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Leslie Kanat and Alan Morris

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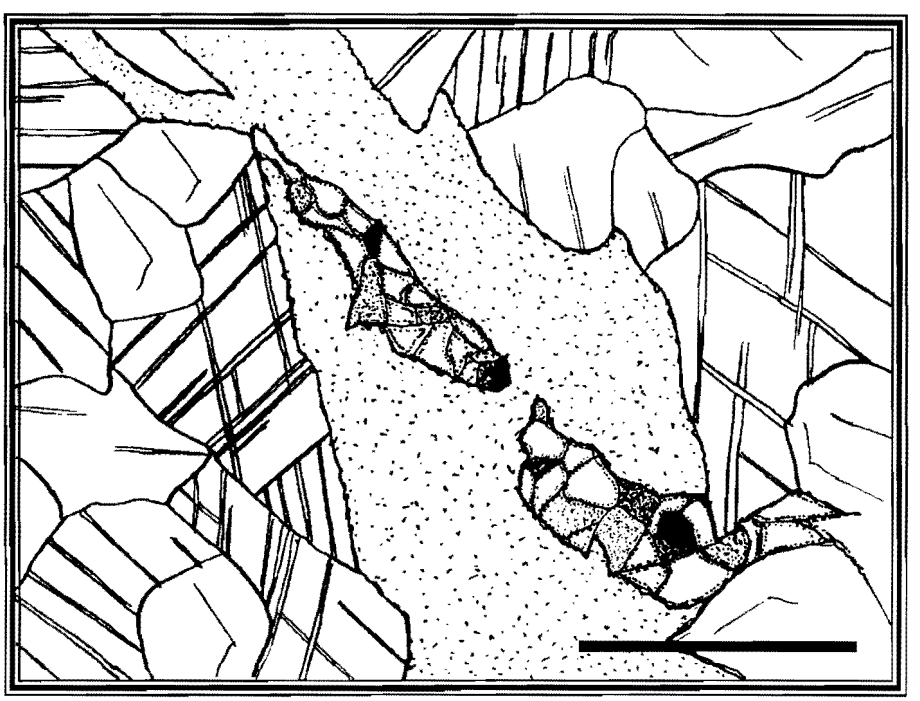

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Cover page. Deformation in the Chaotic Zone. Two textural occurrences of veining are common in dolostone within the Chaotic Zone. In this drawing, fine grained, recrystallized cataclastic quartz (stipple) was injected by later quartz vein (strained) within a massive dolomitic host. The fine grained texture (stipple) is typical for quartz in which cataclasis was followed by recrystallization accommodated dislocation creep. Scale bar: 0.5 mm.

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Contents

Abstract

A modified stratigraphy for the pre-Carboniferous rocks in central Oscar II Land, Spitsbergen, is needed to reconcile recent mapping with earlier interpretations. Outcrop maps and lithological descriptions for the Bullbreen, Comfortlessbreen and St. Jonsfjorden Groups, the Müllerneset Formation, and Vestgötabreen Structural Complex are presented. The contact at the base of the upper Ordovician Bullbreen Group was originally unconformable, although it is now thrust at most localities. A new internal stratigraphy for the Group is presented, and a revised sequence for the St. Jonsfjorden Group is described based on the recognition of sedimentary contacts not previously observed. A change in name from Vestgötabreen Formation to Vestgötabreen Structural Complex is proposed, and several new rock units within this complex are described. Deposition of the Bullbreen Group resulted from uplift of the Vestgötabreen Complex. Continued orogenesis, related to mid-Paleozoic plate motion, drove both units over the Comfortlessbreen and St. Jonsfjorden Groups.

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Introduction

The aim of this paper is to erect a working lithostratigraphic succession for central western Oscar II Land, Spitsbergen (Table 1). Three different accounts of the stratigraphy and structure of Oscar II Land and Prins Karls Forland were published in 1979 (Harland et al. 1979; Hjelle et al. 1979; Krasiltschikov & Kovaleva 1979). The outcrop pattern in the study area closely follows that presented by Harland et al. (1979) and their nomenclature is largely adopted in this work, although we propose a name change for the Vestgötabreen Formation (formerly the Vestgötabreen Suite (Horsfield 1970; Ohta 1979)) to Vestgötabreen Structural Complex. Waddams (1983) indicated that two diamictites in different groups occur in Oscar II Land, but our field observations do not support this interpretation in the St. Jonsfjorden area. In the following account, the history of research is included with the description of each unit in order to preserve name precedence.

Pre-Carboniferous rocks in western Spitsbergen have undergone both mid-Paleozoic and Paleogene orogenesis (see for example Harland 1961; Birkenmajer 1972, 1975, 1981; Harland & Horsfield 1974). As a result of the highly deformed nature of the rocks, unit thicknesses are necessarily estimates.

Uncertainty exists regarding the nature of the original contacts and age of some lithologic units in Oscar II Land. However, there is general agreement on the following points:

1. A significant discontinuity occurs between the Bullbreen Group (Harland et al. 1979; Ohta et al. 1983) and the Vestgötabreen Structural Complex.

2. A late Ordovician depositional age (most likely Caradoc through Llandovery) for the Bullbreen Group (Armstrong et al. 1986; Scrutton et al. 1976) and a mid-Paleozoic metamorphic age for the Vestgötabreen Structural Complex (Horsfield 1972). It is also probable that diamictites which occur in Oscar II Land are Vendian in age (Knoll 1981; Hambrey 1982, 1983).

3. The rock units represent distinct metamorphic facies: Vestgötabreen Structural Complex – blueschists and eclogites; Müllerneset Formation – upper greenschist to amphibolite facies; St. Jonsfjorden and Comfortlessbreen Groups – lower greenschist facies; Bullbreen Group – extremely low grade metamorphism; Carboniferous rocks – unmetamorphosed.

Place names are given in Fig. 1, and the outcrop pattern of the rocks in the St. Jonsfjorden area is

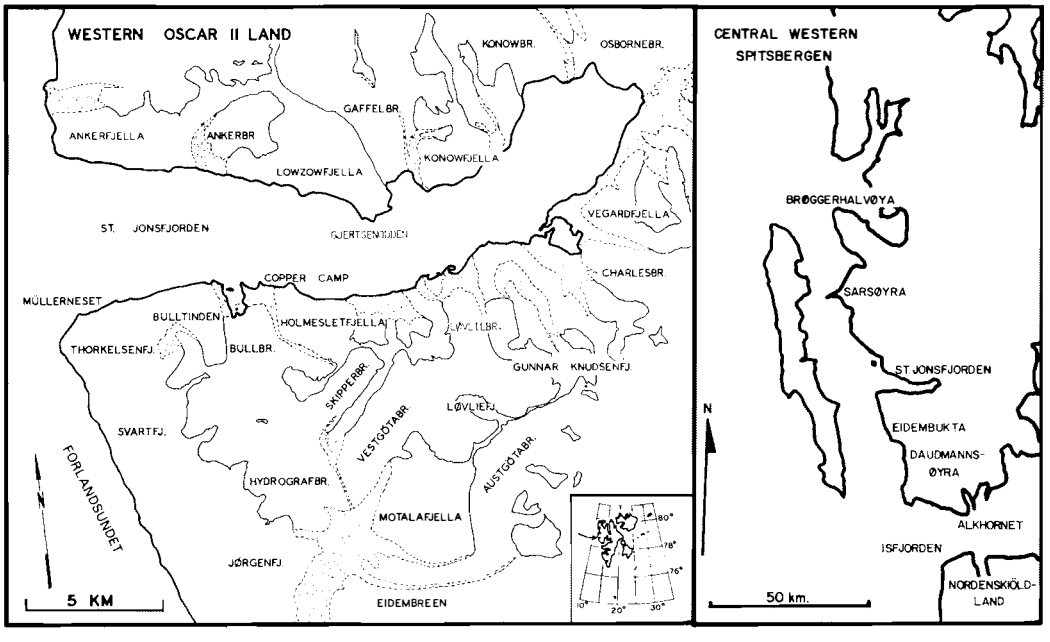

Fig. 1. Localities map of Oscar II Land.

Table 1. A lithostratigraphic succession, central western Oscar II Land, Spitsbergen.

Lithologic unit		member/description	symbol	thickness (metres)	map unit
Strandflat strip unit		limestone	CAR	20	CAR
		bioclastic limestone	-	10	
		conglomerate	-	5	
Bullbreen Group	Holmesletfjella Formation	siliceous slate	BH6	20	
		upper sandstone slate	BH5	100	
		upper slate	BH4	30	
		Bulltinden conglomerate	BH3	60	
		lower slate	BH2	10	
		lower sandstone slate	BH1	150	
	Motalafjella Formation	limestone, slate and conglomerate	BM1	100	
Sarsøyra Formation		(not recognised)	-	-	
Comfortlessbreen Group	Aavatsmarkbreen Formation	dark phyllite	CV3	75	
		chlorite-serpentine phyllite	CV2	10	
		green and cream marble	CV1	25+	
	Annabreen Formation	quartzite	CA1	5+	
	Haaken Formation	green and orange schist	CH2	75+	
		diamictite	CH1	100+	
St. Jonsfjorden Group	Løvliebreen Formation	upper: quartzite and pelite	SL2	300	
		lower: volcanic	SL1	20+	
	Alkhorn Formation	marble	SA2	50+	
		calcareous psammo-pelite	SA1	100+	
	Moefjellet Formation	(not recognised)	-	-	
	Trondheimfjella Formation	(not recognised)	-	-	
Müllerneset Formation		garnet-biotite schist	MUF	800	
Vestgötabreen Complex		orange weathering dolostone	VOD	20	VOD
		medium grey micaceous marble	VM2	50+	
		dark grey micaceous marble	VM1	50+	
		mafic schist	VSH	c.200	
		serpentinite	VSP	15	
		pelitic schist	VPE	10	
		greenstone	VGT	50	
		psammite	VPS	4	
		garnet glaucophanite	VGG	50+	
		eclogite	VEC	40+	

given in Fig. 2. Lithostratigraphic descriptions begin at the top of the succession (Table 1).

Strandflat strip rocks (CAR)

A strongly deformed strip of sedimentary rocks has been faulted into the pre-Carboniferous sequence in Oscar II Land from Daudmannsøyra (northern Isfjørden), north through Eidembukta, along the west side of Svartfjella and Thorkelsenfjella, and north to Brøggerhalvøya (Baker et al. 1952; Cutbill & Challinor 1965; Challinor 1967). In the field area, south of St. Jonsfjorden, these rocks separate the Müllerneset Formation to the west from the diamictites to the east. Elsewhere, south and north of Eidembukta and in Nordenskiöld Land, the Carboniferous rocks rest unconformably on the Comfortlessbreen Group; the upper contact of the Carboniferous is faulted (W. B. Harland 1985, personal communication to LHK).

The strandflat strip rocks comprise three different units:

— An upper buff-coloured limestone member.
— A middle bioclastic limestone member dominated by rugose coral fragments and crinoid ossicles, which towards the base becomes dolomitic and poor in fossil content.
— A basal member cross-bedded, very pale orange, clast-supported conglomerate, containing dominantly quartzite clasts.

These rocks are equivalent to rocks of middle Carboniferous age from the Isfjorden, St. Jonsfjorden and Brøggerhalvøya areas as described by Cutbill & Challinor (1965).

Bullbreen Group

The Bullbreen Group (Harland et al. 1979) is distinguished from other rocks in Oscar II Land by its distinct sedimentary nature, extremely low metamorphic grade, structural style and limited areal extent. Holtedahl (1913) briefly described one member of the Bullbreen Group, but he was not able to define its stratigraphic position with respect to other rock units in the area. Weiss (1953) recognised that bedding was the pronounced planar fabric in some pre-Carboniferous rocks, whereas cleavage was more apparent in others. He was not able to distinguish the Bullbreen Group on structural evidence, nor erect a lithologic sequence for the pre-Carboniferous units.

Horsfield (1970) recognised representatives of the Bullbreen Group and called them the Bulltinden Formation, a nomenclature followed by Hjelle et al. (1979). Harland et al. (1979) recognised a wider association of rock types and restricted the term Bulltinden to the conglomeratic facies and termed the entire package Bullbreen

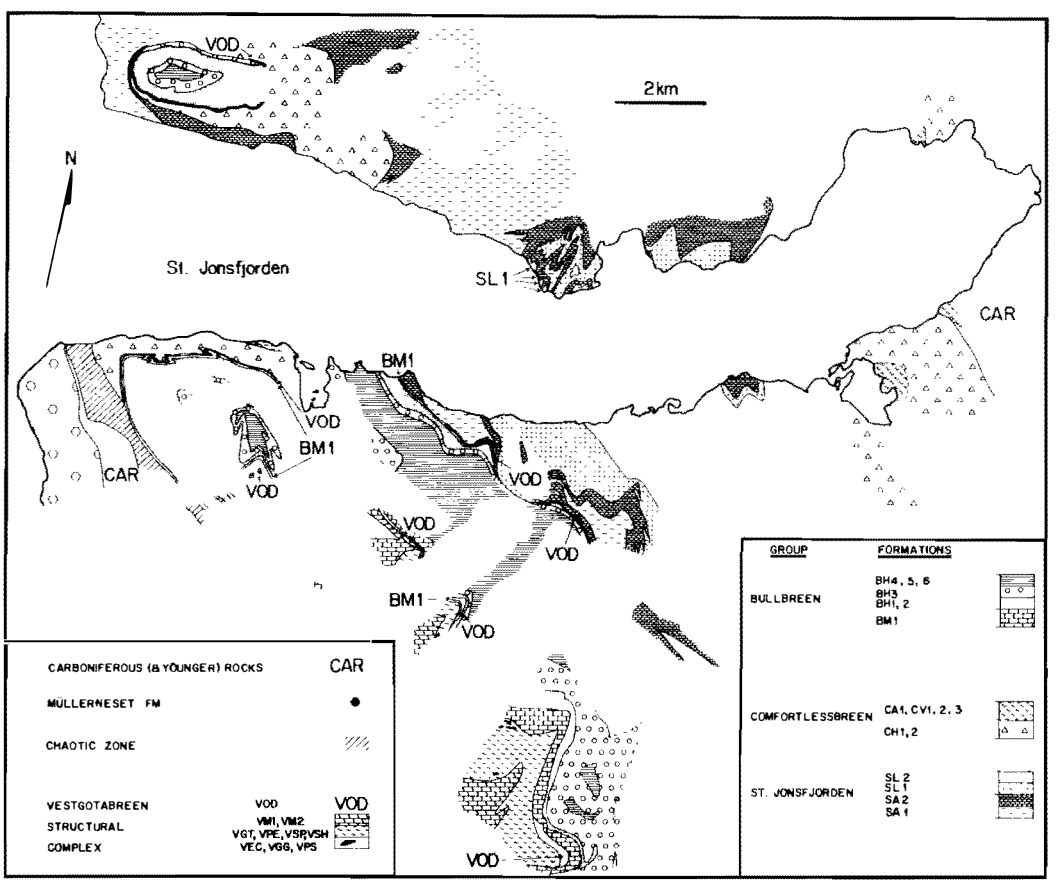

Fig. 2. Geological map of the St. Jonsfjorden area.

Group. The unconformity at the base of the Bullbreen Group inferred by Harland et al. (1979) was further documented by Ohta et al. (1983). In this work we expand the definition of the Bullbreen Group, but preserve the nomenclature suggested by Harland et al. (1979).

The Bullbreen Group can be divided into two formations, similar to those described by Horsfield (1970). The upper formation consists of slate, immature siltstone, sandstone and conglomerate. The lower formation comprises limestone with minor conglomerates and slates. The two formations will be referred to as the Holmesletfjella and Motalafjella Formations, respectively, with a total thickness of 470 m. Hjelle et al. (1979) recognised a similar sequence, although in reverse stratigraphic order.

In the St. Jonsfjorden area the Bullbreen Group crops out in a band from southeastern Motalafjella and Løvliefjellet northwest through the Skipperbreen-Vestgötabreen ridge, Holmesletfjella, Bulltinden, the arête southwest of Bulltinden, and Ankerfjella on the north shore of St. Jonsfjorden.

The base of the Bullbreen Group has been interpreted as an unconformity (Ohta et al. 1983), a thrust (Horsfield 1970; Harland 1978; Harland et al. 1979), a fault (Hjelle et al. 1979), and a conformable contact (Hjelle & Lauritzen 1982). The contact between the base of the Bullbreen Group and the Vestgötabreen Structural Complex has been identified as an unconformity at two localities at Motalafjella (Ohta et al. 1983). This same contact in Holmesletfjella exhibits mylonitic textures and is interpreted as a thrust (Kanat unpublished). A thrust contact is also observed in Ankerfjella between the Bullbreen and Comfortlessbreen Groups (Morris unpublished). Observations have also shown that the repetition of rock units above the surface of the discontinuity is generally a result of folding. No contacts have been observed between rocks of known post-Silurian age and the Bullbreen Group. The group will be described from top to bottom.

Holmesletfjella Formation (BH1-6)

The following lithological descriptions of the Holmesletfjella Formation are similar to those presented by Harland et al. (1979). The thickness estimates, however, are considerably less than those given by earlier workers owing to the recognition of large recumbent folds which repeat the sequence (most notably the conglomerates) in the Holmesletfjella and Bulltinden areas.

This formation was referred to as W6 by Wilson and later named the Holmesletfjella Formation by Harland (1960). Harland incorrectly believed that this formation was older than the Comfortlessbreen Group. In contrast to other workers (Harland et al. 1979; Hjelle et al. 1979), only one major conglomeratic member is distinguished, the Bulltinden Member. The Holmesletfjella Formation consists predominantly of immature clastic rocks with variable amounts of carbonate. Winsnes (1965) mapped the Bulltinden Member as a Precambrian tillite. However, no diamictites of glacial origin have been recognised in this area. Six members are distinguished (five with informal names).

Siliceous slate member (BH6). – The siliceous slate member is best exposed in northern Holmesletfjella. It is a friable, siliceous slate estimated to be at least 20 m thick; an upper contact has not been recognised. It commonly exhibits dark, elongate, irregularly shaped features with elliptical cross sections (approximately $100 \times 20 \times 4$ mm) on fractured, cleaved or bedding surfaces. They have been interpreted as trace fossils by Scrutton et al. (1976) and Harland et al. (1979). The lower contact of the siliceous slate member is sharp and conformable.

Upper sandstone slate member (BH5). – Best exposed in northern Holmesletfjella, this member is also found in central Motalafjella, Bulltinden, and the Skipperbreen-Vestgötabreen ridge with minor outcrops on the arête south of Bulltinden and western Ankerfjella. The upper contact with the siliceous slate member is sharp and conformable. A minimum thickness of 100 m is estimated from exposures in Holmesletfjella. This member consists of interbedded, slightly calcareous sandstone (65%), slates (25%), and immature conglomeratic horizons (10%). The sandstone is medium grained, siliceous, submature and well sorted with a slightly calcareous cement. It is grey weathering to buff in colour, and exhibits well defined bedding. The slates are dark grey and pale grey in colour.

Graded, cross-bedded conglomerates occur in association with the sandstone. They are less laterally persistent than the other horizons and are only traceable for tens of meters. Angular, non-

equant quartzose and carbonate lithic fragments, usually less than 4 mm in diameter, are typical clasts. The lower contact of this member is transitional with the underlying member. The boundary is defined by a decrease in abundance of conglomerate and sandstone horizons, and an increase in the proportion of slate.

Upper slate member (BH4). – The upper slate member is best exposed in northern Motalafjella, with minor occurrences on the arête south of Bulltinden, and on the connecting arête between southern and northern Holmesletfjella. The slate is black, slightly calcareous, approximately 30 m thick and in sharp contact with the underlying Bulltinden Member. At northern Motalafjella the slate is ferruginous and consists of intercalated clays (20%) and silts (80%) with minor sandstone towards the contact with the underlying member.

Conglomeratic member (BH3). – This member contains one of the most striking lithologies in the Bullbreen Group and as a result has the most complete published description of any member of the Holmesletfjella Formation (Holtedahl 1913; Horsfield 1970; Harland et al. 1979; Hjelle et al. 1979; Hjelle & Lauritzen 1982). The conglomeratic member is here informally called the Bulltinden conglomerate. The name Bulltinden had previously referred to all units now regarded as the Holmesletfjella Formation (Horsfield 1970; Hjelle et al. 1979), or it had been applied to the massive conglomerates only (Harland et al. 1979). In this account the predominantly conglomeratic zones, together with subordinate interbedded finer-grained lithologies, are separated from the remainder of the Holmesletfjella Formation and regarded as the conglomeratic member, formally referred to as the Bulltinden conglomerate (or Member), BH3.

The Bulltinden conglomerate is best exposed in Motalafjella, the Skipperbreen-Vestgötabreen ridge and northwestern Holmesletfjella with minor occurrences on Bulltinden and in Ankerfjella. It has a sharp upper contact and its thickness varies from 10 m in the southwest to 60 m in the northeast. There are three components in this member: conglomerate, sandstone, and slate. An antipathetic relationship is observed between the conglomerate and finer-grained components. At Motalafjella the Bulltinden Member consists of 65% conglomerate, 35% sandstone and minor amounts of slate. Elsewhere, the proportions are variable, to the limit of 20% conglomerate, 70% sandstone and 10% slate, found in north central Holmesletfjella.

Coarse-grained conglomerates are characteristic of this member. Individual bedded units vary in thickness from 0.2 m to 5 m with a concomitant variation in clast size from granules to large boulders. Thick-bedded units are found on Bulltinden and in Ankerfjella. In these areas this member is also characterized by a siliceous, fine- to medium-grained sandstone matrix. More thinly bedded units occur in northern Holmesletfjella where the matrix is dominantly calcareous. At Motalafjella both extremes occur. In less deformed areas the clasts have roundness/sphericity values of 0.4/0.2 to 0.8/0.8. The low sphericity values result from the original clast shape and from post-depositional deformation (which is always evident to some extent).

The conglomerates show variation in clast type in proportion to bed thickness: the thicker the bed the greater the variation in clast type. Clast types can be divided into five categories: limestone, schist, dolostone, quartzite, and conglomerate (Table 2). At Motalafjella and the Skipperbreen-Vestgötabreen ridge, the Vestgötabreen Structural Complex contains garnet-bearing schists which are not exposed elsewhere. In the same geographical area, the Bulltinden conglomerate contains a small proportion of garnet-bearing clasts which were probably derived from the Vestgötabreen Structural Complex. No such clasts occur elsewhere in the Bulltinden conglomerate (Plate 1). Characteristic high pressure minerals, or pseudomorphs thereof, have not been recognised within clasts of the Bulltinden conglomerate. At Motalafjella the Bulltinden conglomerate contains fossiliferous limestone clasts as early as late Caradocian (Scrutton et al. 1976; Harland et al. 1979; Armstrong et al. 1986) which are rarely found in the conglomerate in other parts of the study area. Similarly, it is only in this area that fossiliferous zones of the Motalafjella Formation are found.

In northwestern Motalafjella a slumped block of presumed Motalafjella limestone (clast volume c. 100 m^3) containing a diverse faunal assemblage is found within the Bulltinden conglomerate (Scrutton et al. 1976). The faunal assemblage includes Caradoc to Wenlock age fossils (Scrutton et al. 1976; Armstrong et al. 1986). These are the youngest pre-Carboniferous fossils known in the Western Province (Harland et al. 1979).

Table 2. Clast variety in the Bulltinden conglomerate. Modal estimate of all clasts within the Bulltinden conglomerate. Individual lists are arranged in order of decreasing abundance.

Limestone clasts: 40%
dark grey-coloured limestone
medium grey-coloured limestone
grey-coloured limestone
banded limestone
serpentinite

Sandstone clasts: 20%
quartzarenite
sublitharenite
green-coloured sublitharenite
red and green banded sublitharenite

Schistose clasts: 25%
chlorite-phengite schist
siliceous schist
garnet-phengite schist
grey-coloured schist

Dolostone clasts: 10%
brecciated dolostone
buff-coloured dolostone

Conglomeratic clasts: 5%
medium grey-coloured limestone with dolostone and crinoid fragments
medium grained sublitharenite with mature quartzarenite fragments
large slumped blocks of fossiliferous limestone

Igneous clasts: <1%
dolerite (Y. Ohta 1983, field communication to LHK)

It must be stressed that this occurrence of Motalafjella Formation is a large slumped block and not a separate unit. The contact relationship of this block to the matrix and smaller clasts of the Bulltinden conglomerate can be mistaken for that of two adjacent sedimentary units. Quartzose, schistose and calcareous clasts, typical of the Bulltinden conglomerate, begin to appear in the finer grained matrix within 4 m of the contact between the large slumped block and the Bulltinden conglomerate proper. The percentage of clasts increases steadily with increasing distance from the limestone block. Similarly, limestone clasts are numerous near the slumped limestone block and decrease in abundance as the distance from the block increases.

Well-sorted, siliceous sandstone units occur within the Bulltinden Member and have bed thicknesses of 0.04 to 1 m. Slates, 0.01 to 1 m thick, are commonly interbedded with the sandstones. Ball-and-pillow structures, flame structures and flute casts are found at the interfaces between slate and sandstone units. Cross-bedding and graded bedding are common in the sandstones and finer-grained conglomerates.

The lower contact of the Bulltinden Member is sharp and erosive with the underlying slates. In northwestern Holmesletfjella and in the moraine east of Bullbreen there is localized development of an intraformational conglomerate containing rip-up clasts derived from the underlying slates and set in a ferruginous, coarse grained sandstone matrix. This intraformational conglomerate is considered to form the lowermost horizon of the Bulltinden Member in this area. In Ankerfjella and on the Skipperbreen-Vestgötabreen ridge the lower slate member (BH2) is absent, and the Bulltinden conglomerate rests unconformably on the lower sandstone slate member (BH1). Although two different members occur directly below the Bulltinden conglomerate, all evidence suggests that this is an erosive sedimentary contact.

Lower slate member (BH2). – This member crops out on Bulltinden, northwestern Holmesletfjella, Ankerfjella, and Motalafjella. Its upper contact with the Bulltinden Member is sharp and sedimentary. The lower slate has a thickness of 2 to 10 m. In northwestern Holmesletfjella, southern Bulltinden and Motalafjella, the slate is black and ferruginous. East of the Bullbreen moraine, 5 to 20 mm thick bands of disseminated, subhedral pyrite occur parallel to bedding. The lower contact is transitional with the underlying lower sandstone slate member.

Lower sandstone slate member (BH1). – This member is best developed in central western Motalafjella where it is approximately 150 m thick. It also occurs in Ankerfjella, on Bulltinden, and in southernmost Holmesletfjella. In Holmesletfjella and Motalafjella the upper contact is transitional with the lower slate, whereas on Bulltinden it is a sharp sedimentary contact with the Bulltinden Member. Where sandstone comprises 50–70% conglomerate constitutes approximately 10% of this member. Where sandstone becomes volumetrically less important (30–50%) conglomerate is less common. Where slate dominates the member (70% slate, 30% sandstone) conglomerate is absent.

The sandstone is indurated, commonly calcareous, medium- to coarse-grained and grey, weathering to buff in colour. The carbonate content of the sandstone matrix distinguishes this member from the upper sandstone slate member, BH5. Grains are well-sorted, well-rounded, and the rock can be described as a grainstone where both grains and matrix are calcareous. Bedded units vary from 0.1 to 0.75 m in thickness, although the variation in adjacent beds is less than a few percent. Dark grey, slightly calcareous slate, 2–80 mm thick, is interbedded with the sandstone.

Minor conglomeratic horizons within this member are 0.10 to 0.15 m thick. These immature, polymict conglomerates contain granule-sized quartz, limestone, and dolostone clasts. Small 3-5 m wide, 0.02–0.06 m thick channel structures are common in these rocks. The lower contact of the lower sandstone slate member is sharp and conformable with the Motalafjella Formation.

Motalafjella Formation (BM1)

The Motalafjella Formation consists predominantly of limestone as noted by Maton & Harland (1969), and described by Harland et al. (1979). This formation is best exposed at its type locality in Motalafjella where it forms the major peak of the mountain. In addition, a thin limestone horizon which is found consistently below the Holmesletfjella Formation in Ankerfjella, on Bulltinden, in Holmesletfjella and on the Skipperbreen-Vestgötabreen ridge, is presumed to be a lateral equivalent of the Motalafjella Formation. Minor conglomeratic horizons and a thin, green-coloured slate are present at the base of the Motalafjella Formation.

The upper contact of the Motalafjella Formation is sharp and conformable with the overlying Holmesletfjella Formation. The maximum exposed thickness of 100 m is found at the type locality. Elsewhere thicknesses are much less, with a minimum of 3 m found in Ankerfjella. In the Motalafjella area, this formation is a gritty, fossiliferous, cryptocrystalline grey limestone, weathering to buff in colour. Bedding is generally indistinguishable from cleavage, and is petrographically expressed as elongated carbonate and quartz grains in a micritic matrix. Carbonate-filled fractures, perpendicular to bedding, are common. There is a variation in the amount of siliceous detrital material (as much as 30%), fossil type and abundance, and colour (light medium grey to dark grey). Owing to the recrystallized nature of the rock, bedded units are difficult to distinguish, and are assumed to be represented by the colour banding.

Carbonaceous fragments, round crinoid stems (less than 6 mm in diameter), and coral fragments are recognised within this formation at the type locality. Elsewhere, fossils are rare, although carbonaceous fragments do occur. The richest faunal horizons occur as clasts, or slumped blocks, within the Bulltinden conglomerate at Motalafjella. A small proportion of these fossil-bearing clasts contain crinoids with pentameral and round stems (less than 6 mm across), brachiopod fragments and fauna similar to that which is found in the type section. Other fossil-bearing limestone clasts contain portions of the total fossil assemblage as described by Scrutton et al. (1976). The assemblages which have been dated Wenlock to Ludlow in age by Scrutton et al. (1976) occur mainly in the large slumped block in northwestern Motalafjella. Armstrong et al. (1986) recognised lower Caradocian conodonts in the clasts.

It is inferred that the fossil-bearing limestone clasts within the Bulltinden conglomerate were derived from the Motalafjella limestone. Evidence supporting this conclusion is:

1. Similarity of rock type between the clasts and the Motalafjella Formation.

2. Similarity of part of the fossil content within the clasts to that of the complete assemblage of the Motalafjella Formation, including the slumped block.

3. The fossiliferous limestone clasts lack a tectonic fabric which predates their incorporation into the Bulltinden conglomerate. This implies that they could not have been derived from the subjacent metamorphic rocks.

4. No other fossiliferous limestone units have been recognised in the immediate area.

The lower contact of the Motalafjella Formation is everywhere sharp. This contact was originally unconformable on the Vestgötabreen Structural Complex although it is now thrust in most localities. Evidence for an unconformable contact includes minor conglomeratic units at the base of the limestone which truncates the pervasive tectonic fabric of the Complex, and limestone-filled fractures within the Complex greenstones on the arête south of Bulltinden and central western Motalafjella.

Sarsøyra Formation (SZ1-2)

The Sarsøyra Formation is best exposed in northwest Oscar II Land, on Sarsøyra, where it occurs as a narrow, elongate unit of marbles and slates (Horsfield 1970; Waddams 1983). The age of these rocks is unclear and could range from Cambrian to Carboniferous (Harland 1960; Horsfield 1970; Scrutton et al. 1976; Harland et al. 1979; Waddams 1983).

We have observed carbonates, dark green slates, and minor quartzite conglomerates within the Motalafjella Formation at numerous localities south of St. Jonsfjorden, west of Bullbreen (Fig. 2). These may correlate with the Sarsøyra Formation.

Comfortlessbreen Group

The Comfortlessbreen Group is characterized by greenschist facies Vendian glaciomarine sedimentary rocks and was named by Harland (1960) after the glacier near which they occur. Within the study area, this group is best exposed along the south shore of St. Jonsfjorden between an unnamed headland north of Thorkelsenfjella and the western Bullbreen moraine. The structural upper boundary is in fault contact with the Motalafjella Formation approximately 400 m inland from the shore. The western boundary is defined by a sub-vertical fault contact with rocks of presumed Carboniferous age north of Thorkelsenfjella. The eastern contact is not exposed. This group was thought to be 1000 m to 6000 m thick (Hjelle et al. 1979; Hambrey & Waddams 1981; Waddams 1983). The small exposure, coupled with intense folding, allows a minimum estimate of 300 m for the group thickness in the St. Jonsfjorden area.

In keeping with the nomenclature suggested by Waddams (1983), the Comfortlessbreen Group is divided into three formations, each of which will be discussed beginning at the top of the succession.

Aavatsmarkbreen Formation (CV1-3)

This formation consists primarily of dark phyllites, and is best exposed in the St. Jonsfjorden area north of Thorkelsenfjella. The name was used by Waddams (1983), although the rocks had previously been ascribed to part of the Sarsøyra Formation. Waddams (1983) described three divisions within this formation.

The upper division, CV3, is a dark grey, calcareous phyllite which weathers to a rusty orange colour. Quartz pods, 1–10 cm across, are common and some have iron oxidation stains. Deformed and boudinaged dolostone and quartzite beds, usually less than 25 cm thick, are present, but account for less than 10% of the exposure. The unit is fissile, highly deformed, and exhibits two, well-defined planar fabrics. Both the upper and lower contacts are sharp and possibly faulted. A minimum thickness of 75 mm is estimated for this member.

On the arête southwest of Bulltinden, a thin, tightly-folded chlorite-rich schist with minor amounts of a serpentine mineral is recognised. The upper contact is faulted against the Motalafjella limestone, and the lower contact is sharp and possibly conformable with the lower division of this formation. A minimum thickness of 10 m is estimated for this member, CV2, which is believed to be correlative with the middle division as described by Waddams (1983).

The lower division, CV1, is represented by laminated green and cream coloured marbles. Individual laminae within this division vary in thickness from 1 to 10 cm. It is best exposed in northwest Thorkelsenfjella as a narrow band striking NNW and is easily traced from the shore inland. A minimum thickness of 25 mm is estimated.

Annabreen Formation (CA1)

This formation has been referred to as the Irenebreen Quartzites of Lower Carboniferous age by Cutbill & Challinor (1965), and as W8 by Harland (1960). The formation was named after the Anna Sofiebreen glacier on the southern shore of St. Jonsfjorden. Waddams (1983) believed that this formation is best exposed in northwest Oscar II Land and does not occur south of St. Jonsfjorden. Based on descriptions of the unit (Waddams 1983), we recognised this formation in northwestern Vegardfjella, south of St. Jonsfjorden. The outcrop area is small and the contact relationships are not exposed.

Haaken Formation (CH1-2)

Diamictites were first observed in Oscar II Land

by C. B. Wilson (Harland 1960), and subsequently called the Haaken and Engelskbukta Formations by Harland et al. (1979). Hjelle et al. (1979) used the term Tillitic conglomerate to describe the same rock unit. Horsfield distinguished two diamictite horizons within the St. Jonsfjorden area but included them within one unit, the Comfortlessbreen Formation. Waddams (1983) divided the diamictites into two distinct formations (Haaken and Trondheimfjella Formations) separated by 1.8 km of strata. He used two criteria for this distinction: 1) his interpretation of the sequence exposed at Trondheimfjella in northwest Oscar II Land, and 2) a difference in clast compositions between the two horizons. We have been unable to apply his criteria with confidence to identify two distinct diamictites locally within the St. Jonsfjorden area. M. Hambrey (1983, field communication to LHK) was also unconvinced that there are two distinct diamictites locally within the St. Jonsfjorden region.

Diamictites in the St. Jonsfjorden area are associated with rock types that resemble members of the Comfortlessbreen Group as described by Horsfield (1970), Harland et al. (1979), Hjelle et al. (1979), and Waddams (1983). We have therefore retained the name Haaken Formation for these diamictites. Although Waddams (1983) claims that Trondheimfjella diamictites occur in central Oscar II Land, he does not substantiate this with specific localities. We have not positively identified any of the informal divisions of the Trondheimfjella Formation within the St. Jonsfjorden area. The existence of diamictites belonging to both the St. Jonsfjorden and Comfortlessbreen Groups as described by Harland et al. (1979) and Waddams (1983) has not been fully substantiated.

Finely crystalline diamictites, believed to be glacigenic, are the characteristic rock type of the Haaken Formation. This formation has been referred to as the Comfortlessbreen schists (Harland 1960), Comfortlessbreen Formation (Horsfield 1970), Tillitic Conglomerate and Calc-argillo-volcanic Formation (Hjelle et al. 1979), and as the Haaken Formation (Harland et al. 1979; Waddams 1983). Here the formation is subdivided into two members: an upper stone-free member, consisting of calcareous green and cream-coloured psammitic schist (CH2), and a lower member, comprising slightly calcareous, stone-bearing, finely crystalline schistose diamictite and associated silicic conglomerate and quartzite (CH1).

The dominant unit on the strandflat northwest of Bulltinden, east of Thorkelsenfjella and near the east end of St. Jonsfjorden is the upper member, CH2. Green and cream coloured bands are interlayed on the centimeter scale, and the entire member weathers to a light orange colour. The cream coloured bands are richer in carbonate, whereas the green laminae have a larger pelitic component. The upper contact is generally sharp against the overlying Aavatsmarkbreen or Motalafjella Formations, and a minimum thickness of 75 m is estimated.

The clast-bearing member, CH1, is well exposed to the north and along the west side of Thorkelsenfjella, the lower slopes of Ankerfjella and at the east end of St. Jonsfjorden. This member is mapped as the same unit as Horsfield's (1970) massive clast-bearing phyllitic semipelites (Comfortlessbreen Formation, HCo3), and a portion of the Hjelle et al. (1979) Calc-argillo-volcanic Formation.

The clast-bearing member is medium grey, weathering to brown in colour with a minimum thickness of 100 m. It is rhythmically banded on the millimeter scale. Clasts of dolostone, limestone and quartz, usually less than 20 mm across, occur sporadically throughout the outcrop area, and never compose more than 5% of the exposure. Granitic stones have been described in this member by Holtedahl (1913) in a discussion of a limestone conglomerate in Ankerfjella. We have recognised stones with an internal fabric different from that of the matrix, and Wilson & Harland (1964) recognised grey granite and grey granite gneiss clasts within this member. In addition, a clast-bearing, grey-coloured, siliceous, matrix-supported conglomeratic bed occurs within CH1 with clasts of dolostone, quartzite and green-coloured schist fragments. A light pink massive quartzite horizon, approximately 3 m thick, is associated with the conglomerate.

The presence of dropstones and rhythmic bedding indicates that CH1 is a rock formed from ice-rafted, glaciomarine sediment. This interpretation is in accord with those of Hambrey et al. (1981), Hambrey (1983), and Hambrey & Waddams (1981). There is variation in clast content within these diamictites, and our observations do not preclude the presence of more

than one diamictite preserved within the Haaken Formation.

St. Jonsfjorden Group

Harland et al. (1979) divided the St. Jonsfjorden Group into four formations: Alkhorn, Løvliebreen, Moefjellet, and Trondheimfjella (at the base). The outcrop pattern and lithologic succession were given by Horsfield (1970) and substantiated by Waddams (1983). Horsfield (1970) referred to one diamictite horizon in western Oscar II Land (the Haaken Formation), and Harland et al. (1979) placed two diamictite horizons within the Comfortlessbreen Group (the Engelskbukta and Haaken Formations). Waddams redefined the Trondheimfjella Formation and suggested that a stone-bearing unit discovered on southern Brøggerhalvøya represented a lower glacigenic horizon within the Western Province (the upper diamictite still regarded as the Haaken Formation of the Comfortlessbreen Group). Hjelle et al. (1979) described the Calc-argillo-volcanic and Quartzite-shale Formations as their equivalent to the St. Jonsfjorden Group, but they did not include any diamictites. The base of this group is not exposed, although an angular unconformity with the overlying Comfortlessbreen Group has been suggested (Hjelle & Lauritzen 1982). There is general consensus that the St. Jonsfjorden Group is older than the Comfortlessbreen Group (Harland et al. 1979; Hjelle et al. 1979; Hjelle & Lauritzen 1982; Waddams 1983). Ages for the St. Jonsfjorden and Comfortlessbreen Groups are not known, although the diamictite horizons are assumed to be Vendian in age.

Within the study area, the St. Jonsfjorden Group is exposed along both shores of St. Jonsfjorden from east of Bullbreen to Vegardfjella on the south shore, and from east of Ankerbreen to Konowbreen on the north shore. Two of the four formations described by Waddams (1983) (Alkhorn and Løvliebreen) have been recognised in the St. Jonsfjorden area. The formations will be described from top to bottom.

Løvliebreen Formation (SL1-2)

All previous workers have placed the Løvliebreen Formation, or its direct correlative, below the Alkhorn Formation (Horsfield 1970; Harland et al. 1979; Hjelle et al. 1979; Waddams 1983). However, exposures in southern Lowzowfjella and east of Copper Camp show a consistent, unbroken and presumed sedimentary sequence from quartzites down to volcanic green-coloured phyllites (Løvliebreen Formation), to banded marbles, to calcareous psammo-pelites (Alkhorn Formation) at the base. The relationships observed at the two localities necessitate reversal of the relative positions of these formations, although the sequence within each formation remains unchanged.

Harland et al. (1979) divided the Løvliebreen Formation into two members: 1) upper – massive quartzites and intercalated pelites, and 2) lower – fine grained volcanic rocks. The upper member corresponds to the dark quartzites described by Holtedahl (1913), the massive quartzite bodies described by Weiss (1953), and the Quartzite-shale Formation described by Hjelle et al. (1979).

The quartzites, SL2, are dark grey, weathering to black in colour and are approximately 300 m thick. Thin pelitic horizons account for less than 10% of the exposure. Quartz grains are equant, well sorted, fine sand sized particles and exhibit undulose extinction.

The lower volcanic member, SL1, is best exposed within the study area in the southeast portion of Holmesletfjella, just west of Løvliebreen. It corresponds to the Calc-argillo-volcanic Formation of Hjelle et al. (1979). According to Horsfield (1970) and Hjelle et al. (1979), the main exposure is found in southern Gunnar Knudsenfjella, east of Løvliebreen. The rocks are typically well foliated, dark greenish-grey lapilli tuffs, estimated to be at least 20 m thick. They contain albite, calcite and chlorite, with minor amounts of stilpnomelane, phengite, pyrite and rutile. Ohta (1985) calls these rocks the Trollheimen volcanics.

Alkhorn Formation (SA1–2)

This formation derives its name from the calcareous rocks exposed on the north shore of Isfjorden at Alkhornet, and was described by Holtedahl (1913) and recorded by Major et al. (1956). Horsfield (1970) defined the Dahlbreen Formation and divided it into two members: the upper comprising mainly marble and the lower consisting of semipelite. Harland et al. (1979) renamed the Dahlbreen limestone the Alkhorn

Formation, acknowledging Holtedahl's earlier work, and apparently disregarded the lower member (HD2), as did Waddams (1983). Hjelle et al. (1979) included the Alkhorn Formation and the Løvliebreen Formation as separate members of the Calc-argillo-volcanic Formation.

It is suggested here that the Alkhorn Formation be divided into two members similar to those described by Horsfield (1970). The original name, Alkhorn, as defined by Holtedahl (1913), instead of Dahlbreen (Horsfield 1970) will be used in this work. The upper member will be referred to as the marble member and the lower referred to as the semipelite member.

The upper member, SA2, is best exposed along the shore approximately 1500 m east of Copper Camp. This fine-grained, recrystallized marble is dominantly grey in colour with interlayered cream and black horizons, 3 mm to 1 mm thick. Carbonaceous fragments and pisolitic structures are recognised. Quartz pods, which exhibit boudinage structures parallel to the lamination, are present, although rare. Tight asymmetric folds, defined by bedding, are characteristic of this member. A minimum thickness of 50 m is estimated.

The semipelites, SA1, are dark grey in colour, pyritic and variably calcareous. The psammitic layers consist of mature, medium-grained quartz grains cemented by siliceous and/or calcareous cement. Graded bedding is present, although younging directions are ambiguous (observed in various orientations). A minimum thickness of 100 m is estimated.

Müllerneset Formation (MUF)

The Müllerneset Formation crops out on Müllerneset, southwest of St. Jonsfjorden, and occupies most of the Svartfjella coastal plain. Harland et al. (1979) described it as '2000 mm of schistose pelites and semipelites with psammites and white quartzite layers'. Hjelle et al. (1979) described the Müllerneset Formation as garnet-biotite schists and quartzite-shale alternations with a thickness of 800 m. Harland et al. (1979) and Horsfield (1970) described three formations within the Kongsvegen Group (Orvin 1934; Harland et al. 1966) and correlated the upper Nielsenfjellet Formation with the Müllerneset Formation. The thickness estimates by Ague & Morris (1985) correspond well with those presented by Hjelle et al. (1979), and are consistent with the sequence observed by the present authors. The lithologic descriptions more closely follow those by Harland et al. (1979) than those of other workers. Pelites, semipelites, and psammites are the predominant lithologies in this formation on Müllerneset, although lesser amounts of intercalated carbonate rocks do occur.

The formation is exposed as a 1 km-thick folded unit in vertical fault contact with presumed Carboniferous-age rocks to the east and the Comfortlessbreen Group to the west. The exposure can be traced for a distance of approximately 13 km south from St. Jonsfjorden.

Vestgötabreen Structural Complex

The description of these rocks is presented last, although they do not necessarily represent the oldest unit in the study area. The Vestgötabreen Structural Complex is easily distinguished in the field from other rocks in the study area by its physical characteristics (i.e. massive greenstones and coarsely crystalline schists) which are a result of a high pressure, low temperature metamorphic event (Ohta 1979; Kanat 1984; Hirajima et al. 1984; Ohta 1986). The unit occurs as a deformed, narrow thrust slice, approximately 1 km thick, which can be traced over a distance of approximately 15 km subparallel to the regional fabric.

The complex is best exposed in the southwest portion of Motalafjella, although it also occurs on southern Bulltinden, in southern Holmesletfjella, and on the Skipperbreen-Vestgötabreen ridge. The type locality is located on the central western side of Motalafjella. The upper contact is usually adjacent to the Motalafjella Formation. A lower contact has not been observed.

According to Horsfield (1970), glaucophane schists and eclogite rock fragments were first found in 1957 by C. B. Wilson within the moraines of Eidembreen and Vestgötabreen. Subsequently, D. Gee, as a member of the 1962 Cambridge Spitsbergen Expedition, located the source area of these rocks in Motalafjella. The suite was first mapped by Horsfield (1970, 1972) during the 1968 and 1969 field seasons.

Horsfield (1972) distinguished the following rock groups on his geologic map of the area: 1)

glaucophane-bearing rocks, 2) epidote-actinolite greenstones, 3) mica schists, mylonites and breccias, 4) Bulltinden Formation, and 5) marbles. Horsfield (1972) defined group 1 and group 3 as the Vestgötabreen suite. The name derives from the glacier near which the rocks occur.

During the summers of 1973 and 1975, Ohta (1979) mapped the occurrence of this suite and the Bullbreen Group in more detail and added Horsfield's group 2, epidote-actinolite greenstones, to the Vestgötabreen suite and suggested that all these rocks be tentatively named the Vestgötabreen Formation. Ohta (1979) argued for a minor thrust which he used to divide this complex into two units: a) the glaucophane-bearing rocks, eclogitic rocks, calcareous schists and dolostones in the upper part, and b) epidote-actinolite greenstones, dolomites and serpentinites of the lower part.

The two member distinction used by Ohta (1979), Hirajima et al. (1984) and Ohta (1986) is too simple because of the common close juxtaposition of greenstones, garnet glaucophanites, and schistose horizons. Furthermore, the proposed thrust between these two units has not been substantiated by the present authors. Inconsistent stratigraphic relationships and numerous minor thrusts preclude an establishment of a lithologic succession within the Vestgötabreen Structural Complex.

We propose that the words Structural Complex be substituted for Formation in the formal name because of the presence of highly complicated structures and a diverse range of rock types and metamorphic facies (North American Stratigraphic Code, 1983, American Association of Petroleum Geologists Bulletin, Vol. 67, Article 37, point C).

Manby (1978) presented chemical data from selected minerals of the Vestgötabreen Structural Complex. During the 1983 field season, Ohta et al. (1983) began a renewed investigation of these rocks. Hirajima et al. (1984) recognised the presence of lawsonite and pumpellyite in Vestgötabreen Structural greenstones. Rock and mineral chemical data for jadeite bearing psammites within the Vestgötabreen Structural Complex were presented by Kanat (1984) along with a preliminary pressure-temperature estimate for the development of this assemblage. A review of these rocks was presented by Ohta (1986).

Nine informal divisions of the Vestgötabreen Structural Complex are described in order of their apparent structural succession:

1) dolostone division
2) micaceous marble division
3) mafic schist division
4) serpentinite division
5) pelitic schist division
6) greenstone division
7) psammite division
8) garnet glaucophane division
9) eclogite division

Dolostone division (VOD)

This unit is characterized by an orange-weathering dolostone. The dolostone is consistently found below the Motalafjella Formation, and its chemistry and structural and metamorphic styles indicate that it is related to the Vestgötabreen Structural Complex.

Exposure throughout the study area is patchy and unit thickness is variable, ranging from ● to 20 m. The best exposure is on southern Bulltinden where it attains maximum thickness. Elsewhere it is less than 20 m thick and is absent in western Motalafjella. The upper contact is adjacent to the Motalafjella Formation. The lower contact is most commonly associated with the Vestgötabreen Structural Complex, although at Ankerfjella and northern Bulltinden it is adjacent to the Comfortlessbreen Group. Minor occurrences of this division are also found as boudins within the micaceous marble division on the Skipperbreen-Vestgötabreen ridge.

Common to all exposures is a coarsely crystalline siliceous dolostone which contains approximately 5% mariposite (chromian phengite). However, the abundance of mariposite varies sporadically and in places it makes up as much as 10% of the total rock. This unit is light grey and weathers to a distinctive and characteristic orange colour. Internal sedimentary structures are absent and tectonic fabrics are well developed. In some areas, distinctive boxwork quartz-calcite veins are present.

The dolostone is commonly brecciated and the interstices are filled with a light grey limestone derived from the Motalafjella Formation and associated with its emplacement. Quartz grains exhibit strong deformation features (deformation bands, deformation lamellae, undulose extinction and a shape fabric), and the carbonate minerals exhibit two distinct crystal sizes. The dolostone is host to various highly deformed, locally derived,

tectonically included exotic clasts, usually representative of the Vestgötabreen Structural Complex. The size of individual clasts ranges from pebbles to cobbles.

The lower contact is poorly exposed; at certain localities in Motalafjella it is interpreted as an unconformity on top of the Vestgötabreen Structural Complex, but elsewhere it is a tectonic contact. Supporting evidence for this interpretation is the presence of mylonitic textures and juxtaposition of the dolostone with various members of the Comfortlessbreen and St. Jonsfjorden Groups and the Vestgötabreen Structural Complex. Furthermore, the Comfortlessbreen and St. Jonsfjorden Groups display complex folding and refolding which are not recognised in the orange weathering dolostone. The brecciated character, lack of sedimentary structures, association with tectonic boundaries and the presence of exotics indicate that this unit is not simply a sedimentary horizon. The high MgO, chromium and nickel content of the unit, and its association with the Vestgötabreen Structural Complex, suggest that it may represent a carbonated and metasomatised ultrabasic rock unit. The orange-weathering dolostone represents an unconformity and a décollement zone which is best developed on overturned limbs of major folds where the Bullbreen Group is separated from the Vestgötabreen Structural Complex (for example, on southern Bulltinden, in southern Holmesletfjella and Motalafjella).

Micaceous marble division (VM1-2)

The micaceous marble division is found just east of the Vestgötabreen lateral moraine on the central western side of Motalafjella and on the southern portion of the Skipperbreen-Vestgötabreen ridge. The division contains two distinct units: one is dark grey (VM1) and is interbanded with a medium grey lithology (VM2). Both units contain characteristic micaceous partings and a gritty texture which results from the presence of quartz grains and pods usually less than 4 cm long. Quartz-filled tension gashes and asymmetric isoclinal folds are common in this division. Late-stage calcite and quartz veins are parallel and oblique to the foliation. Calcite, phengite and quartz are common with minor occurrences of albite, opaques, pyrite, and chlorite. Garnets, approximately 3–7 mm across, and completely replaced by chlorite, have been found.

The division is tabular in form, individual horizons are approximately 50 m thick and bounded by sharp contacts, presumably thrusts. The lower surface is thrust against the mafic schists, and the upper surface commonly occurs beneath the dolostone division with tectonic contact. The observed lateral extent of this unit is well defined near the moraine, although it pinches out near the 400 m contour where it is enveloped by the mafic schists.

Mafic schist division (VSH)

Rocks from this division are green chlorite-rich schists. It is volumetrically the most abundant and mineralogically heterogeneous division of the Vestgötabreen Structural Complex. Common to all specimens from this division are minerals typical of the greenschist facies: chlorite (as alteration products of white mica and garnet), quartz, calcite, phengite, and albite. However, chloritoid, epidote, garnet, jadeite and glaucophane are recognised in association with the more massive representations of this division. The mafic schist division is in contact with all other divisions of the Vestgötabreen Structural Complex and occurs throughout the exposed area of these rocks. The thickness of this division is difficult to estimate, and a minimum of 200 m is suggested. This division appears to have been produced by tectonic reworking of other divisions within this complex.

Serpentinite division (VSP)

Serpentinites are best exposed in the valley in central Motalafjella. The occurrence of this rock type is very patchy throughout the valley, and the exposures can be traced over distances of less than 20 m. The serpentinites are black in colour, finely crystalline and consist of individual pods ranging from 0.8 to 1.5 m in diameter. The pods are flattened parallel to the pervasive cleavage and have an aspect ratio of approximately 2:1. The serpentine mineral is chrysotile and associated phases include magnesite, dolomite, and chromite. Chrysotile is twinned, and dissected by calcite and/or dolomite veins.

Pelitic schist division (VPE)

This division occurs in central western Motalafjella and the Skipperbreen-Vestgötabreen ridge. Easily distinguished from other units of the

complex, it is well foliated and light grey in colour, with porphyroblasts of garnet and staurolite in a dominantly phengitic matrix. The garnet diameters range from approximately 2 mm in some zones to 15 mm in others. No systematic relationship between garnet diameter and structural position has been recognised. Other minerals in association with those listed above include quartz, chloritoid, chlorite, hematite, and pressure-insoluble, fine-grained opaque material concentrated along cleavage planes. Late-stage calcite veins are present. Tourmaline, epidote, pyrite and zircon also occur as accessory phases within this division.

At central western Motalafjella the division is poorly exposed, and only occurs as scree fragments below an elevation of c. 350 m. The only lithologic contact in Motalafjella is found towards the southwest of the mountain where the division is in contact with eclogite, and garnets have grown across the interface. The best exposure of this division (staurolite absent) is found along the crest of the Skipperbreen-Vestgötabreen ridge where it is thrust bounded by units of the micaceous marble division.

Greenstone division (VGT)

Best exposed in Motalafjella, this division also crops out at all occurrences of the Vestgötabreen Structural Complex. It is distinguished by its massive nature and mineral associations. Individual exposures are never greater than 50 m thick. The common mineralogy is typical of the greenschist facies and includes epidote, actinolite and albite, with barroisite, retrograde chlorite, hematite and garnet, with minor amounts of vein carbonate, quartz, phengite, rutile rimmed by sphene, pressure insoluble opaque material and apatite. The rocks within this division have trace element ratios which suggest that they represent metamorphosed ocean floor tholeiitic basalts (Morris et al. 1983; Kanat 1984; Ohta 1986).

On the arête south of Bulltinden and in central-western Motalafjella, 'stringers' of grey limestone, less than 15 cm thick, are recognised within this division. The limestones could have been incorporated by deformation, or they may be veins or fracture fillings. The limestones cut across an early fabric of the Vestgötabreen Structural Complex and may therefore represent the initial stages of precipitation of the Motalafjella limestone (i.e. the unconformity between the Bullbreen Group and the Vestgötabreen Structural Complex).

This division crops out south of Bulltinden where it is presented as a nunatak. A contact between the Motalafjella limestone and the greenstone division has not been recognised at this locality. Elsewhere, the contact relationships of the greenstone unit are sharp against the micaceous marble, mafic schist, eclogite and garnet glaucophane divisions.

Psammite division (VPS)

The psammite division is best exposed east of the Vestgötabreen lateral moraine on the western face of Motalafjella at elevations of approximately 300 m. The division is characteristically composed of very dusky purple, coarsely crystalline silicic schist, usually 1–4 cm thick, interbanded with thin layers (<1 cm) of grey olive green pelitic horizons and quartz and/or feldspar pods. Calcite veins, approximately 1–2 mm thick, occur at a high angle to the banding. Jadeite, the characteristic mineral of this division (Kanat 1984), occurs with quartz, albite, phengite, hematite, sericite, chlorite, mangnesioriebeckite, calcite, rutile rimmed by sphene, pyrite, and apatite.

The interbanded psammitic and pelitic horizons are commonly less than 25 cm thick and bounded on either side by the garnet glaucophane division. The cumulative thickness of this division is approximately 4 m. Contacts are concordant, and individual horizons can be traced over a distance of a few meters before pinching out.

Garnet glaucophane division (VGG)

The garnet glaucophane division is best exposed in central western Motalafjella at an elevation of 300 m. Almandine rich garnets, 2–10 mm across, are contained within a dusky blue matrix of glaucophane with lesser amounts of phengite and chlorite, and occasional calcite, paragonite, sodic clinopyroxene, hematite, quartz, and rutile rimmed by hematite, with minor amounts of actinolite and epidote. The mineral assemblages are typical of blueschist facies metamorphism. Foliation is defined by the alignment of both phengite and glaucophane as well as by a mineralogical banding. Psammitic layers are also present, but rare.

Exposures appear as weather-resistant blocks (c. 150 × 80 m exposed) approximately 50 m high. These blocks are isolated from the rest of the Vestgötabreen Structural Complex and surrounded by scree and/or ice patches. Horsfield (1972) determined a whole rock K-Ar apparent cooling age for this division of 402 ± 14 Ma.

Eclogite division (VEC)

Eclogites are best exposed in southwest Motalafjella at an elevation of 200 m. Hypidioblastic pink almandine rich garnets, 3–7 mm across, are contained within a dark greenish grey, medium crystalline granoblastic omphacitic matrix which gives the rock a distinct porphyroblastic texture. The following minerals occur within this unit: primary omphacite and almandine, with secondary glaucophane and occasionally chlorite, quartz, epidote, phengite, calcite, hematite, albite, chloritoid, actinolite, and rutile rimmed by sphene. Following the nomenclature suggested by Coleman et al. (1965), this division is a Group C eclogite. The exposure is dissected by idiomorphic glaucophane-quartz-albite veins which are usually less than 6 cm wide.

The major outcrop appears as a weather-resistant block, approximately 70 × 80 m, with a concordant pelitic band in contact with the top of the exposure. The block is surrounded by scree from the mafic schists, thus making correlation with other blocks difficult. This division also crops out at the base of the Skipperbreen-Vestgötabreen ridge near the micaceous marble division.

Chaotic Zone

A zone of tectonically mixed, intensely deformed rocks trends NNW in Thorkelsenfjella and separates Carboniferous rocks to the west from the Bullbreen, Comfortlessbreen and St. Jonsfjorden Groups, and Vestgötabreen Structural Complex to the east. Rocks from the Comfortlessbreen and St. Jonsfjorden Groups are represented in this zone. Individual units are lenticular and difficult to distinguish, and no coherent structure has been observed. It is an important observation that the rock types which occur east of this zone are not represented to the west, and therefore this boundary has regional significance.

Concluding remarks

Based on sedimentary contacts not previously described, we present a revised lithostratigraphic succession for central Oscar II Land, Spitsbergen: 1) the base of the Bullbreen Group has been redefined by incorporating slates and conglomerates, not previously described, at the base of the Motalafjella Formation; 2) the relative positions of the Alkhorn and Løvliebreen Formations have been reversed; 3) the presence of two distinct glacigenic diamictite horizons, described in northwest Oscar II Land by Waddams (1983), cannot be substantiated in the St. Jonsfjorden region. We suggest that a name change to the Vestgötabreen Structural Complex is proposed and a detailed lithological description of these rocks is presented.

One of the most remarkable geological features of southwest Oscar II Land is the relationship between the Bullbreen Group and the Vestgötabreen Structural Complex. Mineral parageneses within the Vestgötabreen Structural Complex indicate depths of burial on the order of 50 km (Kanat unpublished; Ohta 1986). Preservation of these assemblages requires rapid uplift rates in an unstable tectonic regime. The rise of the Vestgötabreen Structural Complex appears to have initiated deposition of the Bullbreen Group in a fault-bounded basin. The metamorphic contrast between the Bullbreen Group and Vestgötabreen Structural Complex, and inclusion of Vestgötabreen clasts within the Bulltinden conglomerate, attest to this relationship. Continued orogenesis drove the Vestgötabreen Structural Complex over the Bullbreen Group, and both are allochthonous with respect to the Comfortlessbreen and St. Jonsfjorden Groups.

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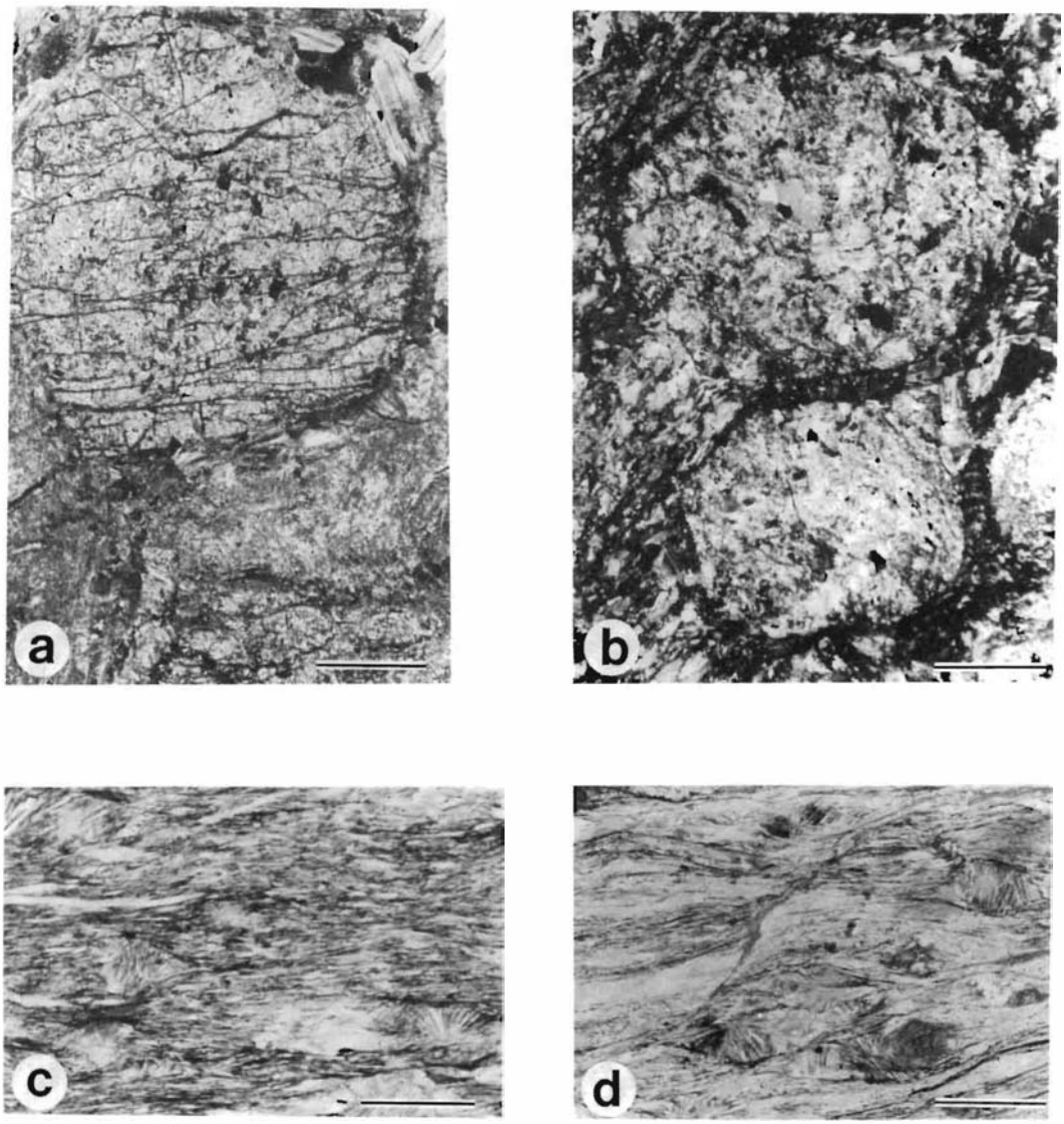
Plate 1

Comparative photomicrographs.
a: Photomicrograph of retrogressed garnetiferous clast from the Bulltinden conglomerate at Motalafjella under crossed nicols (specimen number K3116).
b: Photomicrograph of retrogressed garnet from the mafic schist division of the Vestgötabreen Structural Complex at Motalafjella under crossed nicols (specimen number K3231).
c: Photomicrograph of chloritoid rosettes from a clast within the Bulltinden conglomerate at Motalafjella in plane polarized light (specimen number K3278).
d: Photomicrograph of chloritoid rosettes from the mafic schist division of the Vestgötabreen Structural Complex at Motalafjella in plane polarized light (specimen number K3314). Scale bars = 0.5 mm for all photomicrographs.
* An uncoded ASCII MS-DOS file entitled LHKRKCAT.CUP (221Kb) which catalogues locations, mineral assemblages, and other collection data for all specimens described in the text is available from LHK.


a
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