Whiterockian (Ordovician) conodonts from the Hølonda Limestone of the Trondheim Region, Norwegian Caledonides

STIG M. BERGSTRÖM

Bergström, S. M.: Whiterockian (Ordovician) conodonts from the Hølonda Limestone of the Trondheim Region, Norwegian Caledonides. *Norsk Geologisk Tidsskrift,* Vol. 59, pp. 295–307. Oslo. 1979. ISSN 0029-196X.

Sparse conodonts isolated from the weakly metamorphosed Hølonda Limestone of the eugeosynclinal succession in the Hølonda–Horg district south of Trondheim represent a species association that differs strikingly from previously described Ordovician conodont faunas from Europe, particularly those from the Baltic Shield. Most of the Hølonda species are common in, and characteristic of, Whiterockian faunas of the Toquima-Table Head Faunal Realm in North America, and they suggest that the part of the Hølonda Limestone that yielded the condonts is equivalent to the *Anomalorthis* Zone and the British *Didymograptus 'bifidus'* Zone, that is, to the lower Llanvirnian. The North American rather than European character of the conodont fauna supports the idea that the Trondheim Region is a fragment of the North American plate.

S. M. Bergström, Department of Geology and Mineralogy, The Ohio State University, 125 S. Oval Mall, Columbus, Ohio 43210, USA.

Extensive investigations during the last 25 years have made the Ordovician conodont faunas of the Baltic Shield among the best known of that period in the entire world. By contrast, apart from two brief records (Bergström 1971, 1977), nothing has been published about these microfossils in the Caledonides in Scandinavia. The purpose of the present paper is to document the presence, and discuss the significance, of a remarkable Ordovician conodont fauna in the Hølonda Limestone of the Vehn–Katugleåsen area in the classic Hølonda–Horg district in the eugeosynclinal Trondheim Region of the central Norwegian Caledonides. Most of these conodonts are unknown from Europe previously and the conodont fauna as a whole is clearly of North American, rather than European, type. The present paper is a preliminary report and a full description and discussion of the Hølonda conodonts will be presented in a future publication. However, it seems justified to publish this preliminary paper because the results reached thus far are of both biostratigraphic and biogeographic significance and various circumstances make it unlikely that this project will be completed in the near future. Further, a great deal of active research is currently centered in this part of the Caledonides and the new conodont data are of interest for both local and regional interpretations.

Geologic and paleontologic framework

The Hølonda–Horg district has long been known as a key area in the regional geology of the Norwegian Caledonides and the succession established there has served as a standard for correlations into more highly metamorphosed parts of the mountain chain. Nevertheless, the present knowledge of some aspects of the geology of the district is still not far beyond that gained during studies more than 30 years ago. This is at least partly due to the fact that rapid facies changes, structural complications, and limited exposures in a rather heavily forested area make detailed studies both time consuming and difficult.

Our incomplete knowledge of the geology of the district is also reflected in the stratigraphic nomenclature, which is unsatisfactory in some respects and in need of revision. This applies to the rocks dealt with herein, the Hølonda Limestone. Apart from limestone and marble, this unit includes considerable amounts of mudstone, shale, siltstone, and sandstone and it is not clear if the unit, as now commonly identified in the area, is of the same age throughout the district or represents two or more stratigraphic intervals of different age. In anticipation that recently initiated re-mapping will clarify the

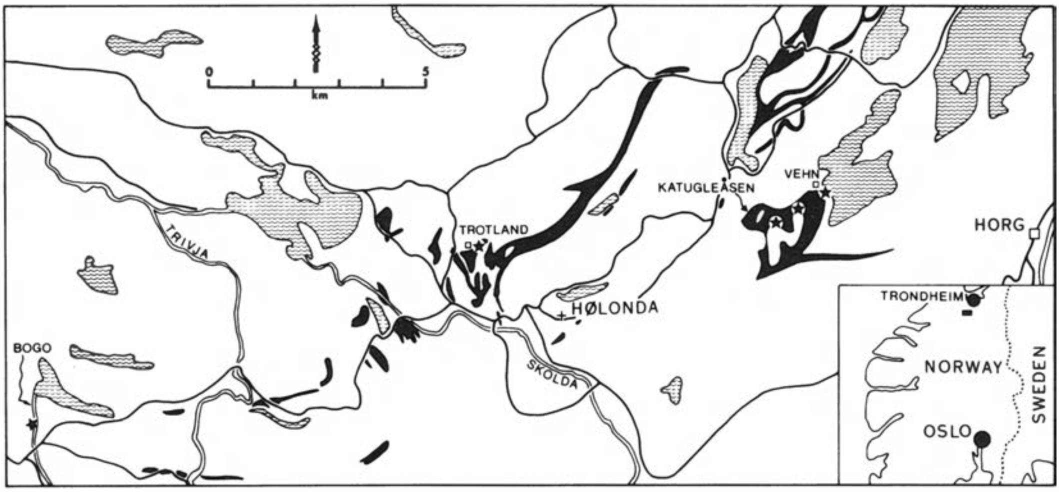


Fig. 1. Sketch-map of the area between Horg and the river Bogo showing mapped distribution (black) of the Hølonda Limestone in the Hølonda–Horg district and possibly equivalent carbonate rocks in the region between Trotland and Bogo. Geology based on Vogt (1945) and Chadwick, Blake, Beswick, & Rowling (1963). Stars denote conodont localities in the Vehn–Katugleåsen area, the shelly fossil localities at Trotland (Strand 1948, Neuman & Bruton 1974), and the graptolite locality on Bogo (Blake 1962, etc.). Black rectangle on inset map shows location of study area in south-central Norway.

three-dimensional lithic relations and serve as a reliable basis for a reappraisal of the lithostratigraphic classification, the term Hølonda Limestone is herein used in the same wide sense as by Vogt (1945) and Neuman & Bruton (1974).

Shelly fossils have been known from the Hølonda Limestone since the 19th century (Brøgger 1875), but they have been described and discussed in some detail in only a handful of publications (Kiær 1932, Strand 1948, Neuman & Bruton 1974). These megafossils are of more than usual interest because they constitute the most extensive shelly fossil assemblage known from the Lower and Middle Ordovician in the entire Norwegian Caledonides and because most of them exhibit definite North American, rather than Baltic, affinities. Because of this, they have figured prominently during the last decade in discussions about plate tectonics and the evolution of the Proto-Atlantic (Iapetus) Ocean (Dewey, Rickards, & Skevington 1970, Ross & Ingham 1970, Whittington & Hughes 1972, Neuman & Bruton 1974).

For many years, the age of the Hølonda shelly fauna remained uncertain. This was largely due to the fact that up to the 1950's, comparable faunas in North America remained poorly known and the contemporaneous Baltic faunas offered few points of comparison. Spjeldnæs (1961), Whittington (1968), and Ross & Ingham (1970) correctly recognized that the Hølonda shelly fauna includes species closely similar to those characteristic of Whiterockian strata in North America, but the first comprehensive modern discussion of the significance of the brachiopods and trilobites – the dominant elements in this shelly fauna – is that by Neuman & Bruton (1974). These authors reaffirmed the Whiterockian character of the assemblage and its North American affinities. As will be shown below, the conodonts provide evidence entirely in line with their conclusions, and these microfossils can be used as a basis for a more precise dating of at least parts of the Hølonda Limestone than that previously available.

Conodont collections

Samples for conodont analysis were collected from the Hølonda Limestone at several localities in the Hølonda–Horg district, but most of these proved to be barren. Even the productive samples have an average yield of only about 10 specimens per kg of rock. Thus far, productive samples have been obtained from three localities, namely:

Limestone nodules in dark calcareous shale at the north side of the dam wall at Damtjernet 0.6 km SW of Vehn farm (samples collected by

Bergström 1963, 1966, and by D. L. Bruton and J. F. Bockelie 1975);

Exposure of limestone 50 m SW of the boat house at Vehn farm (sample collected by Bruton and Bockelie 1975);

Exposure of limestone 2–3 m below the top of Katugleåsen (sample collected by Bruton and Bockelie 1975). The location of the collecting sites is shown in Fig. 1.

The conodonts obtained are moderately well preserved although as a rule more or less fragmentary. They have all been metamorphosed as shown by the fact that their color is now very dark grey to almost black. Their color alteration index (Epstein, Epstein & Harris 1977) is 5, which indicates a heating in excess of 300°C.

The stratigraphic position of the productive conodont samples within the Hølonda Limestone is currently difficult, if not impossible, to establish precisely. Judging from the classical study by Vogt (1945), at least the Damtjernet and Katugleåsen samples ought to come from the upper, if not uppermost, part of the unit. However, David L. Bruton has informed me that recent re-mapping of the Hølonda–Horg district suggests that some of Vogt's (1945) interpretations of the local geology may be in need of revision; accordingly, at the present time it may be premature to assign the conodont-bearing samples to a particular part of the Hølonda Limestone. It should be noted that there is no evidence from the collections at hand that the productive samples represent strata of very different age and for the purpose of the discussion below, the various samples are considered to represent a single unit.

Biostratigraphic significance

Although the currently available collection of conodonts from the Hølonda Limestone includes slightly less than 150 specimens, the association of species is a highly characteristic one, and its affinities are quite obvious. Some of the species represented are known as very rare elements in the Baltic Shield faunas, but the overall similarity to such faunas of late Early and early Middle Ordovician age (cf. Lindström 1960, fig. 5, Viira 1974), or to any other European conodont faunas, is very slight. However, most of the Hølonda species, or very closely related forms, are present in some formations of Whiterockian age in Newfoundland, Quebec, Texas, and central Nevada. The striking similarity between the Hølonda species association and those of some North American Whiterockian units indicates a Whiterockian, that is, in North American terminology early Champlainian (Middle Ordovician), age for the Norwegian conodonts. This is not a very precise dating in view of the fact that in terms of the British succession, the Whiterockian apparently corresponds to an interval from the middle-late Arenigian to well into the Llanvirnian. However, a close comparison with the conodont succession through Whiterockian successions in North America makes it possible to date the Hølonda conodonts more precisely.

At the present time, the Whiterockian has no designated stratotype (s) but the type area of the stage is in central Nevada, especially in the Monitor and Toquima Ranges. Interestingly, among known Whiterockian conodont successions in North America, the Hølonda conodonts show the greatest similarity to that of the Antelope Valley Limestone at Ikes Canyon, Toquima Range. Fig. 2 illustrates the ranges of Hølonda species, and some other taxa, in the March Spring section (Kay 1962:1944) as based on a series of samples obtained from the late Marshall Kay. Stratigraphic and taxonomic notes on the Hølanda conodont species are given in the Appendix.

An inspection of Fig. 2 reveals that the combination of conodont species found in the Hølonda collections is characteristic of the *Anomalorthis* Zone, and it appears that the part of the Hølonda Limestone represented by the conodont collections is coeval with a portion of that zone. This zone and slightly older strata at Ikes Canyon have also yielded undescribed platform conodonts (Fig. 2I, 2J, 2M), which apparently are conspecific with some of those illustrated by Fåhraeus (1970, figs. 3A, 3B, 3E, 3F, 3G) from the Middle Table Head Formation of Newfoundland. These conodonts, as well as many others, serve as useful ties between the Table Head Formation and the Antelope Valley Limestone. The *Anomalorthis* Zone at Ikes Canyon (McKee et al. 1972), as well as the Middle Table Head Formation at Port au Port Peninsula (Bergström 1979) and Black Cove (Morris & Kay 1966, Erdtmann 1971), contain *Paraglossograptus tentaculatus* Zone graptolites. The latter graptolite zone is generally correlated with the uppermost *Didymograptus hirundo* and the *Didymograptus 'bifidus'* Zones in the British

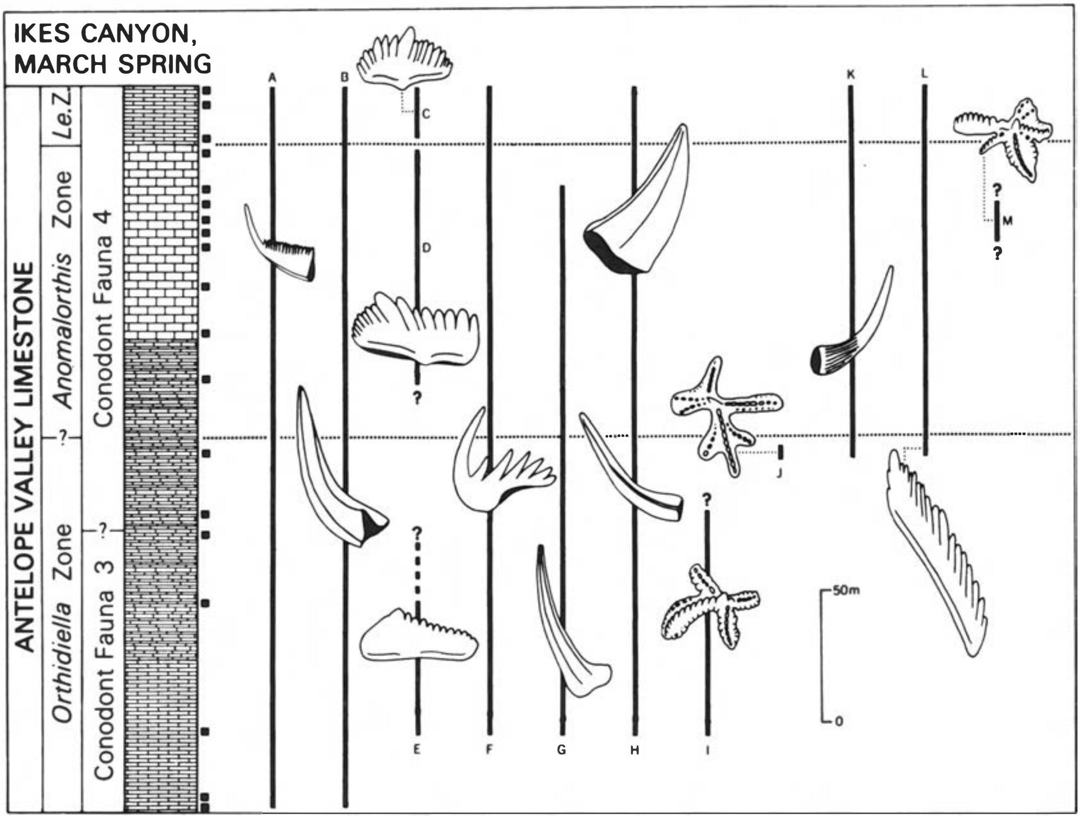


Fig. 2. Known vertical ranges of some important conodonts in the Antelope Valley Limestone in section at March Spring (Kay 1962, table 1), Ikes Canyon, Nevada. Among the illustrated species, A, B, D, F, G, H, K, and L have been found in the Hølonda Limestone and they suggest that the conodont-producing part of this unit in the Vehn–Katugleåsen area is equivalent to the *Anomalorthis* Zone. Squares to the right of columnar section indicate position of samples. The precise level of the base of the *Anomalorthis* Zone is still not firmly established (cf. Ross 1970), and the same is the case with the boundary between the intervals of Conodont Fauna 3 and 4 of Sweet, Ethington, & Barnes (1971). *Le.* Z. is an abbreviation of the '*Leptellina – Sowerbyella* Zone' of Kay (1962). Vertical bars with schematic illustrations of conodont elements represent the following species: A. *Belodella* sp. A Fåhraeus 1970 (belodelliform element); B. *Juanognathus variabilis* Serpagli; C. *Histiodella* n. sp.; D. *H.* sp. cf. *H. serrata* Harris; E. *H. sinuosa* (Graves & Ellison); F. '*Cordylodus*' *horridus* Barnes & Poplawski (two types of elements); G. *Protopanderodus* sp.; H. *Juanognathus asymmetricus* (Barnes & Poplawski); I. *Polonodus*? sp.; J. cf. '*Amorphognathus*' n. sp. Lindström 1964; K. '*Scolopodus*' sp.; L. *Coleodus*? sp. Barnes & Poplawski 1973; M. '*Polyplacognathus*' n. sp. A. Fåhraeus 1970. For further data regarding these conodonts, see Appendix.

sequence (see, for instance, Skevington 1963a, Bergström & Cooper 1973, fig. 9).

The Hølonda conodonts provide little direct evidence useful for correlation with the Baltic platform succession. Specimens of *Histiodella* sp. cf. *H. serrata* have been collected from middle – late Kundan beds in Sweden (Lindström 1960, fig. 5:3) and Estonia (Viira 1967, fig. 4:8, 1974, fig. 163) and elements of '*Scolopodus*' sp. are present in early Kundan strata in Öland. Because the former species has a relatively short vertical range in North America (Fig. 2), it suggests that the Hølonda conodonts are of middle-late Kundan age. The idea that the *Anomalorthis* Zone is at least partly of middle-late Kundan age is also supported by recent finds (A. Löfgren pers. comm. 1977) of undescribed platform conodonts in strata of that age in Jämtland. These conodonts are very similar to, if not conspecific with, Table Head forms illustrated by Fåhraeus (1970, figs. 3A, 3B, 3E), which are present also in the *Anomalorthis* Zone and slightly older strata at Ikes Canyon, Nevada (Fig. 2). In terms of the graptolite zone succession, the middle-late Kundan corresponds to the *Didymograptus 'bifidus'* Zone (see, for instance, Jaanusson 1960). The conodont-based correlation between the *Anomalorthis* Zone and the

Baltic succession is similar to those proposed by Whittington (1968, table 4–2) and Dewey, Rickards, & Skevington (1970, table 1), which were based on other lines of evidence.

Although virtually nothing is known about the local vertical ranges of shelly fossils within the Hølonda Limestone, there is little doubt that these fossils represent a stratigraphic interval of limited vertical extent. As pointed out by recent authors (see, in particular, Neuman & Bruton 1974), most of the Hølonda megafossils exhibit relations to Whiterockian forms in North America. The Hølonda shelly fossil assemblage, as now known, is hardly diagnostic of a particular portion of the Whiterockian of Nevada but judging from the detailed data given by Ross (1970), it appears that the Hølonda megafossils could well come from strata equivalent to the *Anomalorthis* Zone. Accordingly, there is no conflict between the conodont and shelly fossil evidence regarding the age of the Hølonda Limestone.

In this connection it is also of interest to note that the Bogo Shale at the river Bogo (Fig. 1) about 10 km WSW of the Hølonda–Horg district (Blake 1962, Skevington 1963b, Skevington & Sturt 1967, Berry 1968) has one of the very few Pacific Province Early Ordovician graptolite faunas in Europe. Berry (1968) was inclined to refer these graptolites to the *Paraglossograptus tentaculatus* Zone although he did not rule out that they might represent the subjacent *Isograptus 'caduceus'* Zone. Cooper (1973) reported the occurrence in the Bogo Shale of *I. caduceus australis,* a species characteristic of the Australian Yapeenian Stage. This stage is generally correlated with the *Didymograptus hirundo* Zone (see, for instance, Williams et al. 1972, fig. 3), and accordingly, the presence of this graptolite supports Skevington's (1963b) reference of the published Bogo Shale graptolite collection to the *Didymograptus hirundo* Zone. There are limestones similar to the Hølonda Limestone also in the Bogo area but their precise stratigraphic relations to the graptolite-bearing interval(s) are not clear from the available description and geologic map of that area (Chadwick, Blake, Beswick, & Rowling 1963). Thus far, no stratigraphically diagnostic fossils have been reported from these limestones, which apparently occur at more than one stratigraphic level, and their relations to the Hølonda Limestone remain uncertain. Whittington (1968:56) suggested that the Hølonda Limestone is younger than the Bogo Shale which is in good agreement with the known relations between the conodont and graptolite successions.

Paleogeographic significance

Recent discussions about the development of the Iapetus (Proto-Atlantic) Ocean during Ordovician time have been based largely on geological similarities between Europe and North America, paleobiogeographic deductions, and local geologic evidence. Paleomagnetic data have thus far played a relatively insignificant role. Evidently, this is due largely to the fact that most paleomagnetic data available from Ordovician rocks in northwestern Europe and eastern North America are either of unsatisfactory quality and/or suggest plate positions that are difficult to reconcile with other lines of evidence. The only currently published data on the latitudinal position of the Baltic Shield during Llanvirnian time suggest a location within 30 degrees from the pole (Noltimier & Bergström 1976, 1977). The position of the North American plate at that time is even less certain, but, based on values from the late Middle Ordovician Trenton Group of New York State (McElhinny & Opdyke 1973), the eastern margin of this plate appears to have been 15–25 degrees south of the equator. The paleomagnetic data provide no information about the longtitude, and the longitudinal relations between the North-European plate and the North American plate at this time are unknown. A reconstruction of the general geographic relations between these plates is given in Fig. 3.

As noted above, the Hølonda conodont species occur in strata of Whiterockian age in North America, especially the Table Head Formation of western Newfoundland, boulders of the Mystic Conglomerate in Quebec, the Fort Peña Formation in western Texas, and the Antelope Valley Limestone in central Nevada. Interestingly, all these units are within the Toquima-Table Head Faunal Realm of Ross & Ingham (1970), who interpreted this belt as occupying the margin of the North American plate. Other areas proposed to be North American continental plate margin fragments include northern Ireland and the adjacent part of Scotland as well as western Spitsbergen. In northwestern Ireland, only a few conodonts have been collected from the Whiterockian Glensaul Group, but they are not very diagnostic

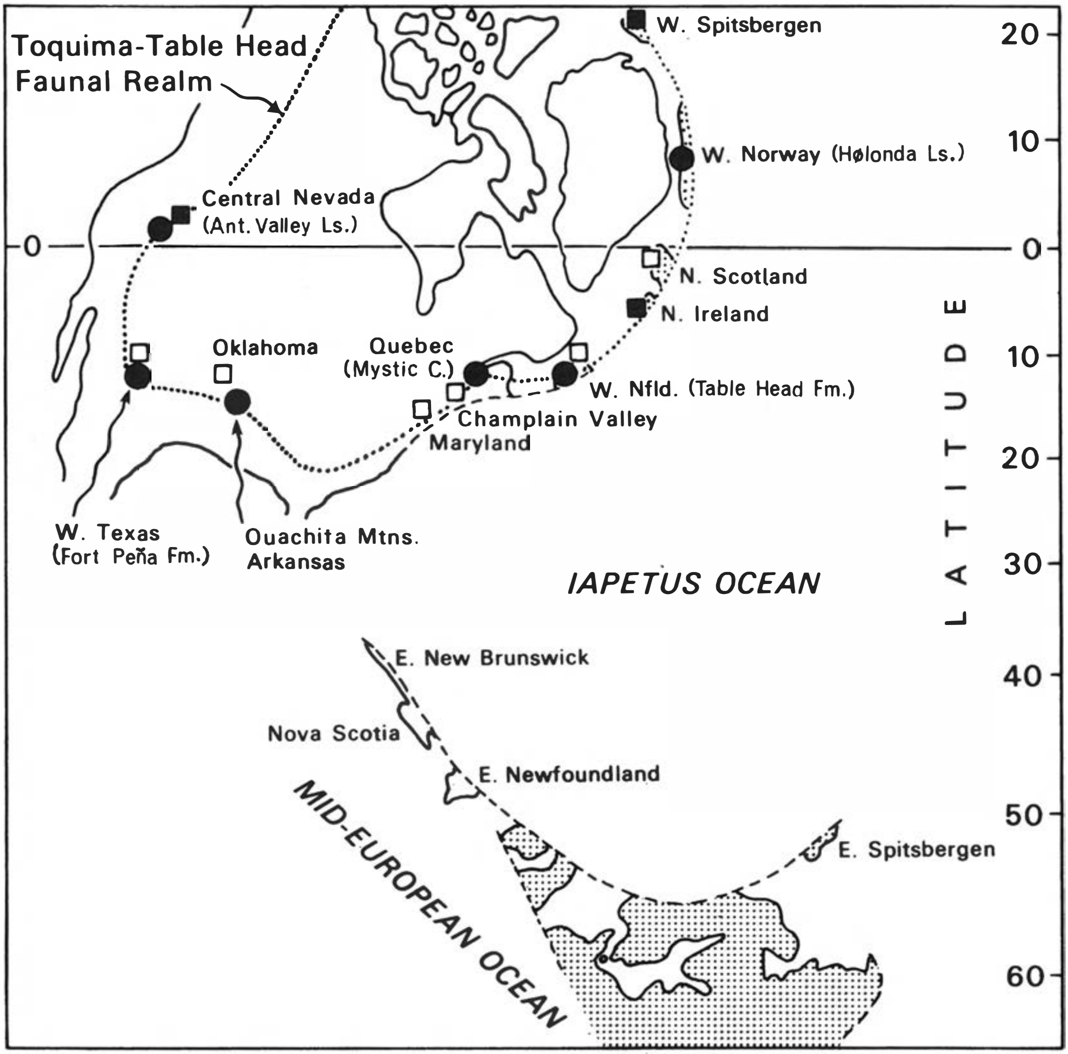


Fig. 3. Sketch-map showing location of *Anomalorthis* Zone conodont occurrences (black dots) similar to those of the Hølonda Limestone in relation to the Toquima-Table Head Faunal Realm (dotted line) as defined on shelly fossils by Ross & Ingham (1970, fig. 1). Latitudinal position of North American plate based on paleomagnetic data from McElhinny & Opdyke (1973), that of the Northwest-European plate on recent paleomagnetic studies of Arenigian and early Llanvirnian limestones of the central Baltic Shield (Noltimier & Bergström 1976, 1977). Black squares denote Whiterockian *Orthidiella* Zone conodont faunas in the Toquima-Table Head Faunal Realm. Open squares indicate occurrences of upper Canadian and/or early Champlainian conodont faunas of North American Midcontinent Province type on the distal part of the continental platform near the Toquima-Table Head Faunal Realm. Note that west-central Norway is interpreted to represent a fragment of the margin of the North American plate. Abbreviations: Nfld., Newfoundland; Mtns., mountains; Ant., Antelope; C., conglomerate. Mercator projection.

biogeographically. They have little in common with those of the Hølonda Limestone but are similar to those in some middle-late Arenigian units, for instance, the upper Cow Head Group of western Newfoundland. This agrees well with age indications provided by the graptolites in the Glensaul Group (Dewey, Rickards & Skevington, 1970). In northwesternmost Scotland, a North American conodont species association is known from the Durine Member of the Durness Limestone (Higgins 1970), but it is not similar to that of the Hølonda Limestone and is probably of pre-Whiterockian age (cf. Dewey, Rickards & Skevington 1970). In Spitsbergen, conodonts of

Whiterockian age are currently being described from the Valhallfonna Formation by Bergström & Barnes, but these conodonts are apparently older (representing the *Orthidiella* Zone, cf. Fortey 1976, text-fig. 1) than those in the Hølonda collections, and the characteristic Hølonda species are absent. As a whole, the Irish, Scottish, and Spitsbergen conodonts just mentioned are less similar to those of the Baltic Shield than to those of some North American formations and they support, in a general way, the reconstruction in Fig. 3.

The fact that the horizontal distribution of conodont species represented in the Hølonda collections closely agrees with the Toquima-Table Head Faunal Realm, which was originally distinguished on the basis of megafossils, might be taken as evidence supporting the idea (Wilson 1966) that the Trondheim Region was a part of the North American plate during Ordovician time. However, a certain degree of caution is warranted when employing conodonts as paleogeographic tools because the extremely wide geographic distribution of many species strongly suggests that these forms had the capacity to migrate across marine waters of oceanic dimensions. Unfortunately, knowledge about the autecology of conodont species is hardly beyond the stage of pure speculation and the factors that controlled various conodont distributional patterns are presently poorly understood. This is illustrated by the fact that we do not know with any degree of certainty which, if any, Ordovician conodonts could migrate across a deep-water ocean and to what extent such a water body could function as an efficient distributional barrier that made successful intercontinental migration routes possible only along continental margins and/or island arcs.

Of importance is also the fact that the Ordovician conodonts known from the easternmost nappes in the Caledonides and in adjacent autochthonous deposits in central Jämtland east of the Trondheim Region are of Baltic type (Löfgren pers. comm. 1977, Bergström coll.) and have little in common with those of the Hølonda Limestone. This, and the fact that the Jämtland conodonts occur in sediments that at least locally are similar to the Hølonda Limestone, certainly suggest the existence of some type of distributional barrier between Jämtland and the Trondheim Region; it would otherwise be difficult indeed to explain how the same conodont species could migrate successfully across an area extending from western Texas to the Trondheim Region but fail to reach areas with apparently similar environments less than 250 km east of the latter area in terms of present-day geography. The precise nature of this barrier is uncertain but the deep-water body of the Iapetus Ocean is an attractive possibility. This interpretation has been adopted as a preliminary working model (Fig. 3) rather than the alternative one, namely that the Hølonda–Horg district and other parts of west-central Norway represent the continental slope margin of the Northwest-European plate. Clearly, the occurrences of Ordovician rocks in the region west of the Hølonda–Horg district are particularly critical for an evaluation of this model. Unfortunately, in most of that area, the metamorphism is too high for the preservation of determinable fossils, and the precise stratigraphic relations between the successions there and those in the Hølonda–Horg district are in most cases very uncertain. Of particular interest in this connection is the relatively weakly metamorphosed, but still little studied, limestone on the island of Smøla in the westernmost Trondheim Region about 120 km west of the Hølonda–Horg district. Previously available information suggested that this unit exhibits some similarity lithically and faunally to the Durness Limestone, and equivalent shallow-water carbonates in western Newfoundland and elsewhere in eastern North America. And in line with the model presented in Fig. 3, one could presume that the Smøla district once was a part of the vast Early Ordovician marine shelf of the North American plate envisioned by, for instance, Swett & Smit (1972, fig. 27). However, I recently had the opportunity to study the limestone on Smøla in the field and found its lithic similarity to the shelf carbonates just mentioned less striking than I had expected. Further, preliminary conodont work suggests that the limestone on Smøla may be appreciably younger than these carbonates. Based on new field data, Bruton and Bockelie (pers. comm. 1978) interpret the limestone on Smøla to have been deposited in a volcanic island environment, and this new interpretation is clearly worth very serious consideration in discussions on the plate affiliation of the western Trondheim Region.

Concluding remarks

Because the data and conclusions presented above are based on conodonts from the Hølonda

Limestone in only a small portion of its distribution area within the Hølonda–Horg district, they are necessarily preliminary and subject to revision and refinement when additional information becomes available. The present project includes plans for extensive collecting in the near future from previously untested limestone outcrops in other parts of the district, especially those having recognizable megafossils, in an attempt to delimit the age of the Hølonda Limestone more conclusively than is possible at the present time, and to clarify if the unit varies in age regionally and represents more than one period of carbonate deposition. Additional data are also likely to shed new light on the significance of the Toquima-Table Head Faunal Realm faunas for the interpretation of the regional geology of the Iapetus area. I believe, however, that the strong environmental control affecting the distribution patterns of marine organisms seriously impairs the use of fossils for evaluations of, for instance, the precise geographic distance and relations between the Early Paleozoic continental plates. It seems to me more likely that critical evidence for such evaluations will rather come from paleomagnetic studies. Unfortunately, the metamorphism and structural displacement that affected the rocks in the Hølonda–Horg district during the Caledonian orogeny make this region an unpromising area for paleomagnetic investigations.

Acknowledgements. – I am indebted to Dr. David L. Bruton for supplying me with some samples and for comments on the manuscript. He has also discussed aspects of the geology of the Hølonda–Horg area with me on several occasions. I am also indebted to Prof. Walter C. Sweet for reading the manuscript and offering very useful advice. Prof. David Skevington kindly supplied information about his work in the Bogo area. Thanks are also due to Mrs. Karen Tyler and Mrs. Helen Jones, and Mr. Robert S. Wilkinson, of the Technical Staff at the Department of Geology and Mineralogy, The Ohio State University, for valuable assistance. I gratefully acknowledge economic support for part of the costs involved in this project from the Swedish Natural Science Council and the Department of Geology and Mineralogy at The Ohio State University. The present study is a part of the *Caledonian Research Project* of *International Geodynamics Project.* The samples supplied by Dr. Bruton were collected within the framework of the International Geological Correlation Programme Project no. 27 *Caledonide Orogen.*

Appendix

Conodont taxonomic and biostratigraphic remarks

Although large collections of conodonts have been assembled from Whiterockian strata in North America, relatively little critical taxonomic work has thus far been published on those conodonts, and even many of the common taxa remain unnamed or are in need of revision. Unfortunately, this applies also to several of the species present in the Hølonda collection, and at the present time, it is therefore necessary to use open nomenclature in the case of many forms. It is important to note that the current provisional classification in no way decreases the stratigraphic utility of these forms because I have been fortunate in having excellent Whiterockian conodont collections from key areas in North America for direct comparisons. Most of the species represented in my Hølonda collections are illustrated in Fig. 4 and the taxonomic relations, distribution, and biostratigraphic significance of each of these are discussed separately below.

Protopanderodus *sp. (Fig. 4A).* – A few Hølonda specimens are apparently conspecific with a form present in the *Anomalorthis* Zone of the Antelope Valley Limestone at Ikes Canyon (March Spring section), Nevada (Bergström coll.), the Fort Peña Formation, western Texas (Bergström coll.), and boulders in the Mystic Conglomerate, Quebec (Barnes & Poplawski 1973, pl. 3, fig. 16, text-fig. 2:1). It is close to, but probably not the same as, *Protopanderodus varicostatus* (Sweet & Bergström). In Nevada, Texas, and Newfoundland, *Protopanderodus* sp. occurs in strata of the *Paraglossograptus tentaculatus* Zone but its precise vertical range remains to be established.

'Scolopodus' *sp. (Figs. 4B, 4D).* – The Hølonda elements referred to this taxon are indistinguishable from specimens present in the Antelope Valley Limestone of Ikes Canyon (March Spring section), Nevada (Bergström coll.), the Middle Table Head Formation of Port au Port Peninsula, Newfoundland (Bergström 1979), boulders in the Mystic Conglomerate, Quebec (Barnes & Poplawski 1973, pl. 3, figs. 6–8), and Zone D1 at Lévis, Quebec (Uyeno & Barnes 1970, pl. XXII, figs. 9, 10). A few specimens of this species have also been collected (Berström coll.) from Hunderumian strata at Hälludden, Öland from either the uppermost

Didymograptus hirundo Zone or lowermost *Didymograptus 'bifidus'* Zone (Skevington 1965, fig. 73). In several recent North American papers elements of this type have been referred to *Scolopodus gracilis* Ethington & Clark, which was first described from the Early Ordovician El Paso Formation of western Texas. However, elements of the Texas species appear to differ from those of the present form in having a shorter base, and these two forms may not even be congeneric. *'Scolopodus'* sp. also exhibits a certain similarity to *Scolopodus strialatus* Harris & Harris from the West Spring Creek Formation of Oklahoma but the latter is as yet too incompletely known to permit close comparison.

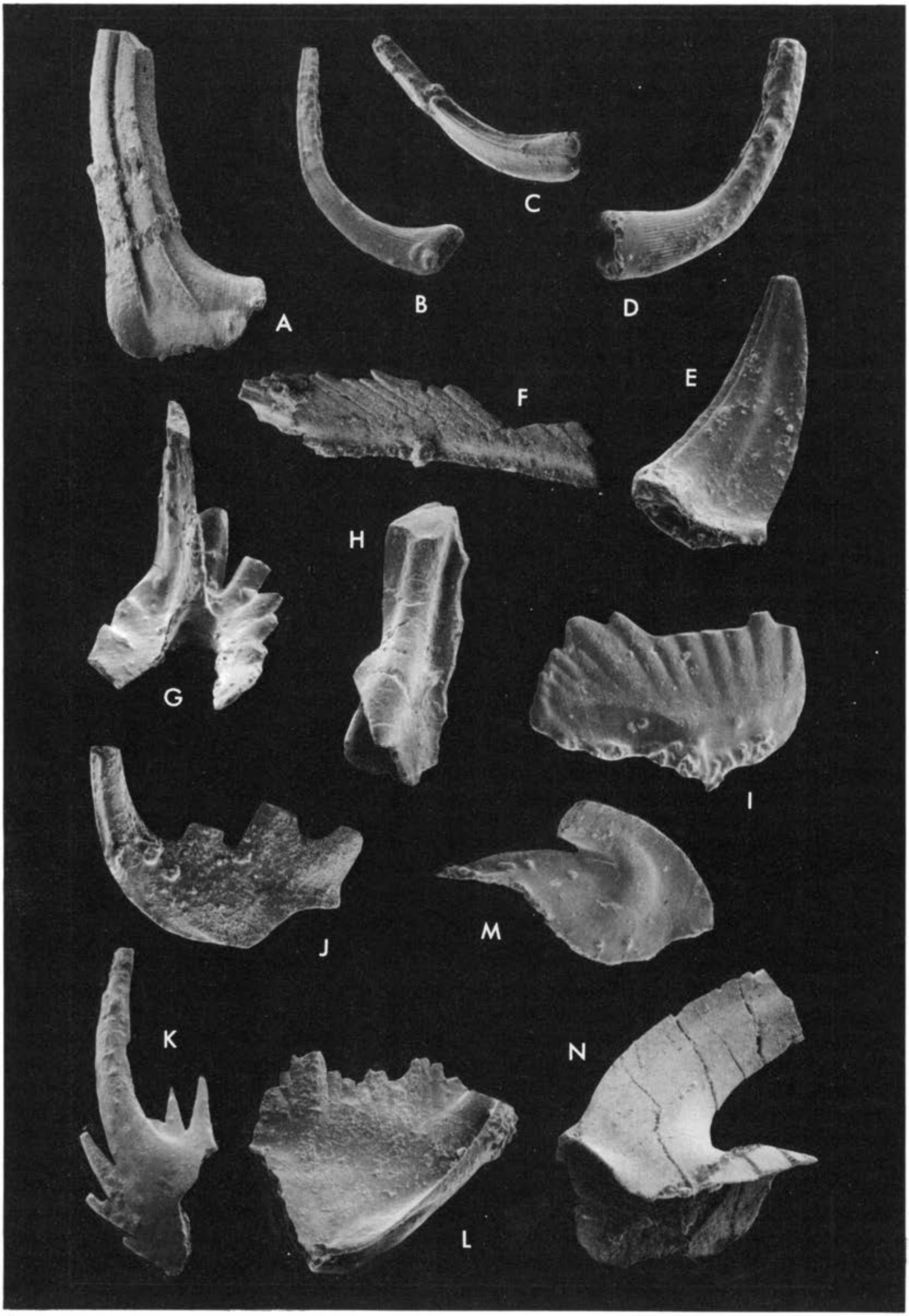
Juanognathus asymmetricus (*Barnes & Poplawski*) (*Figs. 4C, 4E*). – These elements are the most common ones in the Hølonda collections. The type of element illustrated in Fig. 4E is evidently conspecific with *Protopanderodus asymmetricus* Barnes & Poplawski (1973, pl. 1, figs. 14, 16). In the collections at hand, the latter type of element is regularly accompanied by prominently costate elements of the type illustrated in Fig. 4C. These types of elements show considerable similarity to apparently analogous elements in the apparatus of *Juanognathus variabilis* Serpagli, type species of *Juanognathus,* and it seems likely that these elements represent the apparatus of the same multielement species of *Juanognathus,* the appropriate name of which is *J. asymmetricus*. Elements of this species are distinguished from those of *J. variabilis* by having a more slender cusp with less strongly developed costae. Elements of *J. asymmetricus* occur in the Middle Table Head Formation of Port au Port Peninsula, Newfoundland (Bergström 1979), the *Anomalorthis* Zone of the Antelope Valley Limestone at Ikes Canyon (March Spring section), Nevada (Bergström coll.), the Fort Peña Formation of western Texas (Bergström coll.), and boulders in the Mystic Conglomerate, Quebec (Barnes & Poplawski 1973). In addition, a few specimens of both illustrated types of elements occur in samples from the Hunderumian interval at Hälludden mentioned above. Because elements of the types here referred to *J. asymmetricus* are regularly associated with those identified herein as *'Scolopodus'* sp., it cannot be ruled out that they all belong to the same conodont apparatus. However, further studies are needed to confirm the correctness of that idea.

Coleodus? *sp. Barnes & Poplawski 1973* (*Fig. 4F*). – The Hølonda collections include several more or less fragmentary elements, which are evidently conspecific with a Mystic Conglomerate species briefly described but not named by Barnes & Poplawski (1973). *Coleodus* Branson & Mehl is based on an unrecognizable fragment, which is, however, unlikely to be congeneric with the present species. The apparatuses of *Appalachignathus* Bergström et al. and *Bergstroemognathus* Serpagli include elements with some superficial similarity to that under discussion but the absence of other elements of the apparatuses of these genera in collections containing *Coleodus*? sp. suggests that the latter form is not congeneric with either of these genera. Pending further studies, I have chosen to use herein the same designation as Barnes & Poplawski (1973). Apart from its occurrence in boulders of the Mystic Conglomerate (Barnes & Poplawski 1973), the present species has been found in the Middle Table Head Formation of the Port au Port Peninsula, Newfoundland (Bergström 1979), and the Antelope Valley Limestone of Ikes Canyon (March Spring section), Nevada (Bergström coll.). No similar species has previously been recorded in Europe.

Plectodina? *sp.* (*Fig. 4G*). – The only element of this type thus far collected from the Hølonda Limestone exhibits some similarity to elements of *Plectodina* Stauffer but its generic affinity will be uncertain until the other elements of its apparatus are available. Landing (1976, pl. 3, figs. 17, 19, 20) illustrated two specimens identified as *Plectodina* n. sp. from the *Paraglossograptus tentaculatus* Zone of the uppermost Deepkill Shale of New York but his form seems to differ in some respects from the Hølonda specimen and they may not be conspecific.

Juanognathus variabilis *Serpagli* (*Fig. 4H*). – The Hølonda specimens at hand are so similar to Serpagli's (1974) species from the Early Ordovician of Argentina that positive identification appears justified. Elements of this species also occur in boulders of the Mystic Conglomerate, Quebec (Barnes & Poplawski 1973, pl. 1, fig. 15; referred to as *Protopanderodus*? sp.), the Antelope Valley Limestone of Ikes Canyon (March Spring section), Nevada (Bergström coll.), and the Deepkill Shale of New York (Landing 1976). The Hølonda specimens represent the first record of the genus in Europe.

Histiodella *sp. cf.* H. serrata *Harris* (*Fig. 4I*). –


A
B
C
D
E
F
G
H
I
J
K
L
M
N

Several specimens in the Hølonda collections belong to a quite distinct species of *Histiodella* Harris. The same species has been recorded from the Table Head Formation of Newfoundland (Fåhraeus 1970, fig. 3:I; referred to as *Spathognathodus* n. sp. Lindström 1960), boulders of the Mystic Conglomerate, Quebec (Barnes & Poplawski 1973, pl. 1, figs. 17, 18; referred to as *Histiodella sinuosa* (Graves & Ellison)), and the uppermost Deepkill Shale of New York (Landing 1976, pl. 1, fig. 20; referred to as *Histodella serrata* Harris). This species is common in, and apparently characteristic of, the *Anomalorthis* Zone of the Antelope Valley Limestone at Ikes Canyon (March Spring section), Nevada (Bergström coll.), and a closely similar form is also present in the uppermost Fort Peña Formation and lower Woods Hollow Formation, Texas (Bergström coll.). Further, single specimens have been reported from middle and late Kundan (*Didymograptus 'bifidus'*Zone) strata in the Baltic area (Lindström 1960, fig. 5:3, Viira 1967, fig. 4:8, 1974, fig. 163). The present form belongs to a complex of closely related and apparently relatively rapidly evolving species, the taxonomy of which is still not worked out in detail. This complex includes *H. altifrons* Harris, *H. minutiserrata* Mound, *H. sinuosa* (Graves & Ellison), *H. serrata* Harris, the present form and an undescribed species whose elements have essentially erect denticles and subequally long processes (Fig. 2C). The latter species may be a descendent of the present form and it occurs stratigraphically above it in, for instance, the Ikes Canyon section. The Hølonda species is close to *H. serrata* but its elements appear slightly more advanced in having less erect and more distinct denticles, a different profile of the blade in lateral view, and a less prominent cusp. Until the evolutionary development of these forms is clarified it will be uncertain if these differences justify the recognition of a species separate from *H. serrata,* and the Hølonda form is here tentatively compared with the latter species. Indeed, the status of *H. serrata* itself needs study as it seems transitional to *H. sinuousa* even if the morphological extremes in the spectrum of variation are readily distinguishable. However, regardless of these taxonomic problems, the short vertical range and wide geographic distribution of the Hølonda form appear to make it a useful index fossil for close interprovincial correlations.

'Cordylodus' horridus *Barnes & Poplawski (Fig. 4J).* – The few Hølonda elements of this highly characteristic species agree in all details with Barnes & Poplawski's (1973, pl. 2, figs. 16–18) types from boulders of the Mystic Conglomerate of Quebec. Conspecific specimens are also known from the *Paraglossograptus tentaculatus* Zone in the Deepkill Shale, New York (Landing 1976, pl. 1, fig. 11), the Fort Peña Formation, Texas (Bradshaw 1969, pl. 137, figs. 20–23), the Middle Table Head Formation of Port au Port Peninsula, Newfoundland (Bergström 1979), the basalmost Womble Shale at the Walnut Creek highway bridge W of Crystal Springs, Arkansas (Bergström coll.), and the Antelope Valley Limestone at Ikes Canyon (March Spring section), Nevada (Bergström coll.). This species, which has not been reported from Europe previously, appears to be an excellent guide for early Whiterockian (*Orthidiella* and *Anomalorthis* Zones) strata.

'Erismodus' incurvescens *Harris? (Fig. 4K).* – A single specimen from the Hølonda Limestone agrees in essential features with Harris' (1964) species, which was originally described from the early Whiterockian Joins Formation of Oklahoma. It also exhibits some similarity to *Microcoelodus(?) festivus* Moskalenko from the early Middle Ordovician Krivaya Luka Stage of

Fig. 4. SEM micrographs of conodont elements from the Hølonda Limestone. All illustrated specimens are deposited in the collections of the Orton Geological Museum (OSU) at The Ohio State University, Columbus, Ohio. – A. *Protopanderodus* sp., lateral view, × 105. Katugleåsen (sample 76B8-1). OSU 34051. – B. *'Scolopodus'* sp., lateral view, × 90. Damtjernet (sample N66-1). OSU 34052. – C. *Juanognathus asymmetricus* (Barnes & Poplawski), lateral view of scolopodiform element, × 80. Damtjernet (sample N66-1). OSU 34053. – D. *'Scolopodus'* sp., lateral view, × 90. Damtjernet (sample N66-1). OSU 34054. – E. *Juanognathus asymmetricus* (Barnes & Poplawski), posterior view of anteroposteriorly flattened element, × 105. Damtjernet (sample N66-1). OSU 34055. – F. *Coleodus?* sp. Barnes & Poplawski 1973, lateral view, × 50. Damtjernet (sample N66-1). OSU 34053. – D. *'Scolopodus'* sp., lateral view. × 90. Damtjernet (sample N66-1). OSU 34054. – E. *Juanognathus asym- variabilis* Serpagli, posterior view, × 80. Damtjernet (sample 76B4-5). OSU 34058. – I. *Histiodella* sp. cf. *H. serrata* Harris, lateral view, × 120. Damtjernet (sample N66-1). OSU 34059. – J. *'Cordylodus' horridus* Barnes & Poplawski, lateral view, × 150. Damtjernet (sample 76B4-1). OSU 34060. – K. *'Erismodus' incurvescens* Harris?, antero-lateral view, × 80. Damtjernet (sample N66-1). OSU 34061. – L. *Belodella* sp. A Fåhraeus 1970, lateral view of belodelliform element, × 150. Damtjernet (sample 76B4-1). OSU 34062. – M. *Belodella* sp. A Fåhraeus 1970, lateral view of oistodiform element, × 90. Damtjernet (sample N66-1). OSU 34063. – N. *Drepanoistodus* sp., lateral view, × 80. Katugleåsen (sample 76B8-1). OSU 34064.

the Siberian platform. Both these species are as yet incompletely known and the identity of the Hølonda specimen must be considered questionable at the time being. No similar form is previously known from Europe.

Belodella *sp. A. Fåhraeus 1970 (Figs. 4L, 4M).* – Stratigraphically early representatives of *Belodella* are known from the Table Head Formation of western Newfoundland (Fåhraeus 1970, fig. 3:0), boulders in the Mystic Conglomerate, Quebec (Barnes & Poplawski 1973, pl. 4, figs. 19, 20; referred to as *B. erecta*), the Antelope Valley Limestone of Ikes Canyon (March Spring section), Nevada (Bergström coll.), and the Fort Peña Formation of Texas (Bergström coll.). A *Belodella* species is also present in the Early Ordovician San Juan Formation of Argentina (Serpagli 1974, pl. 8, fig. 7) and single specimens of *Belodella* have been collected from middle Kundan strata in the Baltic area (Kinnekulle, Sweden and Oslo district, Norway (Fåhraeus 1970; 2064), and Jämtland, Sweden (Anita Löfgren, pers. comm. 1977). Although its precise vertical range is still not known, the present species appears to have the potential of being a good index fossil.

Drepanoistodus *sp. (Fig. 4N).* – The Hølonda collections include a few specimens of *Drepanoistodus*, which I have been unable to determine specifically. However, they are not closely similar to any Early or Middle Ordovician representatives of the genus known to me from the Baltic platform.

References

Barnes, R. B. & Poplawski, M. L. S. 1973: Lower and Middle Ordovician conodonts from the Mystic Formation, Quebec, Canada. *J. Paleont. 47,* 760–790.

Bergström, S. M. 1971: Conodont biostratigraphy of the Middle and Upper Ordovician of Europe and eastern North America. *Geol. Soc. Am. Mem.* 127, 83–157.

Bergström, S. M. 1977: Whiterockian (Ordovician) conodonts from the Hølonda Limestone in the eugeosynclinal Trondheim region, Norwegian Caledonides. *Geol. Soc. Amer. Abstr. with Progr. 9/5,* 573.

Bergström, S. M. 1979: First report of the enigmatic Ordovician microfossil *Konyrium* in North America. *J. Paleont. 53,* 320–327.

Bergström, S. M. & Cooper, R. A. 1974: *Didymograptus bifidus* and the trans-Atlantic correlation of the Lower Ordovician. *Lethaia 6,* 313–340.

Berry, W. B. N. 1968: Age of the Bogo Shale and western Ireland graptolite faunas and their bearing on dating early Ordovician deformation and metamorphism in Norway and Great Britain. *Nor. Geol. Tidskr. 48,* 217–230.

Blake, D. H. 1962: A new Lower Ordovician graptolite fauna from the Trondheim Region. *Nor. Geol. Tidskr. 42,* 223–238.

Bradshaw, L. 1969: Conodonts from the Fort Peña Formation (Middle Ordovician), Marathon Basin, Texas. *J. Paleont. 43,* 1137–1168.

Brøgger, W. C. 1875: Fossiler fra det Trondhjemske. *Nyt Mag. Naturvidensk. 21,* 95–107.

Chadwick, B., Blake, D. H., Beswick, A. E. & Rowling, J. W. 1963: The geology of the Fjeldheim-Gåsbakken area, Sør-Trøndelag. *Nor. Geol. Unders. 223,* 43–60.

Cooper, R. A. 1973: Taxonomy and evolution of *Isograptus* Moberg in Australasia. *Palaeont. 16,* 45–115.

Dewey, J. F., Rickards, R. B. & Skevington, D. 1970: New light on the age of Dalradian deformation and metamorphism in western Ireland. *Nor. Geol. Tidskr. 50,* 19–44.

Epstein, A. G., Epstein, J. B. & Harris, L. D. 1977: Conodont color alteration – an index to organic metamorphism. *U.S. Geol. Surv. Prof. Pap. 995,* 27 p.

Erdtmann, B.-D. 1971: Ordovician graptolite zones of western Newfoundland in relation to paleogeography of the North Atlantic. *Geol. Soc. Am. Bull. 82,* 1509–1528.

Fåhraeus, L. E. 1970: Conodont-based correlations of Lower and Middle Ordovician strata in western Newfoundland. *Geol. Soc. Am. Bull. 81,* 2061–2076.

Fortey, R. A. 1976: Correlation of shelly and graptolitic Early Ordovician successions, based on the sequence in Spitsbergen. *In* Bassett, M. G. (ed.), *The Ordovician System: Proceedings of a Palaeontological Association Symposium, Birmingham, September 1974,* Univ. of Wales Press and National Museum of Wales, Cardiff, 263–280.

Harris, R. W. 1964: Erismodid conodonts in Simpson (Ordovician) of Oklahoma. *Oklah. Geol. Notes 24,* 171–177.

Higgins, A. C. 1967: The age of the Durine Member of the Durness Limestone Formation at Durness. *Scott. J. Geol. 3,* 382–388.

Jaanusson, V. 1960: Graptoloids from the Ontikan and Viruan (Ordov.) limestones of Estonia and Sweden. *Geol. Inst. Univ. Uppsala Bull. 38,* 289–366.

Kay, M. 1962: Classification of Ordovician Chazyan shelly and graptolite sequences from central Nevada. *Geol. Soc. Am. Bull. 73,* 1421–1430.

Kiær, J. 1932: The Hovin Group in the Trondheim area. *Skr. Nor. Vidensk. Akad. i Oslo, Mat.-naturv. Kl., 1932,* no. 4, 175 p.

Landing, E. 1976: Early Ordovician (Arenigian) conodont and graptolite biostratigraphy of the Taconic allochthon, eastern New York. *J. Paleont. 50,* 614–646.

Lindström, M. 1960: A Lower – Middle Ordovician succession of conodont faunas. *21st Int. Geol. Congr. Repts. 7,* 88–96.

McElhinny, M. W. & Opdyke, N. D. 1973: Remagnetization hypothesis discounted: a paleomagnetic study of the Trenton Limestone, New York State. *Geol. Soc. Am. Bull. 84,* 3697–3708.

McKee, E. H., Nordford, B. S. & Ross, R. J., Jr. 1972: Correlation of the Ordovician shelly facies *Orthidiella* Zone with zones of the graptolitic facies, Toquima Range, Nevada and North White River region, southwestern British Columbia. *U. S. Geol. Surv. Prof. Pap. 800-C,* C145–C156.

Morris, R. W. & Kay, M. 1966: Ordovician graptolites from the middle Table Head Formation at Black Cove, Port-au-Port, Newfoundland. *J. Paleont. 40,* 1223–1229.

Neuman, R. B. & Bruton, D. L. 1974: Early Middle Ordovician fossils from the Hølonda area, Trondheim Region, Norway. *Nor. Geol. Tidsskr. 54,* 69–115.

Noltimier, H. C. & Bergström, S. M. 1976: Paleomagnetic studies of Early and Middle Ordovician limestones from the Baltic Shield. *Geol. Soc. Am. Abstr. with Progr. 8/4,* 501.

Noltimier, H. C. & Bergström, S. M. 1977: Paleomagnetic evidence of the latitude of the Baltic Shield and the North

American Continent during Early and Middle Ordovician time. *Third International Symposium on the Ordovician System, Columbus, Ohio August 1977, Progr. and Abstr.*, 5.

Ross, R. J., Jr. 1970: Ordovician brachiopods, trilobites, and stratigraphy in eastern and central Nevada. *U. S. Geol. Surv. Prof. Paper 639*, 103 pp.

Ross, R. J., Jr. & Ingham, J. K. 1970: Distribution of the Toquima-Table Head (Middle Ordovician Whiterock) faunal realm in the Northern Hemisphere. *Geol. Soc. Am. Bull. 81*, 393–408.

Serpagli, E. 1974: Lower Ordovician conodonts from Precordilleran Argentina (Province of San Juan). *Soc. Paleont. Ital. Boll. 13*, 17–98.

Skevington, D. 1963a: A correlation of Ordovician graptolite-bearing sequences. *Geol. För. Stockh. Förh. 85*, 298–319.

Skevington, D. 1963b: A note on the age of the Bogo Shale. *Nor. Geol. Tidsskr. 43*, 257–260.

Skevington, D. 1965: Graptolites from the Ontikan Limestones (Ordovician) of Öland, Sweden. II. Graptoloidea and Graptovermida. *Geol. Inst. Univ. Uppsala Bull. 43*, 1–74.

Skevington, D. & Sturt, B. A. 1967: Faunal evidence bearing on the age of Late Cambrian-Early Ordovician metamorphism in Britain and Norway. *Nature 215/5101*, 608–609.

Spjeldnæs, N. 1961: Ordovician climatic zones. *Nor. Geol. Tidsskr. 41*, 45–77.

Strand, T. 1948: New trilobites from the Hølonda limestone (Trondheim Region, southern Norway). *Nor. Geol. Tidsskr. 27*, 74–88.

Sweet, W. C., Ethington, R. L. & Barnes, C. R. 1971: North American Middle and Upper Ordovician conodont faunas. *Geol. Soc. Am. Mem. 127*, 163–193.

Swett, K. & Smit, D. E. 1972: Paleogeography and depositional environments of the Cambro-Ordovician shallow-marine facies of the North Atlantic. *Geol. Soc. Amer. Bull. 83*, 3223–3248.

Uyeno, T. T. & Barnes, C. R. 1970: Conodonts from the Lévis Formation (zone D1) (Middle Ordovician), Lévis, Quebec. *Geol. Surv. Canada Bull. 187*, 99–123.

Viira, V. 1967: Ordovician conodont succession in the Ohesaare core. *Eesti NSV Tead. Akad. Toimetised 16*, 319–329. [In Russian].

Viira, V. 1974: Ordovician conodonts of the East Baltic. *Eesti NSV Teaduste Akad. Geol. Inst. Tallinn*, 142 pp. [In Russian with English summary].

Vogt, T. 1945: The geology of part of the Hølonda–Horg district, a type area in the Trondheim region. *Nor. Geol. Tidsskr. 25*, 449–528.

Whittington, H. B. 1968: Zonation and correlation of Canadian and early Mohawkian Series. *In* Zen, E., White, W. S., Hadley, J. B. & Thompson, J. B. (eds.), *Studies of Appalachian Geology-Northern and Maritime*, 49–60. John Wiley and Sons, New York, N.Y.

Whittington, H. B. & Hughes, C. P. 1972: Ordovician geography and faunal provinces deduced from trilobite distribution. *Roy. Soc. London Phil. Trans. B263*, 235–278.

Williams, A. et al. 1972: A correlation of Ordovician rocks in the British Isles. *Geol. Soc. Lond. Spec. Rept. 3*, 74 pp.

Wilson, J. T. 1966: Did the Atlantic close and then re-open? *Nature 211*, 676–681.