, dolomitic quartzite which is gradational from the underlying Seljehaugfjellet Formation. The lowermost beds of the quartzite are commonly cross-bedded, and contain what appear to be rip-up clasts of dolomite. The dolomite content decreases upward, and the top of the 200 m thick quartzite is slightly feldspathic. The upper part of the Trinutane Formation consists of green, thinly laminated phyllite with a resinous luster and orange-weathering ferroan dolomite studded with centimeter-sized pyrite crystals. In most exposures the resinous phyllite and orange dolomite are tectonically interleaved. In the hinge zones of some mesoscopic isoclinal folds the dolomite has been transformed into a pale pink marble. The Trinutane Formation is overlain by reddish-brown quartzitic phyllite (Thiisdalen Formation) and a heterogeneous series of dolomites and phyllites (Dørdalen Formation). These are the youngest preserved Nordbukta rocks, exposed on Fløyfjellet, Dørdalsnuten and Seljehaugfjellet in the inferred hinge of the Proterozoic fold-nappe (Fig. 2).

Magnethøgda sequence

As discussed previously, the regional distribution of Proterozoic rocks in northern WJL suggests that the Magnethøgda sequence east of Recherchebreen (Hauser 1982) may be correlative with the Nordbukta sequence south of Dunderdalen. Tectonic disruption of the Magnethøgda sequence and uncertainties about younging direction within it (Hauser 1982) make unit-by-unit correlations between the sequences difficult, however. In Table 1 Magnethøgda sequence units are designated by numbers which indicate their possible relationships with the Nordbukta sequence.

The predominance of carbonate rocks in the Magnethøgda sequence (Hauser 1982) suggests that it may have affinities with the upper division of the Nordbukta sequence. Hematite-bearing dolomite exposed on Jarnfjellet and Magnethøgda (unit M-5b) contains apparent algal laminae, dolomitic intraclasts and cross beds, and thus is strongly reminiscent of the transition between the grey dolomite of the Seljehaugfjellet Formation and pink quartzite of the Trinutane Formation. Feldspathic quartzite (M-6a) and grey-green quartzite (M-6b) exposed north of Magnethøgda, moreover, are similar to the Trinutane pink quartzite and resinous green phyllite. In the Magnethøgda sequence, however, the arkosic quartzite varies texturally from a clearly sedimentary rock into a mylonite with cm-sized feldspar augen. No comparable texture has been observed in the Nordbukta sequence.

Similarities between the Magnethøgda sequence and sub-unconformity rocks of the Orvinfjellet area (Fig. 1) are particularly noteworthy. The unconformity is particularly well-exposed in this area, and the sub-unconformity rocks were studied in detail by Rogers (1985). Because their relationship with Nordbukta units is not entirely clear, they are listed by number in Table 1. Banded grey and white marble (O-8), exposed as flatirons on the west flank of Peak 665 m near Orvinfjellet, very likely corresponds with Magnethøgda sequence grey and white marble (M-8) on the lower east side of Maria Theresiatoppen. The occurrence of specular hematite bodies on the south side of Peak 665 m also suggests a connection with the iron ore-bearing Magnethøgda dolomites.

The possible link between the Magnethøgda sequence and the sub-unconformity rocks west of Recherchebreen is critical to interpretations of Spitsbergen's Proterozoic and early Palaeozoic history because Recherchebreen is the proposed site of a major late Devonian strike-slip fault zone. Harland (1978b) cited the different character of Proterozoic rocks immediately east and west of the glacier as evidence for a first-order terrane boundary there. An equally plausible explanation is that the trace of the Proterozoic angular unconformity continues beneath Recherchebreen.

Metamorphic grade of sub-unconformity rocks

Most mineral assemblages in the Nordbukta and Magnethøgda sequences indicate peak metamorphic conditions within the greenschist facies (Hauser 1982; Bjørnerud 1985; Kalinec 1985), for example:
—Chlorite + Muscovite + Quartz
—Chloritoid + Muscovite + Quartz
—Dolomite + Quartz
—Calcite + Muscovite + Quartz.
Hauser (1982) reported local occurrences of garnet in a Magnethøgda quartzite (M-6a), but the composition of the garnet has not been studied. Cheng (1984) found a small amount of kyanite in a specimen of (Evafjellet Formation) quartzite collected west of Peder Kokkfjellet.

This is the only known occurrence of kyanite in the sub-unconformity Proterozoic rocks, but it suggests that some of the rocks may have experienced amphibolite-facies metamorphism. The recrystallized feldspar augen in Magnethøgda unit M-6a may also indicate moderately high-grade metamorphism of parts of the Magnethøgda sequence. Further analyses of the Nordbukta and Magnethøgda sequence rocks are needed to constrain the timing and conditions of metamorphism.

Supra-unconformity lithostratigraphy

Dunderbukta-Recherchefjorden sequence

The stratigraphic complexity of the supra-unconformity sequence has been a major reason for the confusion about Proterozoic lithostratigraphic correlations within and beyond Wedel Jarlsberg Land. The lateral complexity of the sequence, however, also provides glimpses into its depositional environment.

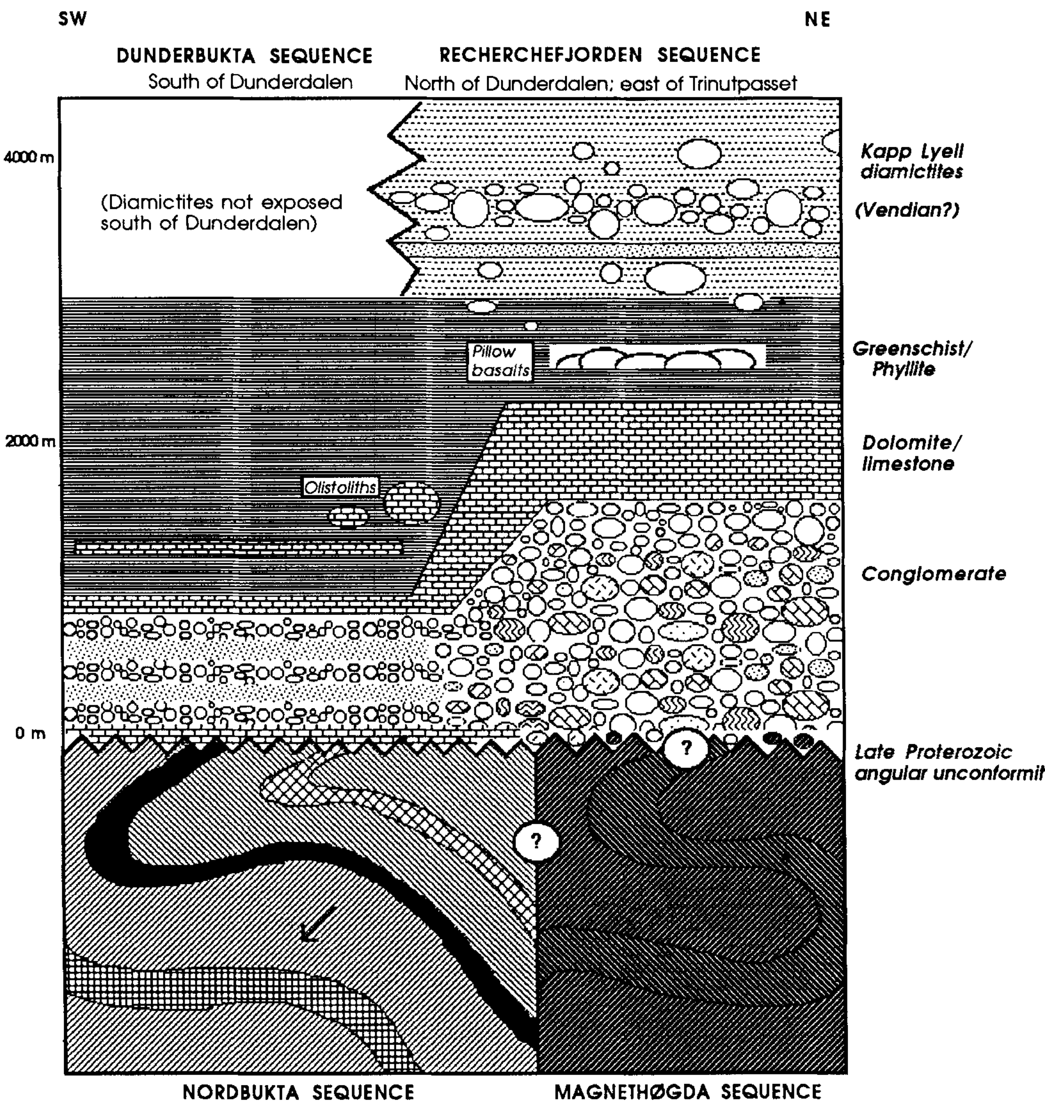

Fig. 3. Lateral thickness and facies variations in the supra-unconformity Dunderdalen-Recherchefjorden sequence. The underlying Nordbukta and Magnethøgda sequences are depicted schematically.

Table 2. Lithostratigraphy of the supra-unconformity Proterozoic sequences, Wedel Jarlsberg Land, SW Spitsbergen.

Unit	Estimated thickness (m)	Probable equivalent in Sofiebogen Group of Hornsund area (Hjelle 1969; Birkenmajer 1981)
KAPP LYELL SEQUENCE		
Diamictite, conglomerate quartzite, phyllite	2,000–3,000	
DUNDERBUKTA and RECHERCHEFJORDEN SEQUENCES		
Dunderdalen Formation Phyllite, greenschist & metabasalt with local bodies of dolomite & quartzite	1,000–2,000	Gåshamna phyllite
Slettfjelldalen Formation Dolomite & limestone	50–300	Höferpynten dolomite
Konglomeratfjellet Formation		
b) Green conglomerate, diamictite & quartzite	300+	
a) Brown conglomerate, diamictite & quartzite	400+	
Thiisfjellet Formation		Slyngfjellet conglomerate
b) Black pyritic limestone	0–100	
a) Dolomite gritstone and conglomerate	0–50	
	UNCONFORMITY	
(Nordbukta Sequence)		(Deilegga Group)

Supra-unconformity Proterozoic rocks are exposed in the central part of northern WJL, from Kapp Lyell southward to the Orvinfjellet area. Although the rocks in this central area clearly constitute a single depositional sequence, lateral facies contrasts are dramatic enough to make a distinction between a western division, the Dunderbukta sequence (exposed from Dunderbukta to Gmeineryggen), and an eastern division, the Recherchefjorden sequence (Chamberlindalen to Orvinfjellet) (Fig. 3). These original depositional contrasts appear to have influenced later Caledonian deformational patterns (Bjørnerud et al. in press), so distinguishing the two subdivisions is also useful from a structural standpoint. In the following discussion the Dunderbukta and Recherchefjorden (D-R) sequences will be described together, with significant differences between them noted where appropriate. Informal formation names are proposed in Table 2.

Four main divisions can be identified within the supra-unconformity sequences (Fig. 3). Beginning at the unconformity, these include:

1) A succession of coarse clastic rocks, mainly conglomerates and quartzites (Konglomeratfjellet Formation), and, locally, a basal unit of sandy dolomites and silty limestone (Thiisfjellet Formation). Combined thickness 800 to 1,700 m.

2) A series of dolomites and minor limestones (Slettfjelldalen Formation) with features including cross-bedding, depositional breccias, stromatolites and chert beds, as well as shallow mafic intrusions in the Recherchefjorden (eastern) sequence (50 to 300 m thick).

3) Green, silver and black phyllite (Dunderdalen Formation) containing discontinuous quartzite and dolomite beds and, in the Recherchefjorden sequence in Chamberlindalen, volcaniclastic rocks and pillow basalts (1,000 to 2,000 m).

4) The Kapp Lyell diamictite sequence (perhaps 3,000 m thick).

Within the framework of these four broad divisions there are many local variations in rock type and stratigraphic thickness.

Basal units: Thiisfjellet and Konglomeratfjellet Formations

Lateral facies changes are most dramatic in the conglomerate succession at the bottom of the supra-unconformity sequence, presumably reflecting a depositional environment with considerable topographic relief. In the Dunderbukta sequence three separate conglomeratic horizons within this succession can be traced with reasonable continuity from Fløyfjellet to Gmeineryggen:

1) Thiisfjellet Formation: Gritstone/conglomerate with grey- to orange-weathering dolomitic matrix and highly variable thickness (0 to 50 m). From Fløyfjellet to Buggefjellet this lowermost conglomerate is both interfingered with and overlain by black, pyritic, phyllitic limestone (50 to 100 m thick), containing isolated beds of quartzite pebble conglomerate.

2) Konglomeratfjellet Formation, lower part: Brown conglomerate/diamictite with a dolomitic matrix and pebble- to cobble-sized clasts composed mainly of dolomite. Many clasts are fragments of oncolites or stromatolites. Some intervals are massive and lack identifiable bedding planes. In other intervals 10 cm to 1 m thick graded beds occur. The bedding is locally contorted by apparent soft-sediment folding, faulting and diapirism. About 400 m thick.

3) Konglomeratfjellet Formation, upper part: Green conglomerate/diamictite with a chloritic matrix and pebble- to cobble-sized clasts composed mainly of quartzite. Graded bedding and ripplemarks are typical sedimentary structures. About 300 m thick.

These divisions are not entirely applicable to the Recherchefjorden sequence. In the Chamberlindalen and Orvinfjellet areas the Thiisfjellet Formation is absent, and the clastic succession as a whole is thicker and coarser-grained. On Orvinfjellet, where the unconformity is clearly exposed, 'brown' and 'green' divisions can be distinguished in the lowermost conglomerates (Rogers 1985). Well-rounded clasts of white, pink and green quartzite – probably derived from the pastel quartzites of the lower Nordbukta sequence – are the predominant types in these boulder conglomerates. Higher in the section the clastic sequence near Orvinfjellet becomes more similar to the Dunderbukta conglomerates and diamictites. Graded bedding, laterally discontinuous strata and apparent soft-sediment structures are typical of rocks in both areas, and indicate rapid deposition by high-energy water/sediment flows. In addition, oncolite clasts occur in a diamict layer on the ridge northeast of Orvinfjellet, suggesting a common source area with the Dunderbukta conglomerates. It seems likely, however, that even laterally traceable strata within the conglomerates represent time-transgressive deposits.

Because the trace of the Proterozoic unconformity is probably obscured beneath Recherchebreen, it is difficult to determine how much of the lower Recherchefjorden sequence is concealed in the Chamberlindalen area. The oldest exposed Recherchefjorden rocks are coarse conglomerates which occur on Konglomeratfjellet and Brenibba. These rocks are very much like the lowermost conglomerates on Orvinfjellet, with rounded, boulder-sized clasts of white, pink and green quartzite. It seems probable, therefore, that they occupy a similar stratigraphic position near the unconformity. Significantly, about 5% of the clasts in the Konglomeratfjellet conglomerate have compositions similar to the feldspathic quartzite (unit M-6a) of the Magnethøgda sequence. The mean clast size of the Recherchefjorden sequence conglomerates decreases northward from Konglomeratfjellet. This trend is probably a combination of progressive fining both laterally and upsection.

Slettfjelldalen Formation

The Slettfjelldalen dolomites and limestones show almost as much lateral viability as the underlying conglomerates and quartzites. Cross-bedding, sedimentary breccias, digitate stromatolites and chert beds occur in various permutations in these rocks, suggesting complex spatial and temporal variations in depositional environment. The Slettfjelldalen Formation has rather different characteristics in the Recherchefjorden and Dunderbukta subdivisions. First, the unit is considerably thicker in the Recherchefjorden sequence (200 to 300 m vs. 50 to 100 m). Second, sills and dykes of alkali basalt composition are common in the Recherchefjorden dolomites but not in their Dunderbukta equivalents. Finally, the deformational fabrics of the carbonates in the two areas are very different. Sedimentary structures in the Recherchefjorden carbonates are modified or obliterated by an intense (Caledonian) mylonitic foliation, while the

Dunderbukta carbonates show only a non-penetrative pressure solution cleavage. While this distinction is not a depositional one, it may reflect mechanical contrasts related to original variations in thickness and composition.

Dunderdalen Formation

Dunderdalen, Chamberlindalen and Trinutpasset are underlain by an extremely thick (1,000 to 2,000 m), but poorly exposed phyllite unit which overlies the Slettfjelldalen Formation. The rarity of good outcrops makes stratigraphic relationships within the phyllite obscure, but several distinctive features of the unit are noteworthy. Discontinuous beds and lenses of quartzite and dolomite, commonly brecciated, occur from place to place in the phyllite. The limited extent and fragmented internal textures of some of these bodies suggest that they may represent olistoliths transported into an otherwise quiet basin. In Chamberlindalen the phyllite contains variolitic pillow basalts and lenses of alkali diabase like that in the underlying dolomites, indicating that volcanism was concurrent with deposition of the unit (Hauser 1982). The phyllite also contains apparent pyroclastic bombs – vesicular spheroids 5 to 10 cm in diameter. These objects have been dolomitized, and they typically occur in a very green fine-grained phyllitic matrix which may represent metamorphosed volcanogenic sediments.

Kapp Lyell sequence

The contact between the thick Dunderdalen phyllites and the overlying Kapp Lyell diamictites is somewhat enigmatic. The increased intensity of a secondary foliation close to the contact could indicate that the two units are in tectonic, rather than stratigraphic, contact (Hauser 1982; Kowallis & Craddock 1984). Sedimentary features indicate, however, that the phyllite-diamictite transition is probably a gradational stratigraphic contact. The uppermost strata of the phyllite unit include coarse-grained quartzites with isolated cobbles and boulders of dolomite. The lowermost beds of the diamictites, in turn, are extremely clast poor, and consist mainly of varve-like laminae of interlayered phyllite and sandy dolomite, with each couplet 0.2 to 1.0 cm thick. The phyllite-diamictite contact is most likely a stratigraphic transition which was the locus of high shear strain during later deformation.

Above the basal transition zone, cobbles and boulders punctuate the varve-like layering of the diamictites. These clasts may well be ice-rafted, although the superimposed tectonic fabric makes it difficult to identify clear examples of dropstone textures. The diamictites contain clasts representative of almost all underlying rock types, including pelite, limestone and dolomite, which appear to be derived from the post-unconformity sequence. The matrix of the diamictites is largely dolomitic, perhaps derived from carbonate rocks exposed at the time of deposition. Graded beds of quartzite, 50 to 100 cm thick, occur at irregular intervals within the otherwise finely laminated rock. These and related features, including flame and injection structures, led Waddams (1983) to describe the Kapp Lyell rocks as 'resedimented' glaciomarine deposits.

On the macroscopic scale the diamictite sequence defines a NW-plunging synclinorium (Fig. 1) which is a second-phase Caledonian structure (Bjørnerud et al. in press). At the mesoscopic scale, however, sedimentary layering in the diamictites is transposed by first-phase isoclinal folds, making the original stratigraphy of the sequence difficult to decipher.

Depositional setting of the Dunderbukta-Recherchefjorden sequence

The following observations summarize Dunderbukta-Recherchefjorden lithostratigraphy:

1) The sequence is divisible into four major units: conglomerates, dolomites, phyllites/metavolcanic rocks and diamictites.

2) Dramatic lateral variations in rock type and thickness occur within the framework of these four divisions. Important differences exist between the post-unconformity strata in the Dunderbukta and Recherchefjorden areas.

3) Sedimentary features of the lower conglomeratic units (Konglomeratfjellet Formation) indicate rapid and localized deposition by high-energy water/sediment flows.

4) Mafic volcanic and shallow intrusive activity occurred during deposition of the upper part of the Recherchefjorden sequence.

Collectively, these observations suggest that the supra-unconformity rocks were deposited in an unstable sedimentary environment. The coarse clastic units in the lower part of the sequence probably reflect the topographic relief which existed after late Proterozoic deformation of the sub-unconformity sequence. The basalts and related rocks in Chamberlindalen indicate that tectonism (rifting?) may also have contributed to the creation of an unstable depositional setting. Syn-sedimentary graben formation in an extensional regime might account for the lateral thickness variations observed in the rocks.

It seems likely that most lithologic units in the Dunderbukta-Recherchefjorden sequence represent time-transgressive deposits, not time-horizons. The basal units (Thiisfjellet and Konglomeratfjellet Formations) may be diachronous deposits which accumulated in topographically and/or tectonically controlled basins. The black limestones of the Thiisfjellet Formation, for example, may represent localized, relatively deep-water deposits. The relatively thick and coarse conglomerates in the east may reflect proximity to the locus of incipient volcanism. The green chloritic matrix of some conglomerates in the Dunderbukta and Orvinfjellet areas could conceivably be time-correlative with the very green volcanogenic (?) phyllites of Chamberlindalen. If so, the conglomerates in the north would be older than those in the south, possibly reflecting the southward propagation of the volcanic centre with time.

Interpretation of Dunderbukta-Recherchefjorden lithostratigraphy is further complicated by probable differences in sedimentation rates for the various units. The conglomeratic units, for example, may have been deposited relatively rapidly, while the Dunderdalen phyllites probably accumulated much more slowly. Depending on the amount of time represented by the Dunderdalen phyllites, the glaciogenic Kapp Lyell sequence could be only slightly younger than, or much younger than the Dunderbukta-Recherchefjorden sequence.

Metamorphic grade of Dunderbukta-Recherchefjorden sequence

The Dunderbukta-Recherchefjorden sequence appears to have experienced metamorphic temperatures and pressures no higher than those of middle greenschist facies. As in the Nordbukta sequence, chlorite, chloritoid and muscovite are typical metamorphic minerals, and the most common rock types (quartzites and dolomites) are not sensitive recorders of low-grade metamorphic temperatures and pressures. The phyllites, greenschists and metabasalts of the Dunderdalen Formation offer the best possibility for geothermometry and -barometry.

Possible correlations with the Hornsund area

The close correspondence between the upper Hecla Hoek rocks in northern WJL and the Sofiebogen Group near Hornsund has been recognized for some time (Orvin 1940; Winsnes 1965; Hjelle 1969). The three formations within the Sofiebogen Group, the Slyngfjellet Conglomerate, the Höferpynten Dolomite and the Gåshamna Phyllite (Birkenmajer 1981), are clear analogs of the Konglomeratfjellet, Slettfjelldalen and Dunderdalen Formations, respectively. In detail, the similarities between the Bellsund- and Hornsund-area rocks are even more striking. For example, the 'brown' and 'green' conglomeratic divisions observed south of Dunderdalen have counterparts in the Hornsund area. According to Birkenmajer (1959, p. 13), 'Two horizons can be distinguished within the (Slyngfjellet) conglomerates, the lower one coloured yellow and the upper horizon with green colour prevailing'. In addition, sedimentary features which are common in the Slettfjelldalen dolomites (e.g. stromatolites, cross-bedding, chert layers and depositional breccias) also characterize the Höferpynten dolomites near Hornsund (Birkenmajer 1970). Lateral variations in stratigraphic thickness and sedimentary facies are typical of both the Sofiebogen Group and the Dunderbukta-Recherchefjorden sequence. It is less easy to make direct correlations between the Nordbukta sequence and the Hornsund-area Deilegga Group, which lies unconformably beneath the Sofiebogen Group. The correlation is hampered because the unconformity almost certainly transects the underlying deformed terrane at different stratigraphic levels in different places.

Discussion and conclusions

In summary, a newly-recognized Proterozoic angular unconformity in northern Wedel Jarlsberg Land records a period of pre-Vendian tectonism. The unconformity truncated the upper limb of a nappe-like fold in the sub-unconformity sequence, leaving the sequence overturned on a regional scale. The age of the Proterozoic deformational event is not yet constrained, but it may eventually provide a basis for tectonostratigraphic correlations with Proterozoic sequences elsewhere in Svalbard and the high Arctic. The Proterozoic unconformity, associated conglomerates and overlying units can be traced almost continuously from Recherchefjorden across Torellbreen to Hornsund, defining a major late Proterozoic sedimentary province in southern Spitsbergen. The supra-unconformity rocks accumulated above a structurally complex basement and regional correlations among sub-unconformity sequences are not clear at this time. The conglomerates which overlie the unconformity may have been shed in an extensional tectonic setting in which syndepositional faulting controlled sedimentation. These conglomerates are distinct from a sequence of apparently glaciogenic diamictites which lie higher in the section.

Apparent correlations between sub- and supra-unconformity Proterozoic rocks on both sides of Recherchebreen and Torellbreen are incompatible with the postulated existence of a fundamental Paleozoic terrane boundary beneath these glaciers (Harland 1978b). If such a boundary indeed exists, it must lie elsewhere.

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