

# Conodonts of Laurentian faunal affinities from the Middle Ordovician Svartsætra limestone in the Trondheim Region, Central Norwegian Caledonides

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Samples from a 122-meter thick limestone succession at Svartsætra, about 13 km east of Meldal in the Trondheim Region, west-central Norway, yielded more than 100 conodont elements representing about a dozen multielement species. All are conspecific with, or closely similar to, taxa present in the upper Middle Ordovician of the North American Midcontinent, and a biostratigraphic assessment indicates that the Svartsætra limestone is coeval with the Shermanian Substage of the Chatfieldian Stage in the uppermost Middle Ordovician of North America. In terms of North American and Atlantic conodont zones, this interval is in the *Belodina confluens* and lowermost part of the *Amorphognathus superbus* zones, respectively. The fauna differs strikingly from most other coeval Baltoscandian conodont faunas, the only known exceptions being those of the Mjøsa Limestone in the Oslo Region and the Vasalemma Formation in Estonia which exhibit the same Laurentian faunal affinities. These units, as well as the Kalstad Limestone of the Meldal area, are interpreted to represent the same brief period of shallow-water, subtropical-tropical, bahamitic limestone deposition with faunas of Laurentian aspect. Because many conodonts apparently could cross oceanic areas, conodonts alone cannot be used to prove the hypothesis that the Svartsætra limestone, as well as the Kalstad Limestone, were originally deposited offshore from Laurentia rather than Baltica.

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## Introduction

Although diverse and stratigraphically significant conodont faunas have been described from Ordovician sequences in Norway since the early 1960's (see, for instance, Hamar (1964, 1966), Kohut (1972), Bergström (1979), Nickelsen et al. (1985), Bruton et al. (1988), Rasmussen & Stouge (1988, 1989, 1995), Bruton et al. (1989), Rasmussen (1991) and Rasmussen & Bruton (1994)), these fossils remain very poorly known, or unknown, in many Ordovician deposits both in the Oslo Region and in other parts of the country. This is illustrated by the fact that conodonts have previously been described from only a single formation, the Hølanda Limestone, in the classical Trondheim Region (Bergström 1979). Although the known Ordovician conodont faunas of the Oslo Region are, with one important exception (that of the Mjøsa Limestone), closely similar to, if not identical with, the coeval ones in Sweden (Lindström 1955, Bergström 1971, Löfgren 1978), the conodont fauna of the Hølanda Limestone (Bergström 1979) is quite different from equivalent Baltoscandic faunas but much more similar to corresponding faunas from the marginal areas of Laurentia. The Laurentian faunal affinity of these conodonts, as well as of many macrofossils in this and other units in the Trondheim area, has led some investigators (see, for instance, Bruton & Bockelie (1980)) to suggest that this region may represent a fragment of Laurentia that became attached to Baltica in post-Ordovician time. In view of this, it is obviously of considerable interest to investigate the conodonts from other carbonate units in the Trondheim area successions. Equally important, such studies have the

potential to produce reliable biostratigraphic information that may help clarify the very poorly known age of several important units in this geologically complex region where both stratigraphical and structural relationships have long been highly controversial.

The most prominent, and probably most studied, limestone unit in the Hølanda-Meldal successions is the Kalstad Limestone, which is still well exposed at its classical locality at Bergsbakken along the highway about 1 km north of Meldal (Kiær 1932). Limestones of substantial thickness and probably comparable age outcrop at several other localities in the Meldal area, particularly on the slopes of the valley of the Orkla river 6-8 km south of Meldal. Several sets of samples collected from the Kalstad Limestone at its type locality were either barren, or contained only sparse conodont specimens of stratigraphically undiagnostic forms of *Panderodus*. In an attempt to discover more significant conodont occurrences, 11 samples were collected in 1982 from a relatively thick limestone succession at Svartsætra, about 13 km east of Meldal. The purpose of the present contribution is to describe the conodont fauna from these samples, which is currently unique for the Central Scandinavian Caledonides in terms of species association and age, and assess its biostratigraphic and paleobiogeographic significance.

## The Svartsætra limestone outcrop

As noted by Bruton & Bockelie (1982, p. 88), the relationships between the limestone succession at Svartsætra and the Kalstad and Hølanda limestones in the north and west, res-

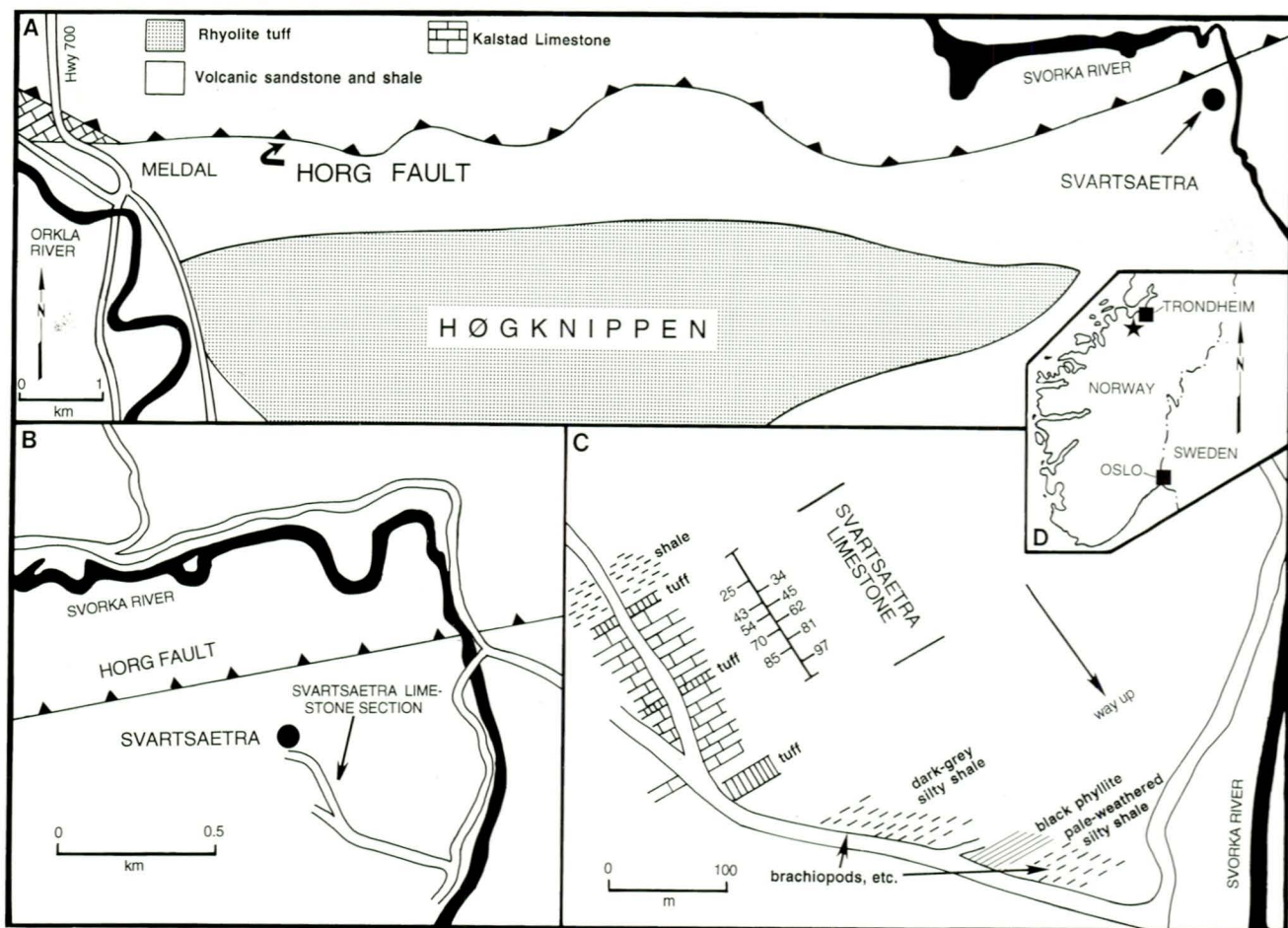


Fig. 1. Sketch maps showing the location of the Svartsætra limestone locality 13 km east of Meldal in the Trondheim Region. A, map showing the general geology south of the Horg Fault; B, map showing the geographic location of the Svartsætra section; C, map of the Svartsætra limestone outcrop and collecting levels of conodont samples. The beds in the outcrop are essentially vertical. Collecting levels were measured from the top of the basal tuff bed at the northwestern end of the section. D, map of southern and central Norway showing location of study area (star).

pectively, remain unknown, and there are rather conspicuous lithological differences between these units. Until the regional relationships of the former unit have been clarified, the informal term *Svartsætra limestone* is used herein for the unit under discussion. A total thickness of about 122 m of limestone was measured along the forest track just southeast of Svartsætra in 1982 when there was an almost continuous exposure because of recent logging and bulldozing of a several meters wide area along both sides of the track (Fig. 1). The lithologically rather monotonous carbonate succession consists of grey to dark-grey, fine-grained, somewhat nodular, irregularly bedded, in places shaly, limestone forming essentially vertical, in some cases rather massive, beds with numerous calcite veins. Near the bottom of the Svartsætra limestone, just above the underlying poorly exposed dark shale is a pale-weathering reddish tuff bed. Other tuff beds occur near the middle of the limestone succession and just above the highest exposed limestone beds at the road intersection (Fig. 1). Because there is a few meters thick unexposed interval between the latter tuff bed and the overlying dark-grey silty shales, the nature of the limestone/shale con-

tact is unknown. No indication of any significant fault or of a possible stratigraphic gap has been seen in the limestone outcrop.

### Material and methods

Most of the 11 samples from the Svartsætra outcrop were collected from the northeastern side of the track where the soil cover had been largely removed exposing many limestone ledges. The position of each sample in relation to the basal tuff bed is given in Fig. 1. About 2 kg of each sample were dissolved in 15% acetic acid following standard conodont extraction procedures. The frequency of conodont elements proved to be low in all samples and one was barren (see Appendix). As is the case at most other localities in the Hølanda-Meldal region (Bergström 1980), the conodont color alteration index (CAI) is 5, indicating a heating of at least 300°C. The state of preservation of most specimens is mediocre, many elements being both broken and tectonically deformed. This, along with the fact that the entire collection at hand, also including indeterminable fragments, contains only slightly more than 100 specimens, makes safe identifi-

cation of the species difficult. Access to large collections of much better preserved specimens of similar, and apparently coeval, faunas from the Oslo Region and eastern North America has greatly facilitated the taxonomic work. Because of the limited number of specimens available, and their rather poor preservation, no formal taxonomic descriptions are included in this paper but brief comments on most of the species identified are given below. Specimens illustrated in Fig. 2 are housed in the type collection of the Orton Geological Museum (OSU) at the Ohio State University, and other specimens are deposited in the Microfossil Collections at the Department of Geological Sciences at the same university.

### The Svartsætra conodont fauna

The general aspect of the conodont fauna of the Svartsætra limestone is quite different from that of most broadly coeval Baltoscandic Middle Ordovician faunas in that it lacks representatives of *Amorphognathus*, *Baltoniodus*, *Dapsilodus*, *Hamarodus*, *Periodon*, *Protopanderodus*, and *Scabbardella*, which are the common genera in those faunas (Sweet & Bergström 1984). However, someone familiar with the Middle and Upper Ordovician conodont faunas of eastern North America will immediately recognize the Svartsætra conodont species association as being of a type present in the Ohio Valley Province (Sweet & Bergström 1984) of the Midcontinent Faunal Realm (Bergström 1990b) as indicated by the presence of, among others, *Aphelognathus*, *Belodina*, *Phragmodus*, and *Plectodina*. As shown by large undescribed collections, the fauna of the Middle Ordovician Mjøsa Limestone in the Mjøsa district in the northern Oslo Region, although more diverse than that from Svartsætra, is of the same type and in all likelihood of the same age. Likewise, as noted by Jaanusson & Bergström (1980) and Sweet & Bergström (1984), upper Middle Ordovician low-diversity conodont faunas of North American aspect also occur in the Saku Member of the Vasalemma Formation (Oandu Stage) in Estonia (see also Viira 1974, Männik 1992). Rare specimens of *Belodina* (Bergström & Bergström 1996) and *Phragmodus* are known to be present in the Upper Ordovician of Sweden but representatives of these genera are unknown in older strata of that country. As is well known, the Mjøsa Limestone, the Kalstad Limestone, and the Saku Member of the Vasalemma Formation contain shelly fossils with North American affinities (see, for instance, Kiær 1932, Spjeldnæs 1978, 1985, Jaanusson 1979). Several authors have interpreted these as representing a short-lived immigration of North American forms during a brief period of deposition of shallow-water, tropical-subtropical, bahamitic limestones in the Oslo Region and Estonia. The Svartsætra limestone may be of the same type although it appears to lack the carbonate mounds ('reefs') present in the Mjøsa (Opalinski & Harland 1981; Spjeldnæs 1982) and Kalstad Limestones (Kiær 1932, Opalinski 1980) and in the Vasalemma Formation (Hints 1990).

### Stratigraphic age

Although a total of less than a dozen conodont species have been identified in the Svartsætra samples (see Appendix), several of these are biostratigraphically highly significant, and, in combination, these species permit a rather precise dating of the unit in terms of standard chronostratigraphic units in the Middle Ordovician of the North American Midcontinent. The upper and lower 20-30 meters of the approximately 120 m thick Svartsætra limestone are less well biostratigraphically controlled than its main part, but there is no evidence of any important faunal change at any level in the succession, and no significant new taxa appear in the upper portion of the unit. Hence, in the absence of evidence to the contrary, it is suggested that the Svartsætra limestone represents a period of carbonate deposition without major breaks.

Four conodont species are particularly important for the biostratigraphically dating of the Svartsætra limestone (Fig. 3). The highly characteristic species *Phragmodus undatus* Branson & Mehl appears in the North American succession in the upper Turinian (upper Middle Ordovician; upper Mohawkian; Leslie & Bergström 1995) and ranges through most, if not all, of the Upper Ordovician (Barnes & Bergström 1988, Fig. 4). This species is exceedingly common in many faunas of the Ohio Valley Province (Bergström & Sweet 1966), and its presence in the Svartsætra collections indicates that this unit is no older than the upper Turinian. Another significant Svartsætra species is *Belodina confluens* Sweet, which ranges from the bottom to the top of the unit. Because this species evolved from *B. compressa* (Branson & Mehl) in the upper portion of the *Amorphognathus tvaerensis* Zone (Sweet 1984), which corresponds to an interval in the middle Shermanian Substage of the Chatfieldian Stage, the base of the Svartsætra limestone is no older than that interval. The appearance of *Belodina confluens* has been used as the base of the *Belodina confluens* Zone in Sweet's (1984) Midcontinent zone scheme. Of stratigraphic importance is also *Plectodina cf. aculeata* (Stauffer). The nominal species appears in the Chazyan Substage and ranges into the middle Chatfieldian Stage (Kirkfieldian-Shermanian substages) (Sweet 1981). Finally, *Aphelognathus cf. gigas* Sweet is known from the upper Kirkfieldian and Shermanian substages of the Chatfieldian Stage. Specimens that are indistinguishable from the Norwegian form occur in the upper Kirkfieldian-Shermanian part of the Trenton Group of New York and Ontario (for excellent illustrations of elements of this form (identified as *Plectodina aculeata*) from the Kirkfieldian Hull Formation of Ontario, see Uyeno (1974, Pl. 2)). Based on the presence of these forms, it is concluded that the Svartsætra limestone in all likelihood is coeval with the Chatfieldian Stage, and that it appears to represent the Shermanian Substage and the *Belodina confluens* Zone in the North American Midcontinent succession. The latter zone is equivalent to the lower portion of the *Amorphognathus superbus* Zone in the Atlantic conodont



zone succession (Sweet 1984). There is no evidence in the collections at hand that the Svartsætra limestone ranges into the Cincinnatian (Upper Ordovician). That the Mjøsa Limestone is of closely similar age is also supported by the occurrence in that unit of *Yaoxianognathus abruptus* (Branson & Mehl). This species has its principal occurrences in Chatfieldian strata although a few specimens have been found in the lowermost Cincinnatian in eastern North America (Sweet & Bergström 1971).

The occurrence of several components of this fauna in the Saku Member of the Vasalemma Formation in Estonia fits well with this age assignment. That is, in eastern North America these species occur in a relatively narrow interval somewhat above the Millbrig K-bentonite that marks the base of the Chatfieldian (Leslie & Bergström 1995). This K-bentonite was correlated with the equally prominent Kinnekulle K-bentonite in Baltoscandia (Huff et al. 1992, Bergström et al. 1995) which marks the base of the Keila Stage (D<sub>II</sub>) in Estonia. The Saku Member of the Vasalemma Formation is placed in the lower part of the overlying Oandu Stage (D<sub>III</sub>), hence in a similar stratigraphic position in relation to the Kinnekulle K-bentonite as that of the Shermanian Substage to the Millbrig K-bentonite in North America (Fig. 4). A link supporting this correlation is also the relatively short-ranging and distinctive graptolite zone index *Climacograptus spiniferus* Ruedemann. This species, recorded in older literature as *Climacograptus diplacanthus* Bulman, which is a junior synonym of *C. spiniferus* (cf. Riva 1976), has long been known from the Oandu (D<sub>III</sub>), Rakvere (E), and lowermost Nabala (F<sub>a</sub>) stages in Estonia (Kaljo & Männil 1990; Männil 1990) whereas in the Cincinnatian region in east-central North America this species occurs in the upper Chatfieldian (Shermanian Substage) and lowermost Cincinnatian (lower Edenian Stage) (Mitchell & Bergström 1991). This Estonian-North American correlation is also in agreement with the fact that the Saku Member of the Vasalemma Formation has been placed in the lowermost

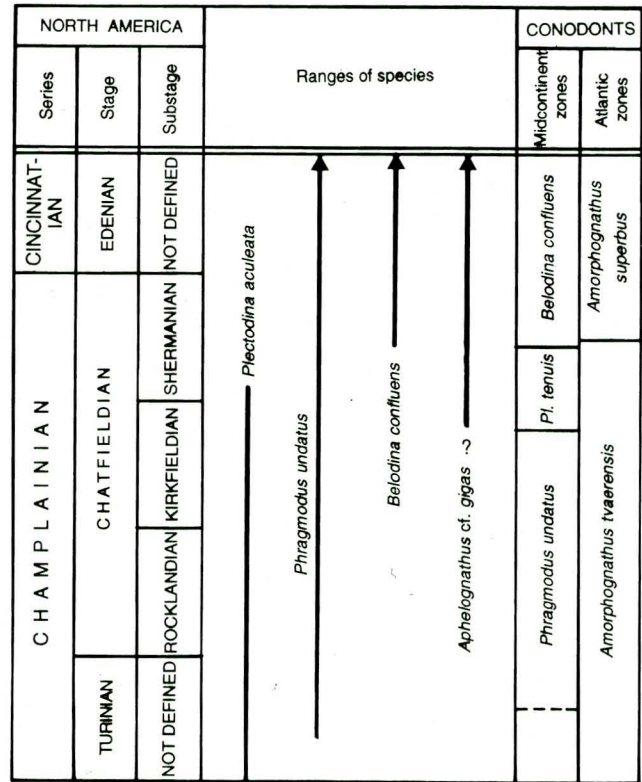


Fig. 3. Chart showing the known vertical ranges of some conodont species in terms of standard upper Middle and lower Upper Ordovician chronostratigraphic and biostratigraphic units in North America.

part of the *Amorphognathus superbus* Conodont Zone (Männik 1992), the base of which is near the middle of the Shermanian Substage in North America (Goldman et al. 1995, Fig. 14). Hence, several lines of independent evidence are in agreement with the trans-Atlantic correlations proposed herein (Fig. 4).

Although it cannot yet be proved by biostratigraphic or other evidence, it seems quite probable that the Kalstad

Fig. 2. «*Distacodus*» cf. *trigonius* Schopf, *Phragmodus undatus* Branson & Mehl, *Drepanoistodus* sp., *Panderodus* cf. *feulneri* (Glenister), *Staufferella* sp., *Belodina confluens* Sweet, *Aphelognathus* cf. *gigas* Sweet, *Plectodina* cf. *tenuis* Branson & Mehl, and *Plectodina* cf. *aculeata* (Stauffer).

A, «*Distacodus*» cf. *trigonius* Schopf (OSU 48630), symmetrical element, lateral view, x100. Sample 82B15-1.

*Phragmodus undatus* Branson & Mehl

B, geniculate element (OSU 48631), lateral view, x150. Sample 82B15-3.

G, S element (OSU 48632), lateral view, x120. Sample 82B15-9.

C, *Drepanoistodus* sp., broken specimen (OSU 48633), lateral view, x120. Sample 82B15-7.

D, *Panderodus feulneri* (Glenister) (OSU 48634), lateral view, x100. Sample 82B15-1.

E, *Staufferella* sp. (OSU 48635), posterior view, x100. Sample 82B15-1.

F, *Belodina confluens* Sweet (OSU 48636), rostrate element, lateral view, x140. Sample 82B15-9.

*Aphelognathus* cf. *gigas* Sweet

H, Pa element (OSU 48637), lateral view, x100. Sample 82B15-9.

I, Sc element (OSU 48638), lateral view, x90. Sample 82B15-2.

J, Pb element (OSU 48639), lateral view, x90. Sample 82B15-7.

M, Pb element (OSU 48640), anterior view, x100. Sample 82B15-3.

O, Sa element (OSU 48641), posterior view, x100. Sample 82B15-8.

*Plectodina* cf. *tenuis* Branson & Mehl

K, M element (OSU 48642), lateral view, x75. Sample 82B15-2.

L, Sc element (OSU 48643), lateral view, x100. Sample 82B15-2.

Q, Sb element (OSU 48644), posterior view, x100. Sample 82B15-7.

R, Pb element (OSU 48645), inner posterior view, x85. Sample 82B15-7.

S, Pa element (OSU 48646), lateral view of fragment that probably belongs to this species, x60. Sample 82B15-2.

T, Sa element (OSU 48647), posterior view of incomplete specimen that tentatively is referred to this species, x85. Sample 82B15-1.

*Plectodina* cf. *aculeata* (Stauffer)

N, Sb element (OSU 48648), posterior view, x100. Sample 82B15-2.

P, Pb element (OSU 48649), lateral view, x140. Sample 82B15-1.

NORTH AMERICA				NORWAY		C. SWEDEN	ESTONIA	S. SCOTLAND	BALTOSCANDIA		
Series	Stages	Substages	Conodo. Zones	Trondheim region (Meldal-Hølanda) Fms.	N. Oslo region (Mjøsa) Fms.	Formations	Fms. & Mbrs.	Units	Series	Stages	Conodo. Zones
CHAMPLAINIAN	CHATFIELDIAN	ROCK-LANDIAN	<i>Phragmodus undatus</i>	SVART-SÆTRA & ?KALSTAD	MJØSA	SKAGEN	VASALEMMA	BALLANTRAE VOLCANIC COMPLEX	VIRUAN	KEILA	<i>Amorphognathus tvaerensis</i>
		KIRKFIELDIAN	<i>Pl. tenuis</i>								
TURINIAN	MILLBRIG K-BENT.	NOT DEFINED	?	?	HOVINS-HOLM	DALBY	KAHALA GRP.	BALLANTRAE VOLCANIC COMPLEX	KINNEKULLE K-B.	JOHVI	
CIN-CINNATIAN	EDENIAN	NOT DEFINED	<i>Belodina confluens</i>				SLANDROM	ARDWELL GRP.	HAR-JUAN	RAK-VERE	<i>Am. superbus</i>
							RÅGAVERE				

Fig. 4. Correlation diagram showing proposed stratigraphic positions of the Svartsætra, Kalstad, Mjøsa, and Craighead limestones and the Saku Member of the Vasalemma Formation, as well as some other important stratigraphical units, in terms of the standard chronostratigraphic schemes used for the upper Middle and lower Upper Ordovician in North America and Baltoscandia, respectively. Note the position of the units with Laurentian faunal affinities in relation to the North American Millbrig and the Baltoscandic Kinnekulle K-bentonites, which have been interpreted to represent the same gigantic ash fall (Huff et al. 1992).

Limestone represents the same period of unusual carbonate deposition as the Svartsætra and Mjøsa limestones. Several authors (see, for instance, Kiær 1932) have compared the fossils of the Kalstad Limestone with those of the Craighead Limestone in South Scotland. A recent study of the Craighead conodont fauna (Bergström 1990a) showed it to be of mixed provincial character but it seems to be of the same age (lowermost *Amorphognathus superbus* Zone; cf. Bergström 1990a) as the Baltoscandian units under discussion. The Craighead is also a unique local carbonate deposit surrounded by clastics and it rests on the Ballantrae Volcanic complex, an ophiolite. Hence, its depositional setting is reminiscent of that of the Kalstad Limestone, which Spjeldnæs (1985) interpreted to have been on the flanks of a volcanic island. It is uncertain if the Svartsætra limestone was laid down under similar environmental conditions but the volcanic island setting certainly does not apply to the Mjøsa Limestone and Saku Member of the Vasalemma Formation that represent shallow-water continental platform, or in the case of the Mjøsa Limestone possibly shelf, carbonates

which are underlain by a stratigraphically rather complete succession of Lower and Middle Ordovician marine sediments.

**Paleoecologic and paleogeographic significance**

As noted above, the Svartsætra conodont species, like those of the Mjøsa Limestone and the Saku Member of the Vasalemma Formation, are forms that in North America are typically found in shallow-water deposits in the Ohio Valley Province. In the biofacies model of Sweet (1988, Fig. 7.3), species assemblages having common representatives of *Plectodina* and *Aphelognathus* and somewhat less common *Phragmodus*, as that of the Svartsætra limestone, are placed in an intermediate shallow-water depth zone between that of the very shallow-water *Rhipidognathus* biofacies and that of the deeper-water *Amorphognathus-Phragmodus* biofacies (Fig. 5). For the biofacies present in the Mjøsa Limestone and the Saku Member of the Vasalemma Formation, Sweet & Bergström (1984) introduced the designation the '*Phragmodus-Icriodella-Plectodina* biofacies' and this term

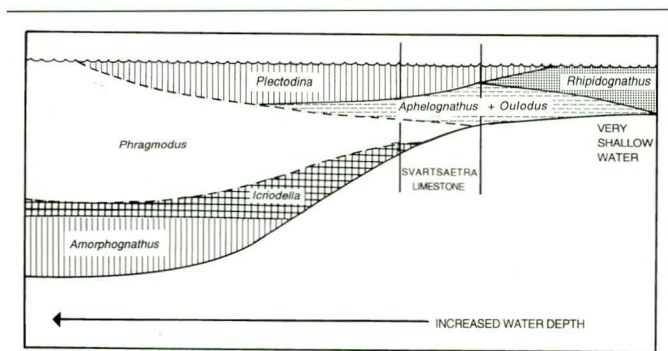


Fig. 5. Projected position of the Svartsætra limestone conodont fauna in terms of Sweet's (1988, Fig. 7.3) Middle-Upper Ordovician conodont biofacies model for the North American Midcontinent. As described in the text, the non-coniform portion of the Svartsætra conodont fauna is dominated by *Plectodina* and *Aphelognathus* with more sparse occurrences of *Phragmodus*.

may be applicable also to the Svartsætra species association despite the fact that no specimen of *Icriodella* has yet been found in that unit. This biofacies is unknown in coeval strata in Sweden although rare specimens of *Icriodella* have been collected from the Moldå Formation (Bergström, unpublished), which is a likely equivalent of the Svartsætra limestone (Fig. 4). It is probable that the water depth in the depositional environment of the Moldå Formation and coeval strata in Sweden was too great for the development of the *Phragmodus-Icriodella-Plectodina* biofacies which is here replaced by the *Hamarodus europaeus-Dapsilodus mutatus-Scabbardella altipes* biofacies of Sweet & Bergström (1984).

The recognition of water depth as a significant control of the distribution of some conodont species is important in paleogeographic interpretations using these fossils. For example, the occurrence of conodont faunas of North American aspect in the Mjøsa Limestone and the Saku Member of the Vasalemma Formation proves the existence of faunal interchange but it does not prove geographic proximity between Baltica and Laurentia because many Ordovician conodonts clearly were able to migrate across the Iapetus and other Early Paleozoic oceans (Bergström 1990b). The conodont faunas of the Svartsætra and Hølonde limestones in the Trondheim region show profound Laurentian faunal affinities but it is uncertain whether this is due to particular environmental conditions that led to the development of a special biofacies in two rather widely separated regions, or to geographic proximity of the Hølonde-Meldal area to Laurentia that led to faunal exchange. Accordingly, it is pertinent to be very cautious when using conodonts like those discussed herein as tools for reconstructions of the paleogeographic relations of the Trondheim district and other areas in the Iapetus region.

### Concluding remarks

The present study is the first report of conodonts of Laurentian faunal affinities in the upper Middle Ordovician of the Trondheim region. These conodonts, although scarce

and not well preserved, provide a rather precise age of the previously undated Svartsætra limestone. Furthermore, based on the reasonable assumption that the well-known Kalstad Limestone at its classical occurrence 13 km west of Svartsætra represents the same phase of unique carbonate deposition in the Trondheim region as that of the Svartsætra limestone, the age of the former unit, which has been highly controversial, may also be finally settled.

Attempts to obtain conodonts from other, more or less metamorphosed, limestone units elsewhere in the Trondheim Region, such as those at Grut south of Meldal and Åsen 40 km northeast of Trondheim (Spjeldnæs 1985) have been unsuccessful. However, some conodont elements that appear to have North American Whiterockian faunal affinity have been isolated from the Snåsa Limestone in outcrops along the E6 Highway southwest of Følling (GR 235 202) near the western end of Lake Snåsa about 95 km northeast of Trondheim. A few conodonts that appear to be of Middle Ordovician age have also been found in the Skølberg Formation of Bruton & Bockelie (1979) on the Island of Smøla off the west coast of Central Norway about 120 km west-southwest of Trondheim, but further sampling is needed to clarify the age and affinity of that fauna. Clearly, conodont research in the Ordovician of the Trondheim Region is both challenging and time-consuming, but as shown by the present study, low-metamorphic Caledonian rocks that look unpromising for this kind of investigations may produce faunas of considerable stratigraphic and paleontologic interest.

### Remarks on selected species

*Aphelognathus* cf. *gigas* Sweet, 1983

Figures 2; H, I, J, M, O, S

This distinct species is characterized by well-developed, in most cases peg-like, process denticles; a slightly angulate Pa element with flaring basal cavity and, in some but not all specimens, a gap in the denticle row just in front of the cusp; angulate (not pastinate) Pb element; bipennate M element; and a bipennate Sc element with several distinct denticles laterally on the anterior process.

The present species appears to be unnamed but it should be noted that some aspects of the taxonomy of *Aphelognathus* are still not well understood. It differs from *Aphelognathus gigas* Sweet from the lower Chatfieldian Fite Formation of Oklahoma (Sweet 1983) in the appearance of the Pa element (=Pb element in Sweet 1983) and in having a Pb element (Pa element in Sweet 1983) that is not clearly pastinate (dichognathiform). However, these differences are relatively small and the present species may well be a direct descendant of *A. gigas*. A form described by Leslie (1995) as *Aphelognathus* cf. *A. gigas* from the upper Turinian and lowest Chatfieldian of the North American Midcontinent is closely similar to the Norwegian species and differs only in that the Pb element tends to be pastinate rather than bipennate. The present species differs from *Aphelognathus politus*

Hinde in, among others, the denticulated margin of the Sc element. The species is well represented in collections from middle-upper Chatfieldian strata in the Trenton Group of New York and Ontario assembled by Schopf (1966) and from the Lexington Limestone of Kentucky and Ohio (Bergström & Sweet 1966). It is quite abundant in undescribed collections from the Mjøsa Limestone and also occurs in the Saku Member of the Vasalemma Formation in Estonia. It appears to have a short range and be an excellent index of the uppermost Middle Ordovician in North America.

*Belodina confluens* Sweet, 1979

Figures 2; F

Representatives of this characteristic species occur through virtually the entire Svartsætra limestone sequence and both rastrate and geniculate elements are present. These are closely similar to specimens from the upper Lexington Limestone in Kentucky (Bergström & Sweet 1966, Pl. 31, figs. 14-17, 19) and other upper Middle and Upper Ordovician units in the North American Midcontinent (for distribution data, see Sweet 1981). The species is rare in northwestern Europe but is known from the Craighead Limestone in the Girvan area, South Scotland (Bergström 1990a, Pl. 3, figs. 8-12), the Jonstorp Formation and coeval strata in Sweden (Bergström & Bergström 1996, Fig. 9.P), the Saku Member of the Vasalemma Formation in Estonia (Viira 1974, Pl. 13, fig. 11), and erratic boulders in Poland (Dzik 1976, Fig. 14.g-h). The species is also present in undescribed collections from the Mjøsa Limestone.

«*Distacodus*» cf. *trigonus* Schopf, 1966

Figure 2; A

A single specimen appears so similar to the symmetrical element of the apparatus of Schopf's (1966) Chatfieldian species from the Trenton Group of New York that it is likely to be the same form but additional specimens are needed to confirm this. It is certainly not congeneric with *Distacodus* Pander, 1856 and probably represents a new genus. This is an unusual form in the North American Middle Ordovician Midcontinent faunas. Specimens from the Upper Ordovician, such as those of the Dubuque Formation of Iowa, are similar morphologically and may represent the same species.

*Drepanoistodus* spp.

Figure 2; C

Specimens of the widespread genus *Drepanoistodus* Lindström, 1971 are present in moderate numbers in the Svartsætra samples. Some are conspecific with *D. superbus* (Branson & Mehl, 1933) whereas the affinities of others, such as the illustrated element, remain in doubt. The taxonomy of the genus is currently unsatisfactory, and large collections of specimens are needed for safe identification of several species. At the present time, Middle Ordovician specimens of *Drepanoistodus* have little, if any, biostratigraphic significance.

*Panderodus* cf. *feulneri* (Glenister, 1957)

Figure 2; D

Some of the Svartsætra samples contain robust elements of a species of *Panderodus* characterized by a very large base and a relatively short cusp. Although reminiscent of *P. feulneri* (Glenister) in general shape, they lack the well-defined lateral costae present in representatives of that species. The present species also resembles *Panderodus breviusculus* Barnes, 1977, but differs in the outline of the base. The Svartsætra species is also present in undescribed collections from the Mjøsa Limestone. *Panderodus feulneri* was originally described from the Upper Ordovician Maquoketa Shale of Iowa (Glenister 1957) and similar forms are widely distributed in the Middle and Upper Ordovician of the North American Midcontinent. These faunas, as well as that of Svartsætra, also contain a much more slender form, which is commonly identified as *Panderodus gracilis* (Branson & Mehl). These species have little, if any, biostratigraphic significance.

*Phragmodus undatus* Branson & Mehl, 1933

Figure 2; G

This highly characteristic species, which has recently been discussed in some detail by Leslie & Bergström (1995), ranges through the entire Svartsætra succession but is represented by only a small number of specimens that in all respects are identical with North American specimens. It is one of the most common conodonts in the upper Middle and Upper Ordovician of North America (for occurrence data, see Sweet 1981) but it is rare in Europe, being recorded, in most cases just as single specimens, from the upper Middle Ordovician of Wales (Savage & Bassett 1985), the Upper Ordovician of the Girvan area, South Scotland (Bergström 1990a, Pl. 4, fig. 10), the Saku Member of the Vasalemma Formation (Viira 1974, Pl. 12, fig. 19), and the Upper Ordovician of Sweden (Bergström unpublished). The species is quite abundant in the Mjøsa Limestone.

*Plectodina* cf. *aculeata* (Stauffer, 1930)

Figures 2; N, P

A few, rather poorly preserved, specimens in the Svartsætra collection are tentatively referred to this species but additional specimens are clearly needed for safe identification. The tentative identification of the Svartsætra specimens is mainly based on the pastinate Pb element. In North America, *Plectodina aculeata* is widely distributed in, and highly characteristic of, strata of Chazyan to early Chatfieldian age (Sweet 1981). The lowest part of its stratigraphical range was distinguished as the *Plectodina aculeata* Zone by Sweet (1984).

*Plectodina* cf. *tenuis* (Branson & Mehl, 1933)

Figures 2; K, L, Q, R, T

A few specimens in the Svartsætra collections are closely similar to *Plectodina tenuis* (Branson and Mehl) and four such elements are illustrated in Fig. 2. Because of the small number of specimens at hand, the identification is tentative but



no significant morphological differences were noted at a direct comparison with the North American form (cf. Sweet 1981, Pl. 12, figs. 11-12, 14, 18). In North America, representatives of *P. tenuis* are known from many localities in strata ranging in age from the Chatfieldian Stage to the Upper Ordovician Richmondian Stage.

#### *Staufferella* sp.

Figure 2; E

A single specimen in the Svartsætra samples is similar to representatives of *Staufferella*, especially *S. falcata* (Stauffer, 1935), but additional specimens are needed for specific identification. This specimen has the conspicuous lateral costae with weakly developed nod-like basal structures characteristic of the genus but the posterior face of the cusp does not exhibit the carinae seen in most specimens from the Middle and Upper Ordovician of North America. More typical *Staufferella* specimens occur in unpublished collections from the Mjøsa Limestone.

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## Appendix

List of conodonts in each of the Svartsætra samples.

Sample m-levels given within brackets represent measurements from the top of the tuff bed near the northwestern end of the section. Number of specimens is given in brackets after each entry.

Sample 82B15-1 (25 m). *Belodina confluens* Sweet (1); *Belodina?* sp. (1); *Panderodus cf. feulneri* (Glenister) (2); «*Distacodus*» cf. *trigonius* Schopf (1); *Panderodus gracilis* (Branson & Mehl) (3); *Phragmodus undatus* Branson & Mehl (2); *Plectodina cf. tenuis* Branson & Mehl (3); *Staufferella* sp. (1); *Walliserodus?* sp. (1); coniform elements indet. (2); blade fragment of *Plectodina* or *Aphelognathus* (1).

Sample 82B15-2 (34 m). *Aphelognathus cf. gigas* Sweet (2); *Belodina confluens* Sweet (2); *Drepanoistodus suberectus* (Branson & Mehl) (2); *Panderodus gracilis* (Branson & Mehl) (4); *Plectodina cf. tenuis* Branson & Mehl (5); Pb element indet. (2); blade fragment (1).

Sample 82B15-3 (43 m). *Aphelognathus cf. gigas* Sweet (1); *Panderodus cf. feulneri* (Glenister) (3); *Phragmodus undatus* Branson & Mehl (1); *Plectodina cf. aculeata* (Stauffer) (1); *Plectodina cf. tenuis* Branson & Mehl (2); coniform element indet. (1); blade fragment indet. (2).

Sample 82B15-4 (45 m). *Belodina confluens* Sweet (2); *Panderodus gracilis*

(Branson & Mehl) (1); *Phragmodus?* sp. (1); *Plectodina* cf. *tenuis* Branson & Mehl (1); coniform element indet. (1); fragment indet. (1).

Sample 82B15-5 (54 m). Barren.

Sample 82B15-6 (62 m). *Belodina confluens* Sweet (2); *Plectodina?* sp. (2); coniform elements indet. (2); blade fragments indet. (5).

Sample 82B15-7 (70 m). *Aphelognathus* cf. *gigas* Sweet (1); *Belodina confluens* Sweet (1); *Drepanoistodus suberectus* (Branson & Mehl) (1); *Phragmodus undatus* Branson & Mehl (1); *Panderodus* cf. *feulneri* (Glenister) (1); *Panderodus gracilis* (Branson & Mehl) (6); *Plectodina* cf. *tenuis* Branson & Mehl (1); *Plectodina* sp. (4); coniform elements indet. (4).

Sample 82B15-8 (76 m). *Aphelognathus* cf. *gigas* Sweet (1); *Panderodus gracilis* (Branson & Mehl) (3); blade fragment (3).

Sample 82B15-9 (81 m). *Aphelognathus* cf. *gigas* Sweet (1); *Belodina confluens* Sweet (1); *Phragmodus undatus* Branson & Mehl (3); *Plectodina* cf. *tenuis* (Branson & Mehl) (1); *Panderodus gracilis* (Branson & Mehl) (4); blade fragments indet. (2); coniform element indet. (1).

Sample 82B15-10 (85 m). Fragment of blade (1).

Sample 82B15-11 (97 m). *Belodina confluens* Sweet (1); *Panderodus* cf. *feulneri* (Glenister) (3); *Phragmodus undatus* Branson & Mehl (2); *Plectodina?* sp. (1); coniform elements indet. (4).