New data on Upper Ordovician conodonts from the Trondheim Region, Central Norwegian Caledonides

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A small collection of Upper Ordovician (Early-Mid Katian) conodonts has been recovered from low-grade metalimestones in the Köli Nappes of the Upper Allochthon of the Trondheim Region, central Norway. For the Snåsavatnet area and the western coast of the Frosta peninsula, these are the first reported conodonts. Conodonts that were obtained from the Svartsætra limestone of the Hølonda area confirm an Early Katian (Caradocian) age for the formation, in accordance with a previous study. The composition of the species and poor preservation of conodonts from the Snåsavatnet and Frosta areas do not permit a precise age assignment. However, the conodont faunas are most probably coeval with that of the Svartsætra limestone, even though the taxonomic composition of conodont assemblages from the latter locality is completely different. The limestones of the Snåsavatnet area (Snåsa Limestone) and the western coast of the Frosta peninsula (Risset limestone) yielded elements of the pelagic conodonts *Ansella* sp., *Periodon grandis* and *Hamarodus* sp., which are characteristic of a wide variety of depositional environments including basinal and slope settings.

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Introduction

Despite a long history of conodont studies in Baltoscandia, our knowledge of conodonts from the Ordovician rock successions of the Köli Nappes of the Norwegian Caledonides is still comparatively poor and unsatisfactory. Several attempts to recover conodonts from the low-grade metalimestone formations of the Trondheim Region have revealed a general scarcity of conodont elements in the metamorphosed rocks as well as a poor preservation of most specimens recovered. Consequently, all the conodont collections studied so far do not exhibit the complete diversity of the fauna and, thus, generally preclude a precise age determination (Bergström 1979, 1997).

The most substantial conodont data have been obtained from the Hølonda and Svartsætra limestones of the Hølonda district in the Støren Nappe of the southwestern part of the Trondheim Region (Bergström 1979, 1997). These studies pointed to Darriwilian and Caradocian ages, respectively, of the conodont faunas, and indicated a faunal affinity to the Laurentian biogeographic province. Later, after the earlier study, it was considered that the Hølonda conodonts also demonstrate some features of open-/deep-water faunas from the marginal areas of different palaeocontinents (Bergström 1990). The *Paroistodus horridus* and *Histiodella* elements, for example, that were recorded in the Hølonda Limestone are known not only from North America, Argentina, Canada and Newfoundland but have also been found in relatively deep-water facies of the Oslo Region and Central Sweden (Löfgren 1978, Rasmussen 2001). These species are more or less cosmopolitan and characterise the open-sea environments. However, the *Coleodus?* sp. and *Juanognathus* elements have not been found in any of the Baltoscandian platform sections and evidently demonstrate the largely Laurentian affinity of the Darriwilian conodont fauna from the Hølonda Limestone.

The Katian conodonts recovered from the Svartsætra limestone, on the other hand, are not unique for the Baltic region. Most of them have been recorded in mainly shallow-marine sediments of the Baltoscandian platform in the Mjøsa Limestone c.100 km to the north of Oslo, and in the Saku Member of the Vasalemma Formation in Estonia (Viira 1974, Bergström 1997). Furthermore, a similar taxonomic composition has been found in a conodont fauna from the coeval dolomites of the Elizavetino Formation in the St. Petersburg region of Russia (T.J.T., unpublished data).

In other carbonate rocks of the Köli Nappes of the Trondheim Region, conodonts are either unknown or occur in extremely low abundances. In this study, a few unidentified conodont elements were recorded in a low-grade limestone formation on the island of Smøla (Fig. 1a) and in an area near Snåsavatnet lake, Nord-Trøndelag, showing that these rocks may be promising for future conodont studies.

In 2005, we commenced a study aimed at recovering conodonts from several limestone bodies in metasedimentary rocks of the Trondheim Region. More than 30 samples from 21 different localities to the north and east of Trondheim were collected (see Appendix); but only three of the samples yielded poorly preserved but identifiable and informative conodonts. We also resampled from parts of the Svartsætra limestone section that had earlier been studied by S. Bergström; and took samples from the Skjølberg Limestone (Bruton & Bockelie 1979) on Smøla. In this paper we present the results of our investigations. Although the number of conodont elements recovered is small, the results do provide some new data adding to our understanding of the faunal diversity and biofacies attribution of conodonts in the Norwegian Caledonides. Because many aspects of these unique conodont faunas from the region remain poorly known and understood, they clearly merit a much more detailed study.

Geological setting

The Scandinavian Caledonide orogen as a whole is composed of a series of nappes and thrust sheets that were transported east- to southeastwards during the Siluro-Devonian, Scandian orogeny onto a crystalline basement ranging in age from Archaean to Mesoproterozoic. Subdivision of the tectonostratigraphy into Lower, Middle, Upper and Uppermost Allochthons (Roberts & Gee 1985) largely reflects the original palaeogeography marginal to the palaeocontinent Baltica (platform and continental rise), and the outboard exotic terranes of the Iapetus Ocean and parts of the margin of the palaeocontinent Laurentia (Roberts 1988, Stephens & Gee 1989, Roberts et al. 2002a).

In this contribution we are concerned solely with the oceanic terranes of the Upper Allochthon, generally referred to as the Köli Nappes (Roberts & Stephens 2000), though in Central Norway known with several local names. These particular nappes are characterised by thick, mostly greenschist-facies, volcanosedimentary successions ranging in age from Early Ordovician (Mid Arenig) to Early Silurian (Llandovery), and in some cases have fragmented ophiolites of Cambrian to Early Arenig age at their bases (e.g., Gale & Roberts 1974, Roberts et al. 2002b, Nilsson et al. 2005).

The identified conodonts reported herein occur in metalimestones of the Støren Nappe, in Ordovician successions that vary from shallow-water and volcanic island fringing deposits to deeper-marine turbidite accumulations. In the Snåsavatnet district, the Snåsa Limestone (Fig. 1) is known to interdigitate with tholeiitic basalts of calc-alkaline, island-arc type (Roberts 1982). The limestone from western Frosta

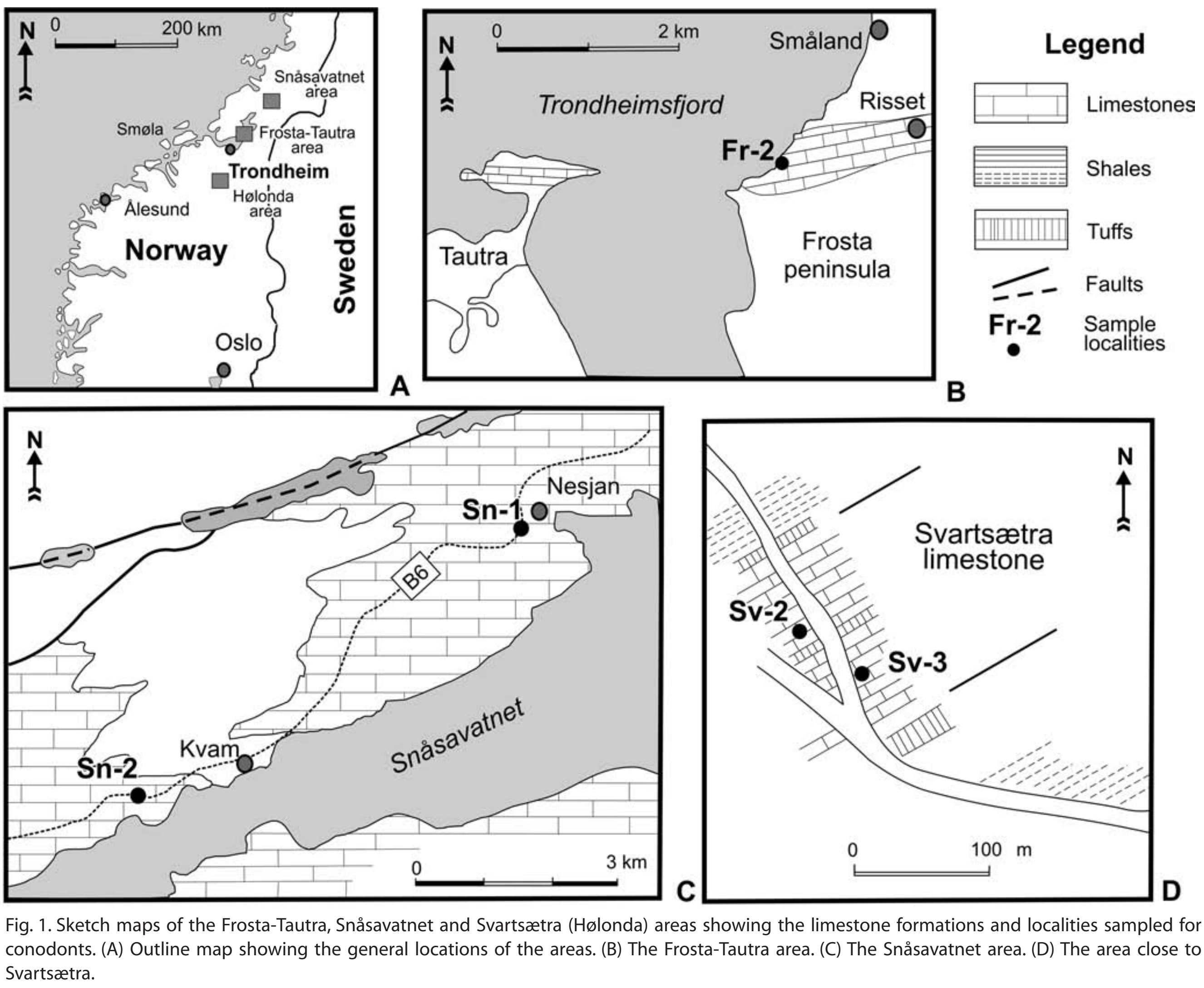

Fig. 1. Sketch maps of the Frosta-Tautra, Snåsavatnet and Svartsætra (Hølonda) areas showing the limestone formations and localities sampled for conodonts. (A) Outline map showing the general locations of the areas. (B) The Frosta-Tautra area. (C) The Snåsavatnet area. (D) The area close to Svartsætra.

peninsula (which extends to the island of Tautra) (Fig. 1) is also associated with tholeiitic volcanites and is succeeded by a heterogeneous succession of sedimentary rocks varying from inferred shallow-marine to deeper-marine, flysch-dominated environments (Roberts 1969, Strømmen 1983). This limestone is here named, informally, the Risset limestone (Fig. 1b). The third, conodont-bearing, carbonate unit considered here is the Svartsætra limestone, near Hølonda, southwest of Trondheim (Fig. 1) (Bruton & Bockelie 1982, Bergström 1997). Although the regional geological relationships are not known, this particular limestone is associated with silty shales and felsic tuff beds.

Material and methods

Samples for conodont study were collected from 21 localities in the Snåsavatnet, Frosta-Tautra and Hølonda areas of Nord- and Sør-Trøndelag, and from a limestone on the island of Smøla in the county of Nord-Møre (Fig. 1 and Appendix). The weight of each sample varied from 1 to 2 kg. In total, 32 kilos of rock were collected and subsequently processed using buffered acetic acid for standard conodont extraction from carbonate material (Jeppsson et al. 1999). The majority of the samples were found to be barren and only six yielded conodont elements. In most cases, conodonts were recovered from the darker-grey carbonates with significant admixtures of terrigenous material. The numerical distribution of conodonts in the productive samples is shown in Fig. 2. The state of conodont preservation varies considerably from very bad to relatively good, but the majority of the elements were partly distorted and discoloured during the processes of metamorphism and deformation. Most elements exhibit a colour alteration index (CAI) value of about 5, suggesting that the rocks were heated to some 300°C during the Scandian orogeny.

The conodont fauna and biostratigraphy

Taken as a whole, the thirty-two kilos of limestones produced just 52 conodont elements. Such a low abundance of conodonts in the carbonates of the Trondheim area was not surprising, as similar low abundances had been reported in previous investigations from the region (Bergström 1979, 1997). A low content of conodonts, in comparison with that from the Lower and Middle Ordovician limestones of the platform part of Baltoscandia, is not a feature necessarily typical of the Upper Allochthon carbonate rocks, but it is quite characteristic of Katian rocks everywhere in Baltoscandia. Studies of the Upper Ordovician in the eastern Baltic (T.J.T., unpublished data), Sweden (Bergström et al. 2004) and in Katian erratics from Finland (Merrill 1980) have shown that Katian sediments usually yield scarce conodonts, generally up to several tens of specimens per kilogram.

In our study, the most abundant, identifiable and informative conodonts were obtained from the Snåsa Limestone close to Snåsavatnet, the Risset limestone on Frosta peninsula, and from the Svartsætra limestone (Fig. 2).

The Svartsætra limestone

The most numerous conodonts were obtained from the informally named Svartsætra limestone formation. One of three samples was barren whereas one yielded 25 conodont elements (Fig. 2). The collection of S. Bergström, taken in 1982 in newly made exposures, was more abundant and contained more than 100 elements (Bergström 1997). Our resampling of this trackside locality was severely hampered by the fact that it is now almost completely covered by vegetation and, accordingly, the restricted recovery of conodont elements did not improve our knowledge on faunal diversity or biostratigraphy of this stratigraphic unit.

The conodont assemblage is numerically dominated by *Panderodus* elements, which accords with the descriptions reported by Bergström (1997). *P. gracilis* is not particularly diagnostic biostratigraphically, but its presence implies an age not older than Late Darriwilian. The other taxa, ?*Aphelognatus* sp. ?*Phragmodus* sp. and *Belodina* sp., are represented by only a few specimens that do not allow us to identify them confidently (Fig. 5). Together, the species confirm an Early Katian age for the Svartsætra limestone, in accordance with the previous study of this formation (Bergström 1997). However, a precise correlation of the North American fauna with those reported from other regions is complicated by the apparently very different ranges of the key North American Midcontinent species of

Localities / Conodont taxa	Snåsa limestone, Sn-1	Snåsa limestone, Sn-2	Risset limestone, Fr-2	Svartsætra limestone, Sv-2	Svartsætra limestone, Sv-3	Smøla Island, Sm-1
Panderodus cf. *gracilis*	–	1	2	5	12	–
Drepanoistodus sp.	–	2	–	–	3	–
Belodina sp.	–	–	–	–	2	–
?*Aphelognatus* sp.	–	–	–	–	3	–
Ansella sp.	–	3	1	–	–	–
Periodon grandis	–	1	1	–	–	–
Protopanderodus sp.	–	1	–	–	–	–
?*Hamarodus* sp.	–	1	–	–	–	–
Unidentified fragments	1	4	2	–	5	3

Fig. 2. List of conodonts and the number of elements recovered in samples from the productive limestone localities.

Panderodus, Belodina and *Phragmodus* outside the North American palaeocontinent, e.g., in Baltoscandia.

As already reported by Bergström, the fauna from the Svartsætra limestone formation differs strikingly from most coeval, Baltoscandian conodont faunas and reveals a closer resemblance to the faunas of the Mjøsa Limestone in the Lower Allochthon north of the Oslo Region and the Vasalemma Formation in Estonia (Viira 1974, Bergström 1997). The latter lithostratigraphic unit encompasses the interval from the uppermost part of the Keila Regional Stage to the lowermost part of the Oandu Regional Stage of the Late Caradocian in terms of the British regional series (Fig. 3). Among the other conodonts recovered from dolostones of the Vasalemma Formation, Viira (1974) illustrated and briefly described, in formal nomenclature, the *Belodina, Aphelognatus* and *Phragmodus* species that are considered to be representatives of the Midcontinental 'Laurentian' fauna.

There is also one more locality in the Baltic region from which 'Laurentian' conodonts have been described. This is the Mochty area near Warsaw, Poland, where erratic boulders have yielded numerous Oandian *Aphelognathus* and *Icriodus* elements (Dzik 1983).

A similar conodont fauna to that found at Svartsætra has also been recovered from dolostones and marlstones of the uppermost part of the Elizavetino formation and the lowermost part of the Ragavere formation in the vicinity of St. Petersburg (Fig. 3). Besides the taxa listed above, the conodont assemblages from this section are rich in *P. gracilis* and *Icriodella superba* elements. The close similarity of conodont assemblages from two rather widely separated localities — the Norwegian Upper Allochthon and the eastern Baltic platform of Baltoscandia (which were even farther apart prior to the Scandian orogeny) — led Bergström (1997) to infer the existence of a brief period of shallow-water, subtropical or tropical deposition in these separate regions. In central parts of the palaeobasins with the deeper-marine settings inferred to exist at that time, representatives mainly of *Baltoniodus, Amorphognathus* and *Semiacontiodus* genera were found.

The Early Katian in the Baltoscandian area was a time of remarkable biotic, climatic, sea-level and facies changes that were even more significant in the shallower-marine parts of the basin in the Estonia and St. Petersburg regions (Ainsaar et al. 2004). Over a vast area of these regions, the deposits of the Late Keila and Early Oandu regional stages are absent as a result of the regression, sea-level drop and non-sedimentation. In a sequence-stratigraphic context this hiatus is interpreted as a first-order sequence boundary (Dronov & Holmer 1999). The carbonates of the Vasalemma Formation in northwestern Estonia and the dolomites of the Elizavetino formation in the St. Petersburg region are mostly shallow-marine deposits of shoal type. In deeper parts of the basin the facies changes were not so remarkable, e.g., in the Siljan area of Sweden this stratigraphic level corresponds to the boundary between the Skagen and overlying Moldå limestones (Ainsaar et al. 2004). The Early Katian sea-level drop in

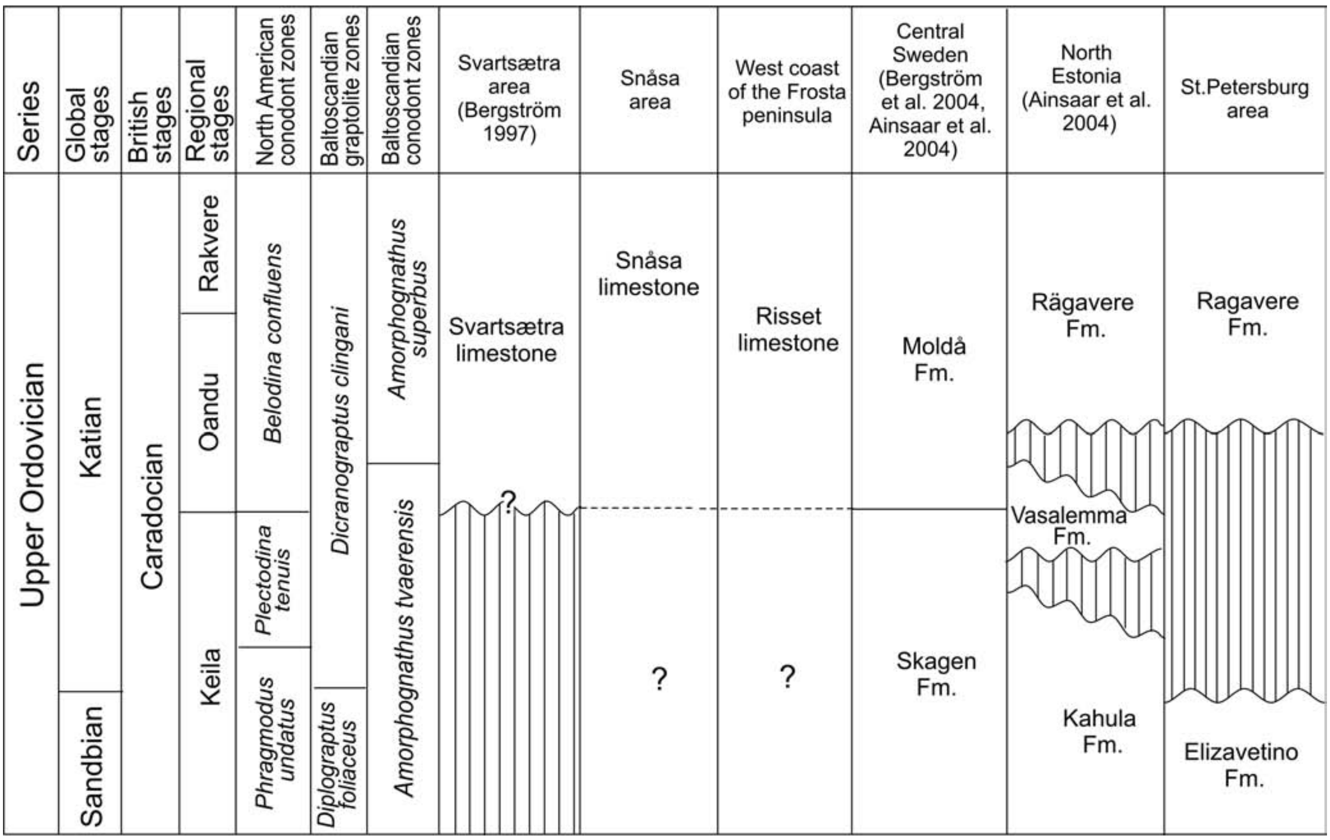

Fig. 3. Correlation of stratigraphic units between selected regions of Norway, Sweden, Estonia and the St. Petersburg area of Russia.

Baltoscandia is believed to have been a part of a global oceanographic event that can also be traced in North America (Holland & Patzkowsky 1998, Saltzman et al. 2003, Ainsaar et al. 2004). Among the arguments demonstrating the synchronism of environmental changes in both continents, i.e., Baltica and Laurentia, are the similar trends in $\delta^{13}C$, coeval facies changes and faunal distribution. As was supposed by Bergström (1997), the Svartsætra limestone with its shallow-water fauna of 'Laurentian' affinity was probably deposited during the same period of regression, even though its depositional setting was not the same as that of the Vasalemma or Elizavetino formations.

The Snåsa and Risset limestones

The conodonts from the Snåsa Limestone formation close to Snåsavatnet and from the Risset limestone on the western coast of the Frosta peninsula (Fig. 2) are scarce and poorly preserved (Figs. 4 & 5). The faunas from these two localities are similar in taxonomic composition but differ in dominant forms. Accordingly, any conclusions about the composition of the conodont fauna on the basis of so little material must be viewed with caution. Nevertheless, the conodonts from the Snåsa and Risset limestones do differ quite significantly from those of the Svartsætra and Hølonda limestones; and all these faunas have only one *Panderodus* species in common.

The most abundant and common component of the conodont faunas from the Snåsa and Risset limestones are the elements of *Ansella* sp.(Fig. 4). Representatives of *Ansella* Fåhræus and Hunter are distributed in almost all continents and typically occur in a wide variety of facies from shallow-water tropical carbonates of North America (Bauer 1994, Leslie 2000) to the deep-marine carbonate and siliceous sequences of open oceanic environments (Tolmacheva et al. 2004, Heredia et al. 2005). The same genus has also been found in Australia (Stait & Druce 1993, Zhen et al. 1999), the Pechora palaeobasin of northern Russia (Mel'nikov 1999), China (Zhang 1998) and Siberia (Tesakov et al. 2003). *A. jemtlandica*, the most well known species of *Ansella*, occurs in the Baltic palaeobasin in its deeper-water, offshore successions (Löfgren 1978, Rasmussen 2001) and has never been recorded in the more shallow-water sediments of the eastern Baltic, the St. Petersburg region or Estonia. The stratigraphic range of *A. jemtlandica* in Baltoscandia is restricted to the Kunda, Aseri and lower Lasnamägi regional stages, whereas the subsequent species of the same phylogeneric lineage in other palaeocontinents occurred in the uppermost Darriwilian, Sandbian (Zhang 1998) and in the Katian (Zhen et al. 1999, 2004, Leslie 2000, Pyle & Barnes 2001, Agematsu et al. 2007). A few elements of the younger *Ansella* taxon found in the Anglo-Welsh region were not described (Ochard 1980), but that paper notes the occurrence of a post-Darriwilian *Ansella* species in the Baltoscandian province. *Ansella* sp. elements found in the Snåsa and Risset limestones most likely also represent a younger species of *Ansella* that flourished in marginal parts of the Baltoscandian basin and in parts of the rapidly contracting Iapetus Ocean realm now represented by the Köli Nappes during the Late Ordovician.

Two elements in the collection appear to belong to *Periodon grandis* (Ethington) (Fig. 4G,H), the youngest taxon in the phylogenetic lineage of *Periodon*. It has a wide geographic distribution and is well known from Upper Ordovician rocks of North America (Bergström & Sweet 1966), Baltoscandia (e.g., Löfgren 1978), Kazakhstan (T.J.T., unpublished data), Australia (Zhen et al. 2003), and the far east of Russia (Tarabukin 2005). *Periodon grandis* occurs in diverse sedimentary facies, but is usually most dominant in deep oceanic and slope sediments, e.g., in chert deposits of Kazakhstan (T.J.T., unpublished data). The first occurrences of *P. grandis* are recorded in the Early Sandbian, and the last occurrences in Late Katian. This species is most distinctive in the conodont faunas from the Snåsavatnet and Frosta (Risset) localities. The *Hamarodus* species are comparatively common and widespread in the Late Ordovician of Baltica and of other palaeocontinents with a conodont fauna of North Atlantic affinity, e.g., South China and Malaysia (Wang et al. 1996, Aghematsu et al. 2007) and have only very rarely been found in North America (Sweet 2000). The earliest occurrence of *Hamarodus* in Baltoscandia and surrounding areas is in the Early Katian (the Oandu Regional Stage).

Overall, the conodont collection from the Snåsa and Risset limestones is too small and the conodonts are too poorly preserved for a precise age assignment, but they most probably indicate an Early-Mid Katian age for the sampled sediments. Although the stratigraphic interval of the Svartsætra, Snåsa and Risset limestones is approximately the same (Fig. 3), it is difficult to say whether or not the deposition of the three carbonate formations was truly contemporaneous.

Palaeoecological significance

The conodont biofacies of the Upper Ordovician of Baltoscandia have been discussed in numerous studies (e.g., Sweet & Bergström 1984, Zhen & Percival 2003, Bergström et. al. 2004) in which they are considered in relation to the depth of the basin. The most typical, relatively deep-water biofacies of the Upper Ordovician fauna from Norway (the Oslo Region) and Sweden is the *Hamarodus-Dapsilodus-Scabardella* biofacies with a dominance of *Hamarodus europaeus* and *Dapsilodus mutatus*. The slightly shallower-marine environments of the Moldå Formation in Dalarna are characterised by abundant *Panderodus, Icriodella* and *Belodina* taxa (Sweet & Bergström 1984, Bergström et al. 2004). The 'Laurentian' fauna that was recorded in the most shallow-water settings in the Mjøsa area of Norway and in Estonia and Russia during Oandian time was tentatively assigned to the *Phragmodus-Icriodella-Plectodina* biofacies (Sweet & Bergström 1984, Bergström 1997). The 'Laurentian' conodonts from the Svartsætra limestone were considered to represent the relatively shallow-marine, North American biofacies that, besides coniform elements, is dominated by *Aphelognathus* and *Plectodina* (Bergström 1997). The attribu-

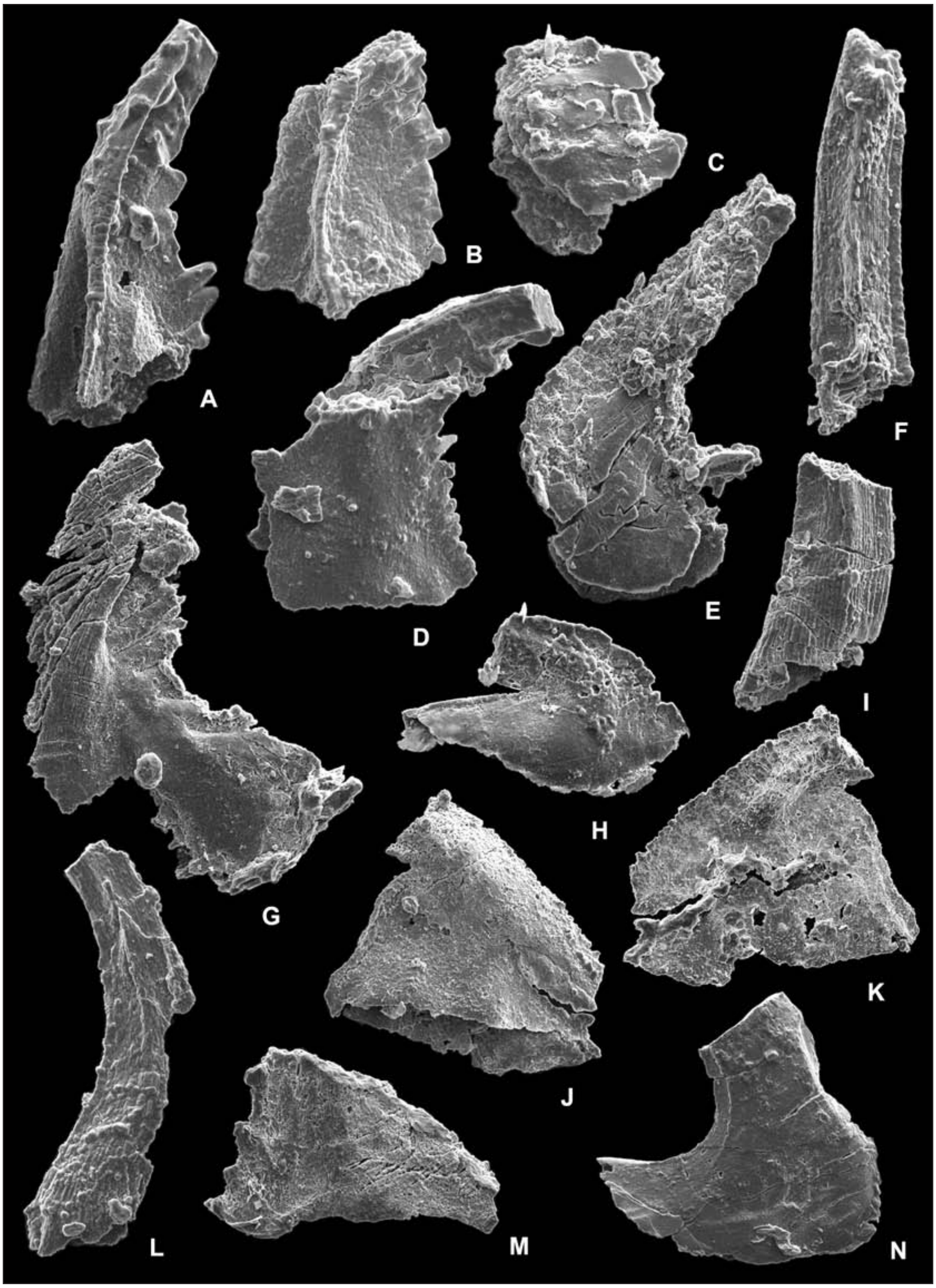

Fig. 4. Conodonts from the Snåsa limestone (Fig. 1c) and the Risset limestone (Fig. 1b).

Ansella sp.

A, Sa element, PMO 212.241, Snåsa Limestone, x 240.

B, Sb element, PMO 212.242, Snåsa Limestone, x 230.

D, ?Sc/?P element, Snåsa Limestone, PMO 212.243, x 200.

J, M element, Risset limestone, outer view, PMO 212.244, x 136.

K, the same element, Snåsa Limestone, inner view, PMO 212.244, x 136.

Drepanoistodus sp.

C, fragmentally preserved oistodiform element, lateral view, Snåsa Limestone, PMO 212.245, x 165.

?*Drepanodus* sp.

E, Sc (sculponeaform) element, Risset limestone, PMO 212.246, x 145.

Panderodus cf. *gracilis* (Branson & Mehl).

F, fragment of element, Risset limestone, PMO 212.247, x 185.

I, fragment of element, Risset limestone, PMO 212.248, x 180.

L, fragment of element, Snåsa Limestone, PMO 212.249, x 185.

Periodon grandis (Ethington 1959).

G, Sc element, Risset limestone, PMO 212.250, x 220.

H, M element, Snåsa Limestone, PMO 212.251, x 180.

Hamarodus sp.

M, fragment of P element with denticles on anterior side, Snåsa Limestone, PMO 212.252, x 170.

Protopanderodus sp.

N, Snåsa Limestone, PMO 212.253, x 120.

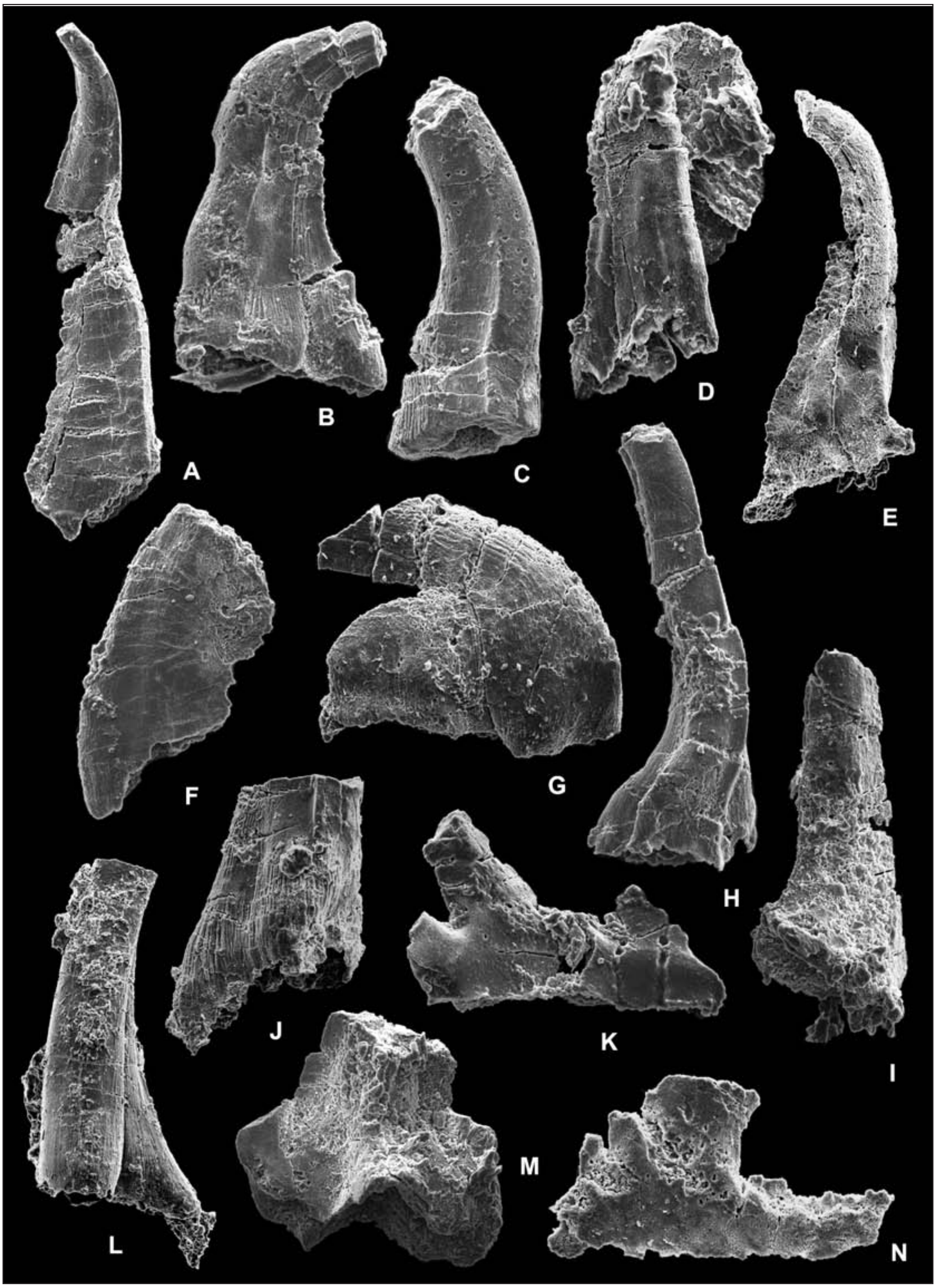

Fig. 5. Conodonts from the Svartsætra limestone (Fig. 1d).
Panderodus sp.
A, r element, PMO 212.254, x 180.
B, ?sq element, PMO 212.255, x 130.
C, ?sq element, PMO 212.256, x 155.
D, deformed element, PMO 212.257, x 120.
E, r element, PMO 212.258, x 190.
H, ?sq element, PMO 212.259, x 170.
J, symmetrical ?p element, PMO 212.260, x 180.
L, symmetrical ?p element, PMO 212.261, x 145.
Belodina sp.
F, fragment of compressiform or grandiform (q) element, outer view, PMO 212.262, x 180.
G, eobelodiniform (r)element, inner view, PMO 212.263, x 150.
Drepanoistodus sp.
I, poorly preserved suberectiform element, PMO 212.264, x 160.
Fragment of unidentified conodont element
K, PMO 212.265, x 165.
?*Aphelognathus* sp.
M, broken Sa element, posterior view, PMO 212.266, x 110.
N, Pa element, PMO 212.267, x 140.

tion of 'Laurentian' conodonts from the Svartsætra limestone to the North American *Aphelognathus-Oulodus* biofacies is, in our opinion, open to question, as a complete diversity of species is not recorded, due to a general paucity of conodont data from the Trondheim Region. Moreover, the treatment of small collections of conodonts in a biofacies context is, to a large degree, uncertain as they tend to be dominated by a particular, more easily recoverable species. In the case of poorly preserved assemblages such as those from the Trondheim Region, the dominant forms in the collection may not be the same as in the original assemblage that can have been strongly influenced by diagenetic processes destroying the most fragile and tiny elements.

However, in spite of the small number of conodonts, it is clear that the faunas of the Snåsa and Risset limestones differ significantly from the conodont fauna described from the Svartsætra limestone. The faunas from Snåsa and Risset contain *Periodon, Protopanderodus, Hamarodus* and *Ansella* species (Fig. 4) that had a pelagic mode of life and ranged widely across the Iapetus Ocean (Armstrong & Owen 2002). Such taxa are characteristic for pelagic biofacies in basinal and slope environments of deposition, influenced by open-ocean conodont communities, although in some cases they have also been recorded in relatively shallow-water sediments. This interpretation of dominant environment and water depth is in accordance with earlier studies of sedimentology and trace fossil assemblages from the Frosta peninsula, where especially the common *Nereites* ichnofacies is indicative of fan-fringe or basin-plain deposits (Roberts 1969, 1984, Uchman et al. 2005). A nice example of a shallower-marine occurrence is the dominance of the Lower Ordovician pelagic conodont *Paracordylodus gracilis* Lindström in the shallow-water glauconitic sand of the Billingen Regional Stage in the St. Petersburg Region and in Estonia (Tolmacheva et al. 2001). The components of pelagic communities in shallow-marine shelfal biofacies are only marginally depth related and indicate a wide influence of oceanic water masses on the shelf environments.

On the other hand, the other faunas that occur in the low-grade metasedimentary rocks of the Hølonda district provide useful indications of the depth of the basin. The Svartsætra limestone is relatively rich in brachiopods, molluscs, trilobites, graptolites, corals and echinoderms (Neuman et al. 1997). Finds of gastropods, cephalopods, lithistid sponges and possibly stromatoporoids and corals have also been reported (Spjeldnæs 1985) and later described and illustrated (Roberts 1998) from the Snåsa Limestone. A similar fauna, with the exception of sponges, was reported from the Tautra limestone (Spjeldnæs 1985), which appears to be a continuation of the Risset limestone (Fig. 1b). All these faunas, and especially the gastropods, are known to have typically dominated near-shore or restricted depositional environments, although cephalopods are indicative of relatively deep-marine settings.

Taxonomic notes

The following remarks apply to the identified conodont elements. The most poorly preserved conodont elements are not illustrated where the material is insufficient even for genus identification.

Specimens are currently housed in the collection of the Palaeontological Museum of the Natural History Museum (prefix PMO), University of Oslo, Norway.

Ansella sp.
Fig. 4: A, B, D, J, K

Five elements in the collection are referred to *Ansella* Fåhræus and Hunter. However, a species identification of the *Ansella* elements is not possible in view of their poor state of preservation. They are black and opaque and have broken cusps that make the depths of their basal cavity and the length of cusps — important for species recognition — invisible. The Sa element (PMO 212.241) bears slightly coarser denticles in comparison with elements of *A. jemtlandica* (Löfgren), a typical Baltoscandian representative of the genus. The M element (PMO 212.244) is deformed so it is difficult to conceive its primary morphology; nevertheless, its base is much larger than the base of *A. jemtlandica*. The base of the M element is also larger than the typical form of *Ansella nevadensis* (Ethington and Schumacher) that has coarser denticles than *A. jemtlandica*. The element (PMO 212.243) illustrated in Fig. 4 D bears small denticles on the posterior margin and could be the key element for the identification of the *Ansella* species, but from the state of preservation of the element we cannot determine if it is planoconvex (Sc) or biconvex (P). Biconvex elements of *A. jemtlandica*, in contrast to planoconvex elements, are adenticulated whereas biconvex elements of younger species have small denticles on the posterior margins (Löfgren 1978, McCracken 1995).

The *Ansella* element from the Hølonda district illustrated by S. Bergström has rather small denticles and it is therefore most probably representative of *A. jemtlandica* (Bergström 1979).

?*Aphelognathus* sp.
Fig. 5: M, N

Three fragmental elements were tentatively designated as the elements of *Aphelognathus* Branson, Mehl, and Branson. All three are inadequately preserved for specific or even certain generic determination since such elements are constituents of several multielement taxa.

Belodina sp.
Fig. 5: F,G

Two elements can without doubt be referred to *Belodina* Ethington. The well-preserved eobelodiniform element (PMO 212.263) has a typical panderodont groove, convex anteroaboral margin and posteriorly extended base. The elements bear faint striae between the anterior margin and the axis of the cusp. However, such eobelodiniform elements are constituents of several multielement taxa of *Belodina* and cannot be used for species identification. The other fragment (PMO 212.262) is of a grandiform or compressiform element but is too poorly preserved for species determination. Although its generic designation is uncertain, it is here termed *Belodina* sp.

Hamarodus sp.
Fig. 4: M

One poorly preserved specimen (PMO 212.252) is doubtfully referred to *Hamarodus* sp. It has a broken cusp, two broken denticles on the posterior margin, and four small denticles on the anterior side of the base that is flattened from the lateral sides. The denticulated anterior and posterior margins of the base and the height of the base allow us to attribute the element to *Hamarodus* Serpagli.

Panderodus cf. *gracilis* (Branson & Mehl 1933)
Fig. 4: F, I, L; Fig. 5: A-E, H, J, L

The identification of species of this genus is extremely difficult in view of the poor material recovered. Although the elements from the localities north of Trondheim (in the Snåsa Limestone and the Risset limestone) are very poorly preserved, they do exhibit a fine striation on their surfaces, which is typical for the *Panderodus* elements. The *Panderodus* fauna from the Svartsætra locality is more abundant but the majority of the elements in the present collection suffered a fragmentation that dissembled their primary morphology. However, the best preserved elements are slender and could therefore be identified as P. cf. *gracilis*.

Periodon grandis (Ethington 1959)
Fig.4: G, H

The Sc element (PMO 212.250) designated *Periodon grandis* (Ethington) is poorly preserved but has the typical morphology of *P. grandis* S elements such as the high base and relatively sharp angle between the posterior process and anterior extension of the base. The single M element (PMO 212.251) is also typical for this species; it has no denticles on the anterior margin and the latter is rather short.

Protopanderodus sp.
Fig. 4:N

The single *Protopanderodus* sp. element (PMO 212.253) is asymmetrical with one lateral costa located on the cusp and the base is close to the posterior margin of the element. The posterior margin is slightly elongated whereas the anterobasal corner is short. The latter feature is more characteristic of *Protopanderodus* elements than of representatives of other morphologically similar genera, e.g., *Besselodus* Aldridge. However, in spite of the relatively nice preservation of the element, isolated specimens of this genus are difficult to identify with certainty, even using cf. designation.

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Appendix

List of the localities sampled for conodonts

Levanger area: 1:50,000 map-sheet 'Stiklestad' 1722 IV. Road-cut in limestone along the minor road to Skånes, east of the hill Borråsen, c. 5 km ENE of Levanger and 5 km SW of Verdal. Grid reference: PR 1885 7360. *Two barren samples*.

Levanger area: 1:50,000 map-sheet 'Stiklestad' 1722 IV. Base of small cliff in limestone, north side of a minor road c. 2 km NW of Levanger. Grid reference: PR 1225 7220. *Two barren samples*.

Frosta peninsula: 1:50,000 map-sheet 'Frosta' 1622 II. Road-cut in limestone on minor road near the farm Dalsveet, c. 5 km ENE of Frosta. Grid reference: NR 9170 5470. *One barren sample.*

Frosta peninsula: 1: 50,000 map-sheet 'Frosta' 1622 II. Small quarry, limestone exposed high in a cliff; sample taken from a large fallen block. Grid reference: NR 9325 4455. *One barren sample.*

Risset limestone: 1: 50,000 map-sheet 'Leksvik' 1622 III. Well exposed shore locality between Holmberget and Lenvik, west coast of Frosta peninsula (Fig. 1b). Grid reference: NR 8360 5185. *A sample (Fr-2) with six conodont elements* (Fig. 2).

Tautra limestone: 1:50,000 map-sheet 'Leksvik' 1622 III (Fig. 1b). Sampled at two localities; grid references NR 8020 5165 and NR 8100 5165. *Three barren samples*.

Snåsa Limestone: 1:50,000 map-sheet 'Snåsavatnet' 1723 II. Long road-cut, west side of the E6 highway, near the farm Nesjan (Fig. 1c). (Fossil locality; see Roberts 1998, NGU Bulletin 434). Grid reference: PS 3700 1875. *One barren sample and one sample (Sn-1) with unidentifiable fragments of conodont elements* (Fig. 2).

Snåsa Limestone: 1:50,000 map-sheet Snåsavatnet 1723 II. Comparatively new road-cut, north side of the E6 highway, near the road junction known as Nordaunankorset (minor road to Meldal) (Fig. 1c). Grid reference: PS 3180 1490. *One sample (Sn-2) with twelve conodont elements* (Figs. 2 & 3).

Hylla limestone: 1:50,000 map-sheet 'Stiklestad' 1722 IV. Very small road-side outcrop, south side of road number 755, just north of Sund, Børgin; c. 1 km southeast of Straumen. Grid reference: PR 1360 8375. *One barren sample.*

Hylla limestone: 1: 50,000 map-sheet 'Stiklestad' 1722 IV. Hylla limestone quarry, western face. Grid reference: PR 1675 8140. *One barren sample.*

Verdal limestone: 1: 50,000 map-sheet 'Levanger' 1722 III. Roadside outcrop, east side of the road leading to the Verdal Quarry, just east of the farm Granly, close to a small bridge over the river Trangdøla. Grid reference: PR 3280 7110. *One barren sample.*

Hølonda area: 1:50,000 map-sheet 'Hølonda' 1521 II. Sharp bend in the road, just east of Gåsbakken. Limestone. Grid reference: 5060 9845. *One barren sample.*

Svartsætra area: 1:50,000 map-sheet 'Hølonda' 1521 II. Along a track, southeast of the old mountain farm Svartsætra, approximately 150 m southeast of locality Sv-3 in Fig. 1d. Shales and calcareous shales. Grid reference: PR 4925 9190. *Three barren samples.*

Svartsætra limestone: 1:50,000 map-sheet 'Hølonda' 1521 II. This is the limestone originally sampled and described by Stig Bergström (1997) (Fig. 1d). Three samples taken from different parts of the formation. All grey-blue (meta)limestone. *One barren sample, one sample (Sv-2) yielded five conodont elements and one sample (Sv-3) contained twenty-five elements* (Fig. 2).

Brenna limestone: Near Brenna, Meråker, c. 70 km east of Trondheim, 1:50,000 map-sheet 'Meråker' 1721 I. A very old, disused quarry in the forest, in (meta)limestone. Grid reference: PR 3890 3405. Grey, 'dirty' limestone at the top of the formation. *One barren sample.* Pale blue-grey, crystalline limestone, middle of formation. *One barren sample*. Cleaved mudstone/claystone – directly above the limestone. *One barren sample.*

Ytterøya: An island in northeastern Trondheimsfjorden, 1:50,000 map-sheet 'Verran' 1622 I. Disused quarry in pale grey/white to laminated blue-grey, low-grade metalimestone. Grid reference: PR 9985 7205. *One barren sample.*

Smøla: Large island in Nord-Møre county (Fig. 1a), 1:50,000 map-sheet 'Smøla' 1321 I. Five samples taken in limestones of the Skjølberg Formation, only one (SM18-03) produced conodont elements. Grid reference: approximately MR 5270 2485, at powerline pole number 31 Sør). *One sample with three unidentified conodont elements.*