Ordovician conodonts from the Bulltinden Formation, Motalafjella, central-western Spitsbergen

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Seven samples from the Limestone and Boulder Conglomerate Members of the Bulltinden Formation have yielded poorly preserved conodonts. On tentative identifications *Periodon aculeatus* Hadding and *Prioniodus* cf. *P. alobatus* Bergström at the base of the formation suggest an Ordovician lower Caradoc, or older age. This confirms that the Vestgötabreen Formation unconformably beneath underwent high-pressure metamorphism during the Taconic and/or Finmarkian phases of the Caledonian orogeny. The conodonts show affinity to the North Atlantic Province suggesting a deeper water marine depositional environment. Conodont colour alteration indices of five indicate that the Bulltinden Formation was heated to temperatures in excess of 300°C, probably during the middle-upper Silurian main Caledonian uplift event.

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Thick Precambrian and Lower Palaeozoic sediments in central western Spitsbergen are highly deformed and have been classified into five formations (Figs. 1 and 2a). The uppermost of these formations is the Bulltinden Formation of Lower Palaeozoic age (Harland et al. 1979; Hjelle et al. 1979; Figs. 2a and 2b). The Bulltinden Formation in Motalafjella is exposed in the centre of an overturned syncline, the axial plane of which dips moderately to the west (Fig. 2c). This formation lies structurally beneath, but stratigraphically and uncomformably above the Vestgötabreen Formation, a high-pressure metamorphic complex (Horsfield 1972; Ohta 1979; Ohta et al. 1984; Ohta et al. 1986; Fig. 2c).

The Bulltinden Formation comprises three members, at the base the Limestone Member, the Boulder Conglomerate Member, and at the top the Sandstone-Shale Member. The Sandstone-Shale Member occurs outside Fig. 2b, the area under consideration. Only the lower two members have yielded conodonts and are described in ascending order (Table 1).

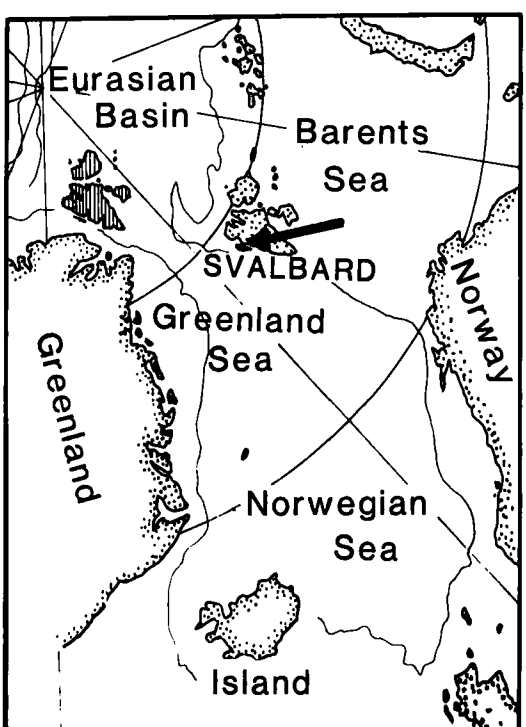
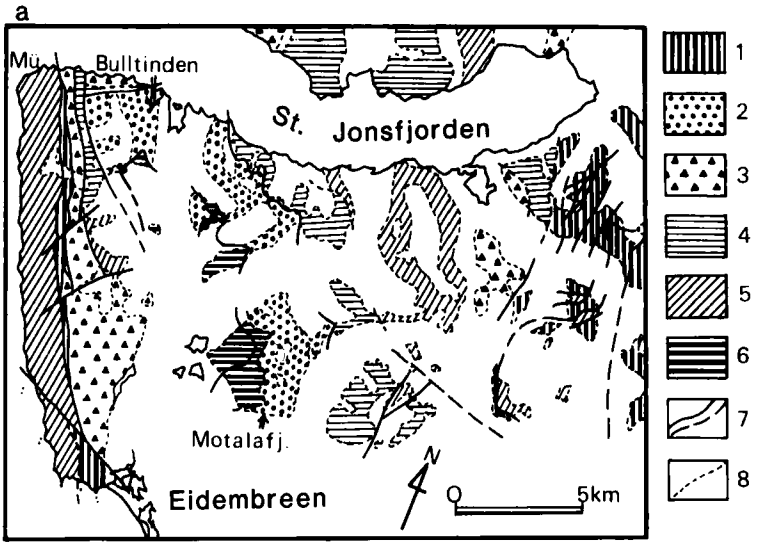


Fig. 1. Svalbard, with its pre-Tertiary position in the northeast of Greenland (shadowed). Arrow = Motalafjella.

Limestone Member (Fig. 2b)

This member is typically 30–80 m thick and consists of sheared, dark limestones. At the base an unconformity is marked by the presence of a


a
Mu
Bulltinden
St. Jonsfjorden
Motalafj.
Eidembreen
N
0
5km
1
2
3
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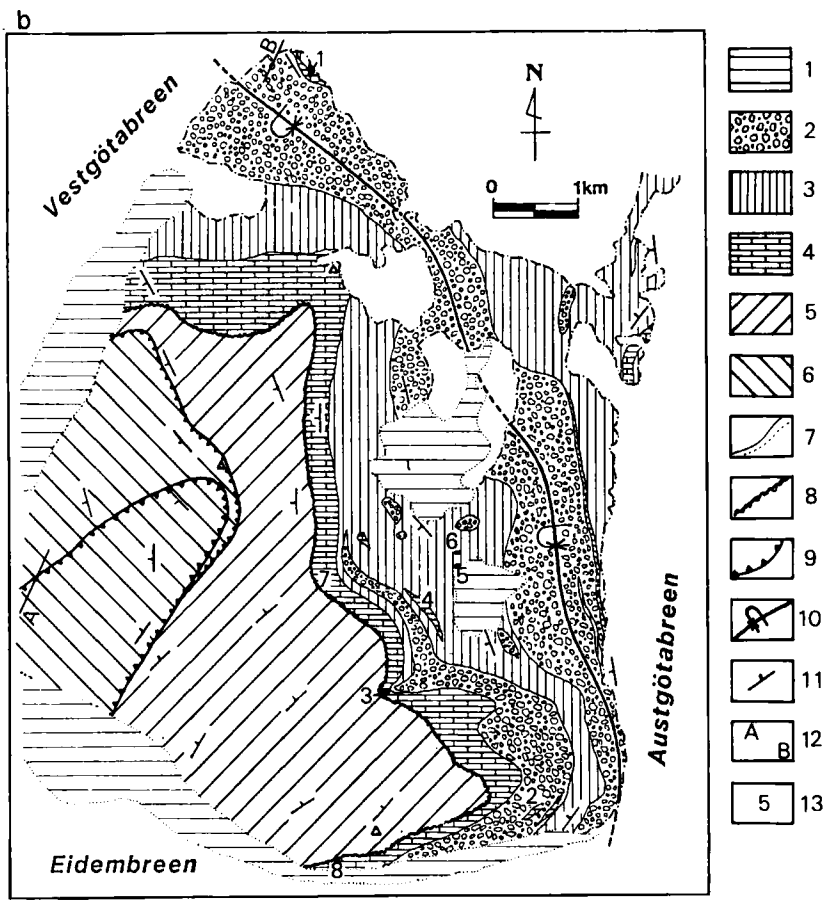
5
6
7
8


b
Vestgötabreen
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Eidembreen
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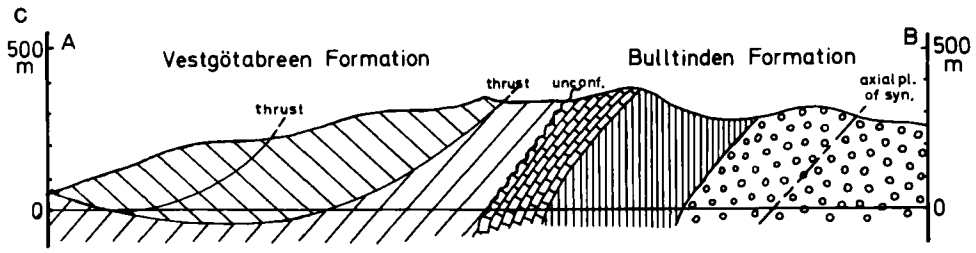


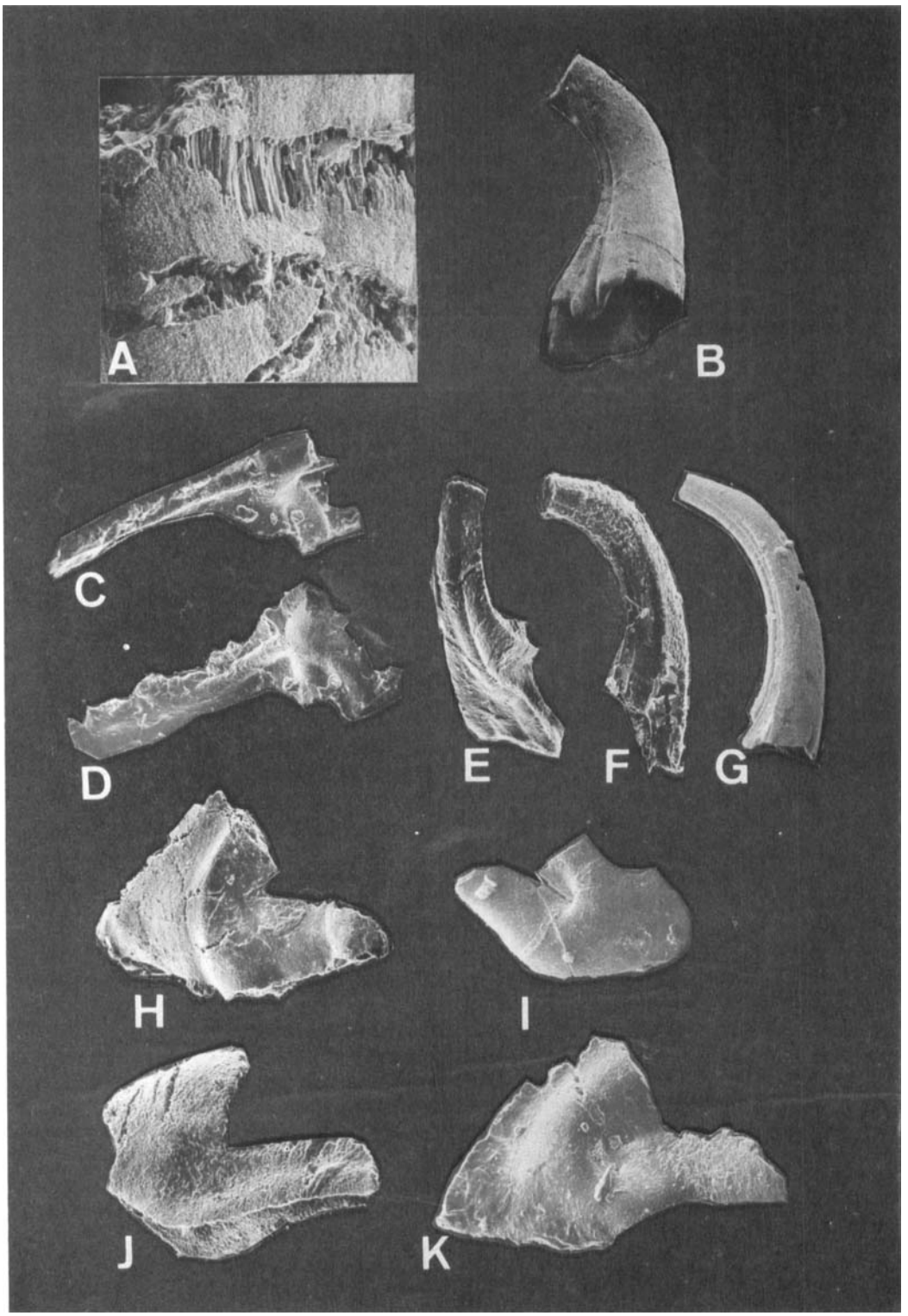
Fig. 2. Motalafjella. a. Geological map of southern side of St. Jonsfjorden, central-western Spitsbergen. – Legend: 1. Carboniferous and Permian; 2. Bulltinden Formation; 3. Eocambrian tillite formation; 4. Calc-argillo-volcanic formation; 5. Quartzite-shale formation; 6. Vestgötabreen Formation; 7. Fault and thrust; 8. Lithological boundary. Mü: Müllerneset. – b. Geological map of Motalafjella. – Legend: 1. Moraine; 2, 3, 4. Bulltinden Formation: 2. conglomerate of the Boulder Conglomerate Member, 3. sandstone and shale of the Boulder Conglomerate Member, 4. Limestone Member; 5, 6. Vestgötabreen Formation: 5. Lower Unit (low grade), 6. Upper Unit (high grade); 7. Lithological boundaries; 8. Unconformity; 9. Thrust; 10. Axial trace of overturned syncline; 11. Bedding and cleavage; 12. Position of geological profile; 13. Fossil localities. 1 and 2 were reported by Scrutton et al. (1976). – c. Geological profile along the western part of Motalafjella.

fossiliferous, sandy, grey limestone-conglomerate containing large angular to rounded clasts of garnet-mica schists, metabasites, greenschists and dolomites. These lithologies are found within the Vestgötabreen Formation (Ohta et al. 1984). Conodont samples 83 JP 159, loc. 3; 83 JP 167, loc. 4; 83 JP 171, loc. 7; and 83 JP 190, loc. 8 (all localities are shown in Fig. 2b) were collected through this member.

Sample 83 JP 159 (loc. 3, Fig. 2b) collected for conodonts also contained gastropods including *Maclurites* which most probably indicate a middle to late Ordovician age (J. S. Peel, pers. comm.).

Table 1. Specimen abundances and processed sample weights. F denotes fragments only.

Taxa \ Sample nos.	83 JP 159	83 JP 167	83 JP 171	83 JP 190	83 JP 168	83 JP 169	75 YO 536
Weight processed (kg.)	2.9	6.2	0.5	0.4	0.9	1.2	1.4
?*Belodina* sp. indet.		1					
?*Dapsilodus* sp. indet.		1					
Panderodus sp.	1	1	F		F	F	
Periodon aculeatus							
M	1	2					
Sb		2					
Prioniodus cf. *P. abbatus*							
Sa		1					
'prioniodiform'		1					
Protopanderodus sp. indet.							
asymmetrical acodontiform	1						
?*Scalpellodus* sp. indet.							
symmetrical P		1					
Walliserodus cf *W. curvatus*							
symmetrical P							1
Walliserodus sp. indet.							
symmetrical P		1					
?*Plectodina* sp./?*Oulodus* sp.							
S element							1
Oistodiform element sp. indet.	1						
Genus and sp. indet.						1	


A
B
C
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Boulder Conglomerate Member (Fig. 2b)

The Boulder Conglomerate Member is between 30 m and 250 m thick, and comprises conglomerates and sandstone-shale alternations; the latter predominate in the upper part of the Member, and laterally both show rapid thickness variation. The conglomerate comprises clasts of crystalline limestone, dolomite, quartzites, serpentinite, greenschists and mica schists. These are interspersed with slumped limestone lenses containing olistostromes up to 20 m across, and isolated pebbles and thin lenses of conglomerate. In Motalafjella the Conglomerate Member contains several fossiliferous lenses of limestone which have yielded a lower Silurian fauna of *Paleofavosites*, *Catenipora*, *Tryplasma*, *Ketophyllum* and *Harpidium* (aff. *Lissocoelina*) at loc. 1 (Fig. 2b) (Scrutton et al. 1976). Ohta et al. (1984) also recorded additional fossiliferous localities within the member, finding gastropods, corals cephalopods and trilobites. In a petrographic study of the Bulltinden Formation, Horsfield (1972) assumed an age of Ordovician or younger.

Conodont samples collected from the limestone lenses in the Boulder Conglomerate Member include 83 JP 168, loc. 5; 83 JP 169, loc. 6; and 75 YO 536, loc. 1 (all localities in Fig. 2b) (the last from the upper part of the Member and is the same as locality 3 in Fig. 1 of Scrutton et al. 1976).

The conodont faunule

Four dark, coarse-grained limestone samples were collected from the Limestone Member and three from the Boulder Conglomerate Member (Fig. 2b). These underwent standard processing techniques for conodonts. Conodonts were moderately abundant only in sample 83 JP 167 (loc. 4, Fig. 2b) and preservation was poor in all cases. Specimens record a conodont colour alteration index (C.A.I.) of five, which suggests heating to at least 300°C (Epstein et al. 1977). Many specimens are fragmentary or fractured and exhibit recrystallization (Fig. 3A).

It is not the aim of this paper to present a taxonomic study of the conodonts, merely to record their presence and provide dates for the Bulltinden Formation. Unfortunately the specimens of *Belodina* sp. *?Plectodina* sp./*?Oulodus* sp., the Sa element of *Prioniodus* cf. *P. alobatus* and four specimens of *Periodon aculeatus* (M and Sb elements) were lost in the SEM vacuum. The latter species are critical for dating the base of the Limestone Member and the Material is to be recollected for a larger taxonomic study.

The conodont faunule is of low diversity and abundance (Table 1). Samples 83 JP 159 (loc. 3, Fig. 2b) at the base of the Limestone Member and 83 JP 167 (loc. 4, Fig. 2b) in the upper part of the Limestone Member contain *Periodon aculeatus* Hadding, a species known to range from the late Arenig *Microzarkodina ozarkodella* subzone to the Llandeilian *Pygodus anserinus* Biozone (Ziegler 1981), and may range into the lowest Caradoc (Repetski & Ethington 1977). A fragmented specimen of the oistodiform M element of *P. aculeatus* in 83 JP 159 lacks discernible denticles on the anterior edge of the cusp; this may be an artifact of preservation or suggestive of specimens closer to *P. flabellum* (Lindström 1955; Løfgren 1978). If the latter is the case, the lower part of the Limestone Member may be restricted to the Arenig (Ziegler 1981). Sample 83 JP 167 contains two elements tentatively assigned to *Prioniodus* cf. *P. alobatus* as the amorphognathiform element is absent and the prioniodiform element lacks a complete posterior process. Confirmation of the presence of *P. alobatus* would suggest a lower Caradoc age (Bergström 1971; Ziegler 1981) for the upper part of the Limestone Member. The remaining samples from the lower and middle parts of the member yield undiagnostic conodonts of Lower-Middle Ordovician aspect.

Sample 75 YO 536 (loc. 1, Fig. 2b) from near the top of the Boulder Conglomerate Member, contains a broken ramiform element which may be assigned to *?Plectodina* sp. or *?Oulodus* sp.

Fig. 3. Conodonts. A: Partial recrystallization developed in a *Panderodus* sp. A 40849/11, × 165. B: *Panderodus* sp. A 40851/13, × 50. C, D: *Prioniodus* cf. *alobatus*, prioniodiform element, inner side (C), outer side (D). A 40848/2, × 77. E: *Juanognathus* sp. A 40848/17, 88 ×. F, G: *Panderodus* cf. *?gracilis*, A 40848/19 (F), A 40851 (G), × 88. H, J, K: *?Periodon* sp. *indet*, M element. A 40848/10, /11, /9. × 88 I: Gen. & sp. *indet*. A 40850/11, × 82.

The conodont collection is housed at the Paleontologisk Museum, University of Oslo, under the numbers A 40486 – 40851. 83 Jp 159 = A 40846; 83 JP 190 = A 40847; 83 JP 167 = A 40848; 83 JP 168= A 40849; 83 JP 169 = A 40850, 83 JP 171 and 75 YO 536 = A 40851.

This would suggest late Ordovician or early Silurian age.

The faunule recovered from Motalafjella shows an affinity with the North Atlantic Province (Barnes et al. 1973) and facilitates correlation in terms of the Balto-Scandinavian conodont zonal succession (Bergström 1971). Faunas representative of the North Atlantic Province apparently reflect 'normal' marine conditions at either high or low latitudes (Barnes & Fåhraeus 1975). The *Periodon-Prioniodus* association is found in the deeper water environments of the shelf margin or continental slope (Barnes et al. 1973; Barnes & Fåhraeus 1975; Ethington & Repetski 1984).

Discussion

Conodont and macrofossil dates suggest that the Limestone Member of the Bulltinden Formation is of probable lower Caradoc or older age, while the upper part of the Boulder Conglomerate Member may range into the lower Silurian. These dates place a minimum age on the deformation and high-pressure metamorphism of the Vestgötabreen Formation which is unconformably overlain by the Bulltinden Formation. These events are now known to be older than previously supposed, i.e. Scrutton et al. (1976) inferred the events were older than lower Silurian, but provided no specific date. We suggest they can be correlated with the early Caledonian, Taconic and/or Finmarkian phases of orogeny.

In northern Svalbard gneisses and migmatites associated with the main Caledonian uplift have yielded K-Ar dates of 360–430 Ma (Gayer et al. 1966; Ohta et al. 1986). These postdate the Bulltinden Formation.

All conodont specimens record a C.A.I. value of five (Epstein et al. 1977), suggesting that the Bulltinden Formation has been metamorphosed by temperatures in excess of 300°C. This is in general agreement with chemical data presented by Ague & Morris (1985) which suggest that garnet-mica schists at Müllerneset (Fig. 2b), 10 km to the northwest of the present area, were formed at 460–517°C. Both sets of data suggest a post-Bulltinden Formation metamorphism event which would appear to correlate with the middle upper Silurian, main Caledonian uplift event, the Scandian phase. This thermal event is probably simultaneous with the formation of the overturned syncline in Motalafjella (Fig. 2c).

Thus, the Bulltinden Formation separates two deformation and metamorphic phases in the Caledonian orogeny in Svalbard, the older Taconic/Finmarkian phase with a high-pressure metamorphism and the younger Acadian/Scandian phase with an intermediate P/T metamorphism. The younger event has been observed in wide areas of the Svalbard Caledonides, while the Taconic Formation one is restricted to occur in some small tectono-stratigraphic units in western Spitsbergen.

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