

Middle Ordovician conodonts from allochthonous limestones at Høyberget, southeastern Norwegian Caledonides

JAN AUDUN RASMUSSEN & SVEND STOUGE

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Middle Ordovician (Llandeilo–Early Caradoc) conodonts are recorded from the limestone at Høyberget, southern Norwegian Caledonides. The conodont fauna, including *Pygodus anserinus* Lamont & Lindström and *Baltoniodus variabilis* (Bergström), corresponds to the upper part of the *Pygodus anserinus* and the lower part of the *Amorphognathus tvaerensis* conodont zones. On the basis of the stratigraphic position the overlying black shale unit is correlated with the upper *Nemagraptus gracilis* and the *Diplograptus multidens* graptolite zones.

Jan Audun Rasmussen, Institute of Historical Geology and Palaeontology, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark; Svend Stouge, Geological Survey of Denmark, Thoravej 8, DK-2400 Copenhagen NV, Denmark.

Non-fossiliferous and fossiliferous limestones outcrop sporadically within the Norwegian Caledonides (Spjeldnæs 1985; Bruton & Harper 1988). Some of the fossiliferous limestone units have been correlated with the Arenig–Early Llanvirn ‘Orthoceras Limestone’ in the Oslo area and the lateral equivalent Stein Limestone in the Ringsaker area. This correlation has usually been based on lithological and broad stratigraphical similarities and/or weak fossil evidence.

During our work on Arenig–Llanvirn conodont faunas in the Oslo Region (Rasmussen & Stouge 1988; Rasmussen in prep.) the limestone at Høyberget (formerly Høgberget) east of Snerta (Fig. 1) was also sampled. The conodonts however, were much younger (Middle Ordovician rather than Early Ordovician) than was expected from earlier interpretations. Here we present the data obtained from Høyberget and demonstrate for the first time the occurrence of Llandeilo–Early Caradoc conodonts within the Norwegian Caledonides.

Actinoceroid cephalopods have been known from the limestone at Høyberget since 1863 (Kjerulf 1863), and on this evidence it was correlated with the ‘Orthoceras Limestone’ and the Stein Limestone (Schiøtz 1883; Bjørlykke 1905; Holtedahl 1920, 1921; Skjeseth 1962). The lime-

stone at Høyberget is overlain by a fossiliferous black shale which was considered contemporaneous with the ‘Ogygiocaris Series’ in the Oslo Region, i.e. Llanvirn–Early Llandeilo (e.g. Bjørlykke 1905; Holtedahl 1920, 1921).

Recently the nautiloid genus *Ornoceras* Stokes has been recognized in material collected from the limestone at Høyberget, and a Late Arenig to Late Llanvirn age was suggested (Spjeldnæs 1985). As a consequence, the overlying unnamed black shale unit would correspond to the *Hustedograptus teretiusculus* graptolite Zone (Llandeilo) (Spjeldnæs 1985).

The conodont data presented here show the age of the limestone to be Llandeilo–Early Caradoc (Middle Ordovician). The Høyberget conodont fauna is clearly younger than the Lower Ordovician conodont successions known from the ‘Orthoceras Limestone’ and the Stein Limestone (Kohut 1972; Rasmussen & Stouge 1988; Rasmussen in prep.). Consequently, it is likely that the black shale overlying the limestone at Høyberget covers the upper part of the *Nemagraptus gracilis* graptolite Zone and may extend into the *Diplograptus multidens* graptolite Zone – that is, an early Caradoc rather than Llandeilo (*Hustedograptus teretiusculus* Zone) age.

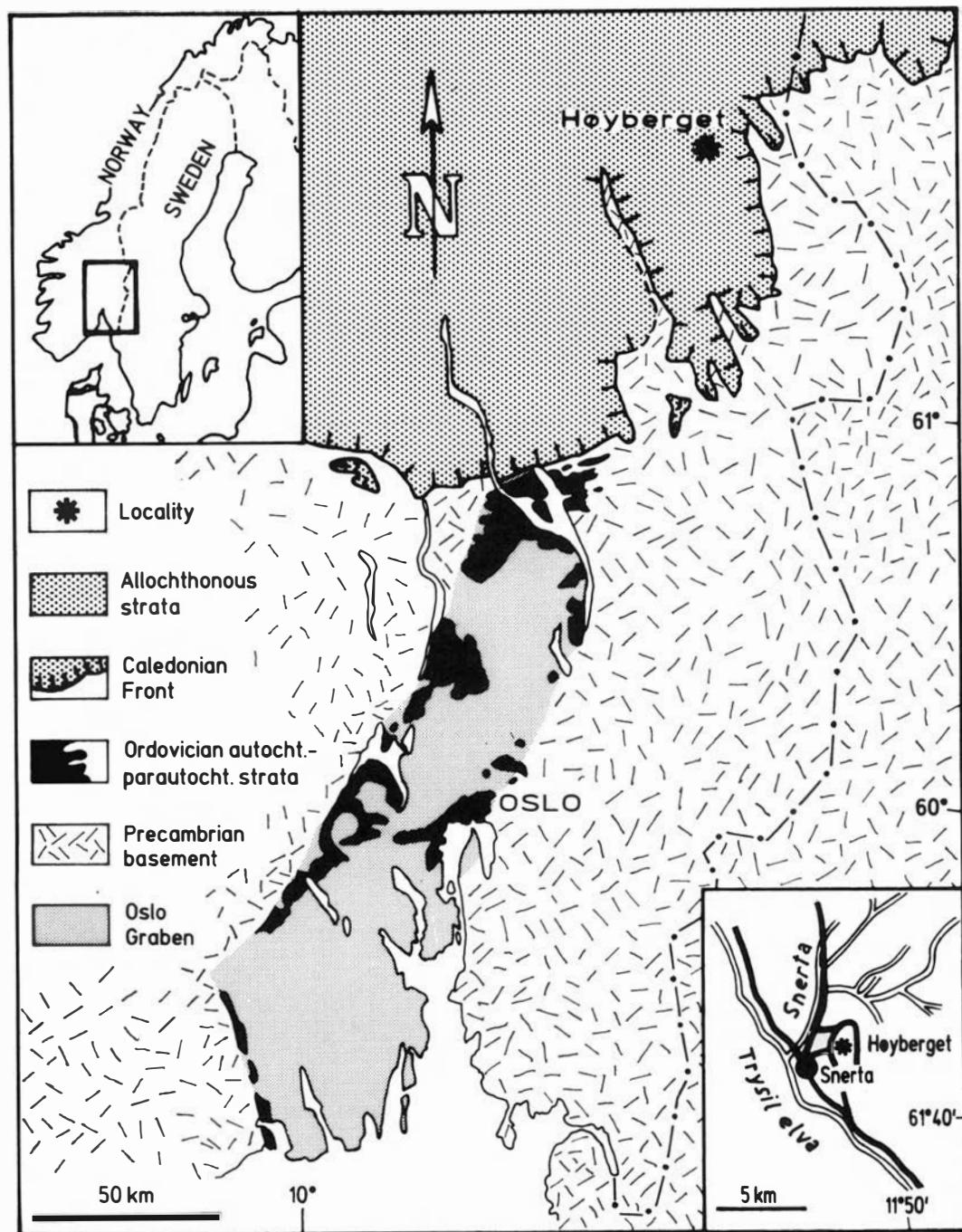


Fig. 1. Location map.

Location and geological setting

The locality is situated at the western side of Høyberget, approximately 1 km east of Snerta village within the map sheet Elvdal 2018 III (UTM coordinates PP452441) (Fig. 1).

The limestone at Høyberget is about 5–10 m thick (Holte Dahl 1921) and is overlain by a black shale unit. It is fossiliferous, impure, and has intercalations of argillaceous material. The bedding planes of the limestone show a characteristic weathered, reticulate surface.

These two Ordovician units overlie the Upper Proterozoic sandstones and shales of the Hedmark Group (Vendian) (e.g. Schiøtz 1883; Bjørlykke 1905; Holte Dahl 1920; Nystuen 1982). At Høyberget, the Hedmark Group and the Ordovician limestone and the black shale units are all incorporated in the Lower Allochthon of the Osen–Røa Nappe Complex of the Norwegian Caledonides (Nystuen 1981; Bockelie & Nystuen 1985). The limestone and the black shale unit are structurally overlain by the Middle Allochthon Kvitvola Nappe, which was thrust discordantly upon the Osen–Røa Nappe Complex (Nystuen 1980, 1983; Bockelie & Nystuen 1985). The

emplacement has brought the Vendian Engerdalen Group into structural superposition on the Ordovician sediments (Nystuen 1980, 1983). The thrust plane between the Osen–Røa Nappe Complex and the Kvitvola Nappe is marked by a conspicuous 6 m thick mylonite zone (Bjørlykke 1905).

Previous investigations

The first recorded fossils from the limestone at Høyberget are those mentioned by Kjerulf (1863), who documented the nautiloid cephalopods which are most abundant in the lower part of the unit. One species was identified as *Orthoceras crebreseptum* Hall, or a closely related species. Recently, Spjeldnæs (1985) noted that some of the Høyberget nautiloids have annulate siphuncles, and belong to the genus *Ormoceras* Stokes. The Høyberget cephalopods were compared with those known from the top of the ‘Orthoceras Limestone’ in the Oslo Region (Spjeldnæs 1985), and therefore the limestone at Høyberget was interpreted to span the interval from the upper part of the ‘Orthoceras Limestone’ to well into the ‘Ogygiocaris Series’, at or above

BRITISH SERIES	GRAPTOLITE ZONES	CONODONT ZONES AND SUBZONES		RANGES OF SELECTED SPECIES	OSLO	HØYBERGET
Caradoc	<i>Diplograptus multidens</i>	<i>Amorphognathus tvaerensis</i>	<i>Baltoniodus gerdae</i>		Lower Chasmops Shale	Black shale unit
Llandeilo	<i>Nemagraptus gracilis</i>	<i>Pygodus anserinus</i>	<i>Baltoniodus variabilis</i>		Ampyx Limestone	Limestone at Høyberget
(Un-classified)	<i>Hustedograptus teretiusculus</i>		<i>Amorphognathus inaequalis</i>			
Llanvirn	<i>Didymograptus murchisoni</i>	<i>Pygodus serra</i>	<i>Amorphognathus kielensis</i>	<i>Pygodus anserinus</i>	Ogygiocaris Shale	(Missing)

Fig. 2. Correlation table. (Data from Bergström 1971; Bergström et al. 1987; Berry 1964; Hamar 1964, 1966.)

Table 1. Distribution of conodonts from the limestone at Høyberget.

Species		Sample no.	1	2	Total
? <i>Ansellia</i> sp.....			1	1	1
<i>Baltoniodus variabilis</i> (Bergström).....	6	6	12		
<i>Drepanoistodus</i> sp.....	1		1		
" <i>Oistodus</i> " <i>venustus</i> Stauffer	1	5	6		
<i>Periodon aculeatus</i> Hadding	2	31	33		
<i>Protopanderodus robustus</i> (Hadding).....	6	1	7		
<i>Protopanderodus varicostatus</i> (Sweet & Bergström).....		1	1		
<i>Pygodus anserinus</i> Lamont & Lindström.....		11	11		
<i>Scabardella altipes</i> (Henningsmoen).....	12	15	27		
<i>Strachanognathus parvus</i> Rhodes	1		1		
Platform conodonts (fragmentary)	2	1	3		
Unidentifiable elements	7	9	16		
Total		38	81	119	

the top of the *D. murchisoni* Zone. Other fossil groups known from the limestone include gastropods (Kjerulf 1863; Schiøtz 1874; Holtedahl 1921) trilobites (Schiøtz 1874), brachiopods, ostracodes and echinoderms (Henningsmoen 1979). None of these records, however, have biostratigraphical importance.

The only fossils reported from the overlying black shale unit are biostratigraphically undiagnostic. The poorly preserved fauna comprises cephalopod fragments (Holtedahl 1921), echinoderms (Schiøtz 1874; Bjørlykke 1905), asaphid trilobites (Holtedahl 1921), gastropods (Kjerulf 1863; Schiøtz 1874; Bjørlykke 1905; Holtedahl 1921), and brachiopods (Henningsmoen 1979).

Conodont collection

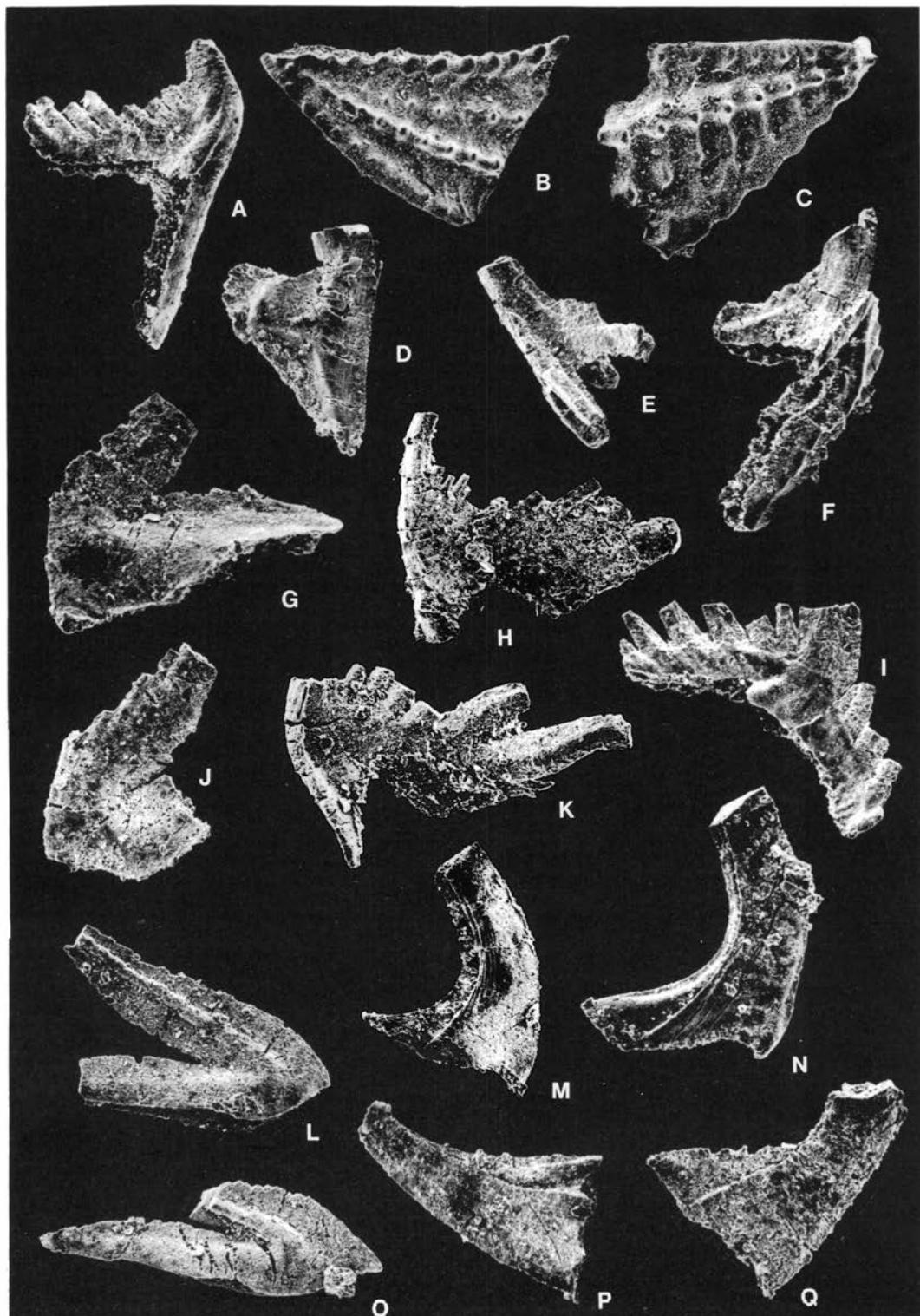
Two samples were collected and processed for conodonts using standard techniques (e.g. Lind-

ström 1964). The limestone at Høyberget is partly covered in the road section 1 km east of Snerta village (Fig. 1), but loose blocks are well distributed in the area. Sample 1 (0.7 kg) was collected from a large erratic with cephalopods, whereas sample 2 (1.4 kg) is from beds *in situ*.

One hundred and three reasonably well-preserved conodont elements have been identified (Table 1; Fig. 3) and all have a CAI of 5–6. This shows that the rocks have been heated from a minimum of 300°C to about 550°C (Epstein et al. 1977; Rejebian et al. 1987).

The fauna is characterized by *Pygodus anserinus* Lamont & Lindström, *Baltoniodus variabilis* (Bergström) and *Periodon aculeatus* Hadding, and the coniform genera *Protopanderodus*, *Scabardella*, *Strachanognathus* and '*Oistodus*' *venustus* Stauffer are present in varying numbers (Table 1).

Fig. 3. □ A–C. *Pygodus anserinus* Lamont & Lindström. A. Pastinate P element. MGUH 18900. Sample 2: 70×. B. Stelliscaphate P element. MGUH 18901. Sample 2: 50×. C. Stelliscaphate P element. MGUH 18902. Sample 2: 85×. □ D–F. *Baltoniodus variabilis* (Bergström). D. Geniculate coniform M element. MGUH 18903. Sample 1: 65×. E. Quadriramate ramiform S element. MGUH 18904. Sample 2: 100×. F. Pastinate pectiniform P element. MGUH 18905. Sample 1: 60×. □ G–K. *Periodon aculeatus* Hadding. G. Geniculate coniform M element. MGUH 18906. Sample 2: 140×. H. Dolabrate ramiform S element. MGUH 18907. Sample 2: 85×. I. Digyrate P element. MGUH 18908. Sample 2: 90×. J. Geniculate coniform M element. MGUH 18909. Sample 2: 60×. K. Dolabrate ramiform S element. MGUH 18910. Sample 2: 95×. □ L, O. '*Oistodus*' *venustus* Stauffer. L. Geniculate coniform element. MGUH 18911. Sample 2: 90×. O. Geniculate coniform element. MGUH 18912. Sample 2: 80×. □ M, P, Q. *Scabardella altipes* (Henningsmoen). M. Non-geniculate coniform element. MGUH 18913. Sample 2: 70×. P. Non-geniculate coniform element. MGUH 18914. Sample 2: 90×. Q. Non-geniculate coniform element. MGUH 18915. Sample 1: 95×. □ N. *Protopanderodus robustus* (Hadding). N. Symmetrical non-geniculate coniform element. MGUH 18916. Sample 1: 105×. (All illustrated specimens are deposited at the Geological Museum, Copenhagen, Denmark (MGUH).)



Age of the fauna

Pygodus anserinus (Fig. 3A–C) is the index species of the *P. anserinus* conodont Zone (Bergström 1971), but the species ranges up to the top of the *Baltoniodus variabilis* Subzone of the succeeding *Amorphognathus tvaerensis* Zone (Bergström 1971; Bergström et al. 1987) (Fig. 2). The presence of *Baltoniodus variabilis* (Fig. 3D–F) suggests that the limestone at Høyberget correlates with the interval from the *Amorphognathus inaequalis* Subzone of the *Pygodus anserinus* Zone to the *Baltoniodus variabilis* Subzone of the *Amorphognathus tvaerensis* conodont Zone (Fig. 2). This interval mainly covers the *Nemagraptus gracilis* graptolite Zone (Bergström 1986; Finney & Bergström 1986; Bergström et al. 1987). Other fragmentary platform conodonts have been found but their poor state of preservation allows for neither a specific nor a generic identification. The other conodonts recognized (Table 1) are longer ranging species with lower biostratigraphical resolution.

Correlation

The conodont fauna from the limestone at Høyberget is similar to that of the Middle Ordovician (Llandeilo) Ampyx Limestone in the autochthonous and paraautochthonous strata of the Oslo Region (Hamar 1964, 1966). *Pygodus anserinus*, *Baltoniodus variabilis*, *Protopanderodus robustus* (Hadding), *Periodon aculeatus*, *Scabardella altipes* (Henningsmoen) and '*Oistodus*' *venustus* occur in both units. It should be noted that the older species *Pygodus serra* (Hadding) and *Baltoniodus prevariabilis* (Fähræus) are present in the lower part of the Ampyx Limestone (Hamar 1964) while they have not been found in the limestone samples from Høyberget (Table 1). The possible appearance of *Amorphognathus tvaerensis* Bergström (= *Ambalodus triangularis* Branson & Mehl sensu Hamar 1966) within the Lower Chasmops Shale (Bergström 1971, p. 104) indicates that the limestone at Høyberget is younger than the lower part of the Ampyx Limestone, but older than the Lower Chasmops limestone (Caradoc) in the Oslo Region (Fig. 2).

In Baltoscandia, Llandeilo–Caradoc conodont faunas are well known from Scania (Hadding 1913; Lindström 1955; Bergström 1971, 1973a, 1986; Bergström & Nilsson 1974), central Sweden

(several localities) (Bergström 1962, 1971, 1973a, 1986) and Estonia (Viira 1967, 1974). Outside Baltoscandia the *Pygodus anserinus* conodont Zone is widely distributed. In the Caledonian–Appalachian fold belt it has been recorded from Scotland, Ireland, Newfoundland and eastern United States (Lamont & Lindström 1957; Bergström 1971). It has also been documented from small limestone units associated with volcanic arcs (Bergström et al. 1974; Stouge 1980a, c; Fähræus & Hunter 1981) and other sites along the eastern and western margins of the Appalachians (Bergström 1971, 1973b; Stouge 1980a, b).

Significance of the fauna

Eustatic changes during the Middle Ordovician are well established and unconformities at or near the base of the Llandeilo in shelf areas on both sides of the Iapetus Ocean are known (Leggett 1978; Leggett et al. 1981; Stouge 1981a, c; Fortey 1984; Thickpenny & Leggett 1987; Fortey & Cocks 1988), while a major transgression is evident during the late Llandeilo and early Caradoc.

The Llandeilo regressive/transgressive turnover is marked by a transition from radiolarian cherts to *Nemagraptus gracilis*-bearing black shales in the Caledonides of Ireland and southern Scotland (Leggett 1978). Shallow water limestones were deposited in volcanic regions of central Newfoundland during the lowstand (Stouge 1980a; Fähræus & Hunter 1981). These limestones were succeeded by *Nemagraptus gracilis*–*Diplograptus multidens*-bearing black shales (Bergström et al. 1974). In view of this the limestone at Høyberget was probably deposited during the initial transgression that reached Norway in late Llandeilo–early Caradocian and the succeeding black shale unit is probably equivalent to the widespread *N. gracilis*–*D. multidens*-bearing black shales of the Caledonian–Appalachian Orogen.

Summary

The Late Llandeilo–Early Caradoc age for the limestone at Høyberget is based on the occurrence of the diagnostic conodont species *Pygodus anserinus* and *Baltoniodus variabilis*. As a consequence, the overlying black shale unit is correlated with the upper *N. gracilis*–*D. multidens*

graptolite Zones. This dating is significant in that the Norwegian Caledonides are now shown to include Middle Ordovician limestone horizons spanning the Llandeilo–Caradoc series boundary. In this way the Norwegian Caledonides show sequential similarity to other regions within the Caledonian–Appalachian fold belt, where *Pygodus* species are well distributed. Caution is needed in future attempts to correlate non-fossiliferous limestone units within the Scandinavian fold belt with the autochthonous/paraautochthonous Arenig/Llanvirn limestone units of the Oslo Region.

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