Barrandegnathus n. gen. (conodonta) from the Komstad Limestone (lower Mid Ordovician), Scandinavia, and its palaeogeographical significance

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A characteristic early Mid Ordovician conodont fauna first recorded from Bohemia is known from Morocco and southwestern Scandinavia. It is characterized by *Barrandegnathus* n. gen. (type spe- cies: *Baltoniodus bohemicus* Dzik, 1983). *Barrandegnathus bohemicus* is considered to be endemic to the Tornquist Sea, but it is often associated with Baltic Province conodonts.

The fauna was first described from the Klabava Formation the sediments of which accumulated in the Prague Basin, Czech Republic and was subsequently recorded as reworked Ordovician conodont fauna preserved in Upper Silurian strata from Morocco and from the Komstad Limestone in south west Scandinavia. The stratigraphical range of the species is confined to the late part of the early Mid Ordovician (Darriwilian; Volkhov Regional Stage).

Barrandegnathus bohemicus probably migrated to Baltica with cold-water ocean currents moving from the high latitudinal Perunica terrane to the Gondwana supercontinent and to the southwestern margin of the Baltica continent.

Baltic Province conodonts are recorded from cool-water carbonates at or just off the periphery of Gondwana. Rifting along the Gondwana margin followed by drifting of palaeocontinents and terranes towards mid-high latitudes promoted deposition of cool-water carbonates. Baltic Province conodonts are recorded from Gondwana and Gondwana derived continents. The distribution of cool-water carbonates and the associated conodont fauna shows that Baltic Province conodonts were not con-fined to the Baltica continent.

Barrandegnathus n. gen. is introduced; the genus is represented by *B. bohemicus* (Dzik, 1983).

Keywords: Bornholm, Scania, conodonts, Middle Ordovician, biostratigraphy, palaeogeography, *Barrandegnathus* n. gen. *bohemicus* (Dzik, 1983).

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Conodont faunas from relatively low yielding areas may be rewarding for correlative, provincial and palaeogeographic perspectives. One example of this is the conodont fauna first known from the Klabava Formation of Prague Basin, Czech Republic (Fig. 1; Dzik 1983a). The macrofauna of the Prague Basin is mostly endemic to the basin and hence fossil based correlation to other regions may be difficult (Havlí ek & Fatka 1992). The Prague Basin is indeed not known for its abundance of conodonts, but the conodont biota reported from the succession i.e. *Baltoniodus bohemicus*, *Drepanodus arcuatus* and *Drepanoistodus basiovalis* (all *sensu* Dzik 1983a) is very characteristic. Dzik (1983a) placed this fauna within the earliest Arenig and the conodonts were derived from the high palaeolatitudes on the southern hemisphere representing cold-water faunal association of the Mediterranean Province. The recent discovery of the same faunal elements associated with Baltic Province conodonts from the Khemis-n'Ga locality of western Morocco (Bultynck & Sarmiento 2003) indeed confirmed this idea as Morocco was situated on the Gondwana supercontinent and in a high latitudinal to nearly south polar location according to recent palaeogeographical models (Cocks & Torsvik 2002, 2004; Fortey & Cocks 2003).

Fig. 1. Map showing the locations with *Barrandegnathus* n. gen. (*) and Baltic Province conodonts (□) in Europe, Turkey and northwest Africa. The Baltic Province conodont fauna is found in Baltica, Gondwana (Morocco), (West) Avalonia (Ganderia-New Brunswick) and South China. *Barrandegathus* is 'endemic' to the Tornquist Sea. The Baltic Province conodont fauna is found on Baltica and on continents that rifted and drifted away from Gondwana (i.e. Avalonia) and moved from high to mid high latitudes (or from low latitudes to mid latitudes i.e. South China) on the southern hemisphaere.

The discovery of the same taxa from southwestern Scandinavia presented here does provide links from Perunica to Gondwana and Baltica. The record of the taxa in southwestern Scandinavia is from deep shelf environments. The fauna provides precise correlation between the deposits of the East European/Baltic Platform and the Prague Basin within the brief time interval of the early Mid Ordovician (i.e. within the upper Volkhov Regional Stage). In addition it provides new information to the previous ideas on faunal communication (e.g. Dzik 1983a, b; Gutiérrez-Marco *et al*. 1999) between the Perunica terrane, West Gondwana supercontinent and Baltica continent.

Material

The present material was isolated from the Komstad Limestone (Jaanusson 1960), which is known from the Scania Region, Sweden and on Bornholm, Denmark (Figs 1, 2; Poulsen 1965, 1966; Bergström 1982; Stouge 1975; Nielsen 1995; Erlström *et al*. 2001; Stouge & Nielsen 2003) and in the German offshore G-14 well (Maletz 1997; Stouge 2001a).

The Komstad Limestone consists of lime mudstone and wackestone with thin silty partings and minor shale. The unit varies from a few meters to more than 15 m in thickness (Nielsen 1995, fig. 1).

The Komstad Limestone accumulated during the overall transgressive-regressive cycles of the Volkhov–Kundan stages (Nielsen 1992, 1995, 2004; Dronov & Holmer 1999; Laškovas 2000; Saadre *et al*. 2004).

Localities

The material described below was collected from the Limensgade and Skelbro localities on Bornholm,

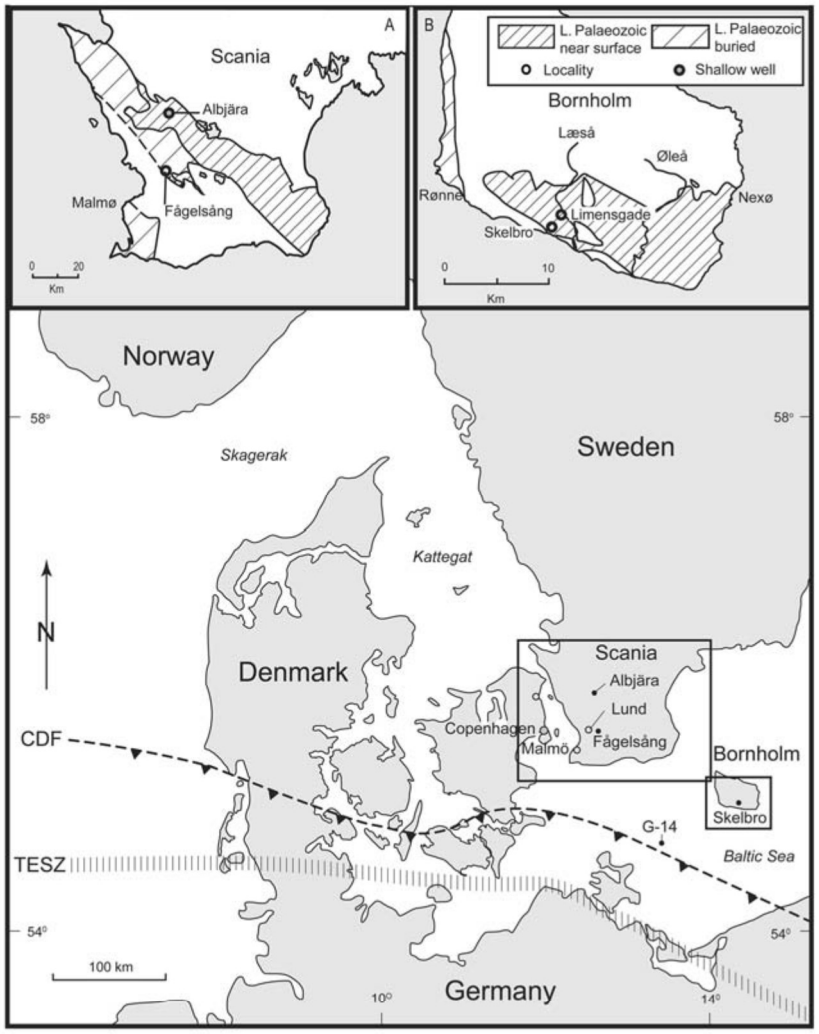

Fig. 2. Location map with Komstad Limestone localities mentioned in the text. CDF = Caledonian Deformation Front; TESZ = Transeuropean Suture Zone.

Denmark, and from the Fågelsång locality and Albjära well in Scania, Sweden (Fig. 2).

Skelbro and Limensgade, Bornholm

Location. Details on the location of the two Bornholm localites are given in Nielsen (1995; see Fig. 2).

Stratigraphy. Poulsen (1965, 1966) and Nielsen (1995) outlined the stratigraphy and described the trilobites from the Komstad Limestone on Bornholm. Stouge (1975) provided information on the conodont succession from the localities.

Lithological succession. The Komstad Limestone overlies the Mid Cambrian – Lower Ordovician Alum Shale Formation with a prominent disconformity. The succession exposed consists from the bottom to the top of bedded limestone with minor glauconite and phosphate intraclasts - especially in the lower part - up to 1 m thick. Above follows a 2 m thick succession of two lithofacies. The lower 1 m consists of mudstone and separated by thin silt/shale. These are overlain by 1 m of wackestone with siltstone and marl.

About 1 m succession of wackestone to packstone concludes the Komstad Limestone on Bornholm. The uppermost part of the Komstad Limestone is phosphatised. On Bornholm, the Dicellograptus Shale formation disconformably overlies the Komstad Limestone.

Fauna and age of the succession. Trilobites from the Komstad Limestone are well documented. Brachiopods, ostracodes (Tinn & Meidla 1999) and cephalopods are also present. The trilobite assemblage is placed in the *Megistaspis polyphemus*, the *Megistapis simon*, *Megistaspis limbata* trilobite zones of the Volk-

hov Regional Stage (Mid Ordovician) and the top of the limestone is referred to the *Asaphus expansus* trilobite Zone of the Kundan Stage (Nielsen 1995).

Conodonts are from the *'Baltoniodus' triangularis, Baltoniodus navis* and *Paroistodus originalis* zones *(sensu* Lindström 1971; Stouge 1975), the *Microzarkodina parva (sensu* Bagnoli & Stouge 1997), the *Baltoniodus norrlandicus (sensu* Stouge 1989) and the *Lenodus antivariabilis (sensu* Bagnoli & Stouge 1997) conodont zones of the Volkhov Regional Stage. The conodont assemblage from the top of the Komstad Limestone indicates the presence of the *Lenodus variabilis* Zone of the Kunda Stage.

Fågelsång, Scania, Sweden

Location. The precise location of the Fågelsång location (Fig. 2) is given by Ahlberg (1992), Nielsen (1995); Bergström *et al.* (2002) and Stouge & Nielsen (2003).

Stratigraphy. The Komstad Limestone overlies conformably the Tøyen Shale. About 3 m of the 5.3 m thick upper member are exposed (Stouge & Nielsen 2003). The upper part of the Komstad Limestone is exposed in old quarries at Fågelsång whereas the lower part is only known from wells (Nielsen 1995; Stouge & Nielsen 2003). The Almelund Shale conformably overlies the Komstad Limestone (Bergström *et al.* 2002).

Lithological succession. The exposed succession includes a wackestone unit with silty partings, a unit composed of nodular limestone and dark shale succeeded by a unit of wackestone and packstone. Bentonites are present in the succession. (Nielsen 1995; Stouge & Nielsen 2003).

Fauna and age of the Fågelsång succession. The lower member of the Komstad Limestone is referred to *Megistapis simon* and probably includes lower *M. limbata* Subzone (Stouge & Nielsen 2003). The upper *Megistaspis limbata* Subzone is found in silty limestone changing upwards into cleaner wackestone below the nodular dark limestone and shale. The dark shale and nodular limestone belong to the *Asaphus expansus* Zone.

The conodont succession extends from *Baltoniodus norrlandicus* Zone and ranges into the lower part of the *Lenodus pseudoplanus* Zone (Stouge & Nielsen 2003, figs 5, 7).

Albjära well, western Scania, Sweden

Location. The Albjära well is situated in western Scania (see Lindholm 1991, fig 2; Fig. 2).

Stratigraphy. The Komstad Limestone in the Albjära-1 well is 3.5 m thick (Maletz 1995; Stouge *et al.* 2001). It is a distal exposure and much of the lower part of the Komstad Limestone is replaced by black shale referred to the Tøyen Shale. The Almelund Shale overlies the Komstad Limestone in the Albjära-1 well.

Lithological succession. The succession includes mudstone with minor shale partings in the lower part succeeded by an interval of nodular limestone in dark-grey shale. The Komstad Limestone and similar to Fågelsång concludes with a wackestone and packstone unit. Bentonites are preserved in the succession.

Fauna and age of the Albjära succession. Graptolites from the Tøyen Shale are from the *Undulograptus austrodentatus* (Arenig/Darriwillian) graptolite Zone and those from the overlying Almelund Shale are referred to the *Holmograptus lentus* Zone (Llanvirn; Maletz 1995, 2005; personal communication 2001). The conodonts are from the *Lenodus antivariabilis* Zone and extend into the *Lenodus pseudoplanus* Zone (Stouge *et al.* 2001).

Sedimentological and environmental interpretation of the Komstad Limestone

The sediments of the Komstad Limestone accumulated in deep shelf environments along the margin of the East European/Baltic platform (Stouge & Nielsen 2003).

The succession records the transition from carbonate accumulation of the deeper shelf to terrigenous sedimentation of the deep to very deep shelf with a return to carbonate accumulation of the shelf and to clastic deposition of the deep shelf.

Systematic palaeontology

All the specimens illustrated are housed in the collection of the Geological Museum, Copenhagen, and their catalogue numbers bearing the prefix MUGH.

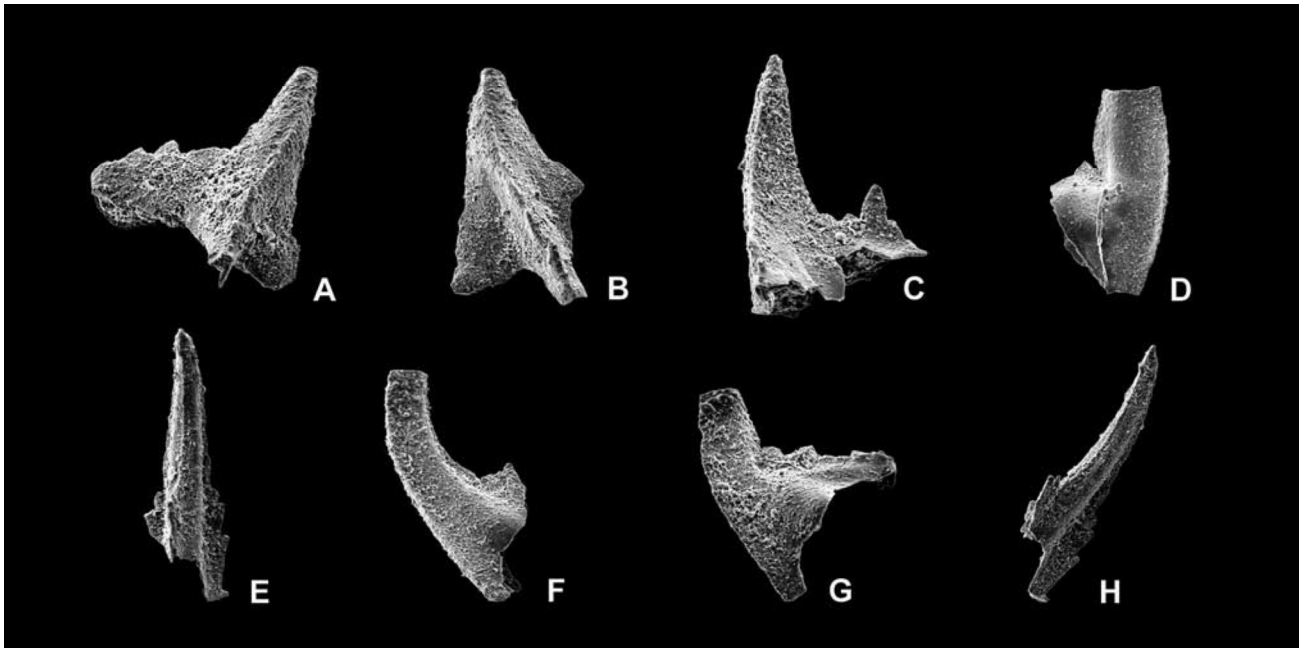

Fig. 3. *Barrandegnathus bohemicus* (Dzik, 1983). Al specimens are ×100. – A. P1 element, MGUH 27756. Bornholm: Limensgade Quarry, # 55 – B. P1 element, MGUH 27757. Bornholm: Limensgade Quarry, # 56 – C. P2 element. MGUH 27758. Bornholm: Skelbro Quarry, # 9. – D. M element, MGUH 27759. Bornholm: Limengade Quarry, # 55.– E. S0 element, MGUH 27760. Bornholm: Limensgade Quarry, # 55. – F. S1 element, MGUH 27761. Bornholm: Limensgade Quarry, # 56. – G. S2 element, MGUH 27762. Bornholm: Limensgade Quarry, # 55. – H. S3–4 element, MGUH 27763. Bornholm: Limensgade Quarry, # 56.

Family Balognathidae Hass, 1959

Genus *Barrandegnathus* n. gen.

Type species. *Baltoniodus bohemicus* Dzik, 1983a.

Derivation of name. After Joachim Barrande (1799–1883), the French palaeontologist that devoted his work to Bohemia.

Diagnosis. The septimembrate apparatus of *Barrandegnathus* is composed of P_1, P_2, M and a series of four morphological distinct S elements (*sensu* Purnell *et al*. 2000). The elements are predominantly hyaline with white matter present in the distal part of the denticles. Both P elements and the M element are robust with stout cusps and strong sharp edges. The P elements have short anterior and lateral, undenticulated to weakly denticulated processes.

Remarks. *Barrandegnathus* n. gen. resembles *Trapezognathus* Lindström, 1954, *Lenodus* Sergeeva, 1963 and *Eoplacognathus sensu* Dzik (1994) and Löfgren & Zhang (2003). *Barrandegnathus* is here considered related to the two first genera and hence it is placed in Balognathidae Hass, 1959 (*sensu* Stouge & Bagnoli 1999).

The *Barrandegnathus* P, M-element and the S_2-element are diagnostic for the genus. The S_{3-4}-element of *Barrandegnathus* is not 'trapezoid' in shape, which otherwise is characteristic for the S_{3-4}-elements of *Trapezognathus* and *Lenodus*.

So far, only one species is referred to the new genus.

Barrandegnathus bohemicus (Dzik, 1983)
Fig. 3A–H

1983a *Baltoniodus bohemicus* sp. n., Dzik, pp. 339–342, pl. 2, fig 5; pl. 4, figs 1–4; pl. 5, figs 1–4.
2003 *Trapezognathus* sp., Bultynck & Sarmiento, pp. 267–268, pl. 2, figs. 5–6; pl. 3, figs. (?)1, 7, 9, 11, 13.
2003 *Trapezognathus quandrangulum* Lindström – Bultynck & Sarmiento, p. 267 (*partim*), pl. 4, fig 12.

Diagnosis. See diagnosis for the genus.

Remarks. Dzik (1983a) recorded and described all the elements of the species.

The M element resembles the corresponding element of *Gothodus*, Lindström in the development of a downwards directed and distally pointed anterior process. It differs by having a large stout cusp and it

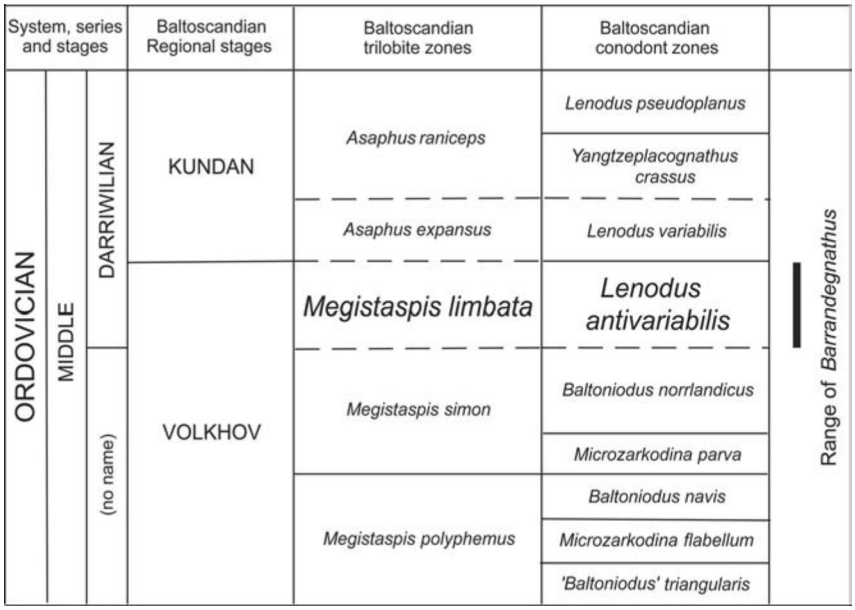

Fig. 4. Lower to Mid Ordovician conodont and trilobite zones of Baltoscandia and the range of *Barrandegnathus bohemicus* in the investigated sections. Conodont zones modified from Lindström (1971), Löfgren (1978, 1994, 1995); Bagnoli & Stouge (1997), Stouge & Bagnoli (1998) and Zhang (1998b).

may carry denticles on the upper margin of the base - a feature that otherwise characterizes the genera *Trapezognathus* and *Lenodus*.

The M element of *Trapezognathus* sp. illustrated by Bultynck & Sarmiento 2003 (pl. 3, fig. 1) probably is an M element of *Lenodus antivariabilis*. The denticulated element referred to *Trapezognathus quadrangulum* Lindström by Bultynck & Sarmiento (pl. 4, fig. 12) belongs to *Barrandegnathus* rather than to the *T. quadrangulum*.

Material. – 172 specimens (Skelbro: 57, Limensgade: 44, Fågelsång: 63; Albjära: 12).

Barrandegnathus n. gen. in the Komstad Limestone

Barrandegnathus bohemicus (Dzik, 1983) n. gen. characterises the fauna; it is associated with *Erraticon* and '*Baltoniodus*' sp. (a prioniodontid genus composed of nondenticulated elements; see Stouge & Nielsen 2003, fig. 5). *Barrandegnathus* and '*Baltoniodus*' sp. are only known from the Komstad Limestone on Bornholm and in Scania. The two taxa are completely absent from the East European/Baltic Platform and have not been recorded from the Oslo Region (Rasmussen 1991, 2001).

Other common associated species include *Baltoniodus norrlandicus*, *Lenodus antivariabilis*, *Microzarkodina parva*, *Protopanderodus* spp., *Scalpellodus* and *Cornuodus*. Species of *Drepanoistodus* and *Drepanodus* are also present. These taxa are together with *Erraticodon* more widespread and occur on the platform and platform margin of Baltica (e.g. Bednarczyk 1998; Löfgren 1978, 1995, 2000a, b; Rasmussen 1991, 2001; Viira *et al*. 2001; Zhang 1998b) and on other palaeocontinents (Nowlan 1981; Landing *et al*. 2003). The associated taxa are (except for *Erraticodon*) considered typical of the Baltic Province of the Atlantic Realm (Bagnoli & Stouge 1997; Rasmussen 1998).

Barrandegnathus bohemicus (Dzik 1983) n. gen. and the most characteristic associated species in the Komstad Limestone appear within the silty limestone lithofacies and extend into the succeeding wackestone. The taxon does not extend into the uppermost part of the Komstad Limestone (Fig. 4; Stouge & Nielsen 2003, fig. 5).

Comparison of *Barrandegnathus bohemicus*-bearing strata

Bornholm and Scania. On Bornholm, Denmark and Scania, Sweden the range of *Barrandegnathus bohemicus* is from the top of *Baltoniodus norrlandicus* Zone to near the top of the *Lenodus antivariabilis* Zone (Fig. 4). The species is constrained to the *Megistaspis limbata* Zone of the upper Volhov Regional Stage (Fig. 4; Nielsen 1995; Stouge & Nielsen 2003).

In Scandinavia, the *Megistapis limbata* Zone corresponds to the lowermost part of the Darriwilian Stage

of the international Middle Ordovician Series (Stouge & Nielsen 2003).

Czech Republic. The sediments of the Prague Basin are very rich in fossils, and the macrofauna and microfauna/flora are referred to the Mediterranean Province of the high latitude on the southern hemisphere (Havlíček 1989; Havlíček *et al*. 1994).

The low-diversity conodontfauna (Dzik 1983a) was recovered from siliciclastic sediments associated with Fe-nodules and volcanics, which are referred to the Klabava Formation (Havlíček 1981; Havlíček & Fatka 1992). *Barrandegnathus bohemicus* occurs in the *Azygograptus ellesi-Tetragraptus reclinatus abbreviatus* graptolite Zone (*sensu* Kraft & Kraft 1999), which correlates with the upper part of the Arenig (Bohemia/Gondwana) Series.

Morocco. The *Barrandegnathus* fauna from the Khemis-n'Ga locality in western Morocco was recorded as reworked Ordovician conodont fauna from an Upper Silurian silty-carbonate unit (Bultynck & Sarmiento 2003). The Silurian sediments overlie lower – mid Arenigian sand and siltstones with a prominent erosional unconformity (Beun *et al*. 1986). The conodont fauna is the first record of early Mid Ordovician faunas from western Morocco, thus representing an unexposed interval in the region (Bultynck & Sarmiento 2003; see also Gutiérrez-Marco *et al*. 2003). The Moroccan conodont fauna is relatively diverse and resembles in most aspects the Komstad Limestone fauna of southwestern margin of Baltica - in the presence of *Barrandegnathus* but also with the additional presence of other Baltic taxa – allowing for a correlation to the *Baltoniodus norrlandicus* and *Lenodus antivariabilis* conodont zones.

Palaeogeographical distribution of *Barrandegnathus*

Barrandegnathus is recorded from the Prague Basin, which belongs to the single peripheral terrane Perunica of the West Gondwana supercontinent, West Gondwana supercontinent and the southwestern margin of Baltica continent (Havlíček 1981, 1989; Havlíček *et al*. 1994; Cocks & Torsvik 2002, 2004; Fortey & Cocks 2003). All three regions were facing the Tornquist Sea (Cocks & Torsvik 2002, 2004; Fortey & Cocks 2003; Torsvik & Rehnström 2003). The Perunica terrane maintained a high latitudinal position, whereas Morocco (West Gondwana) with its occurrence of *Barrandegnathus* and the Baltic fauna was situated in a high to mid-high latitudinal position during the lower Mid Ordovician. *Barrandegnathus* was restricted to the Tornquist Sea and Perunica and Morocco were close to each other during late Arenig. The Komstad Limestone accumulated at a mid-southerly position on the Baltica palaeocontinent and was separated from Perunica and Gondwana by the Tornquist Sea (Cocks & Torsvik 2002, 2004; Fortey & Cocks 2003; Torsvik & Rehnström 2003). On Baltica *Barrandegnathus* is – as mentioned above – only found in the Komstad Limestone.

Distribution of Baltoscandian conodonts adjacent to Gondwana

Other terranes peripheral to West Gondwana i.e. Armorica and Iberia (Fortey & Cocks 2003; Gutierrez-Marco *et al*. 1999, 2003) have not yielded conodonts contemporaneous to the *Barrandegnathus* fauna. The areas Turkey, South China and New Brunswick, Canada however provide further information.

Turkey. Early Darriwilian conodonts are known from several localities in the Taurides or the Tauride Belt (Barnes *in* Dean 1973; Gedik 1977; Sarmiento *et al*. 1999). The Cambrian – Mid Ordovician Seydisehir Formation is predominantly a siliciclastic unit with few nodular limestone beds. The sediments accumulated on the extensive Tauride Platform at the Gondwana margin but two distinct limestone units (i.e. the Sobova Limestone and the younger Tekmen Member) interrupt the overall siliciclastic sedimentation of the Seydisehir Formation (Gedik 1977; Sarmiento *et al*. 1999; Kozlu *et al*. 2003).

The yield of conodonts is relatively low in the sand and siltstones but the limestone nodules and the two limestone units produced early and mid Ordovician conodonts that in general show Baltic Province affinities. One exception to this is the report of *Oepikodus evae* (= *Prioniodus evae* of Gedik 1977) and *Bergstroemognathus* sp. (i.e. *Falodus* sp. of Gedik 1977) - a faunal association, which is more typical for low latitudinal East Gondwana and Laurentia rather than Baltica.

The well-developed Mid Ordovician conodont fauna recorded from the Sobova Limestone (Barnes *in* Dean 1973; Gedik 1977) shows close affinities with the fauna from the East European/Baltic Platform. The fauna from the Sobova Limestone correlates to the Baltoscanian *Baltoniodus norrlandicus* and *Lenodus antivariabilis* conodont zones.

South China. The Dawan Formation in the Hubei district of South China consists of a complex mixture of carbonate, shale and cool-water carbonates. The associated conodont fauna changes from warm-water types to conodonts with Baltic affinity (An 1981, 1987; An *et al*. 1985; Lindström *et al*. 1991; Stouge 2001b; Zhang 1998a). The faunal shift occurs in the late Early Ordovician and the base of the Middle Ordovician is characterized by the appearance of '*Baltoniodus*' *triangularis* (Wang *et al*. 2005). From this level the succession lithologically resembles that of Baltoscandia (Lindström *et al*. 1991) and the conodont zones can be matched to those known from Baltoscandia (Stouge 2003). The *Baltoniodus norrlandicus*, *Lenodus antivariabilis* and younger zones can be distinguished and the fauna is clearly of Baltoscandian affinity (Zhang 1998a; Wang & Bergström 1999; Stouge 2003).

New Brunswick. Mid – late Arenigian conodonts with strong Baltic Province affinity are known from two locations in New Brunswick, Canada (Nowlan 1981; Landing *et al*. 2003) i.e. the (west) Avalonia (= Ganderia microcontinent of van Staal *et al*. 2003). The first occurrence is from central New Brunswick, where *Microzarkodina flabellum* s.l. is recorded from the uppermost part of the lower Tetagouche Group.

A Mid Ordovician (*Lenodus antivariabilis* and *L. variabilis* zones) conodont fauna is recorded from a limestone boulder in the Triassic Lepreau Formation in southern New Brunswick. The conodont yielding limestone unit is a cool-water carbonate with a diverse conodont fauna of Baltic affinity (Landing *et al*. 2003). The appearance of the conodonts of Baltic Province suggests that west Avalonia (i.e. Ganderia) reached a high to mid latitudinal position (e.g. Landing 1998, 2003) during the late Arenig.

Neither of these pre-Caradoc Baltic conodont faunas is associated with *Barrandegnathus*.

Discussion

The arrival of *Barrandegnathus* in late Volkhov to Baltica was probably a result of various palaeobiogeographical factors, notably the extent and timing of the late Volkhov transgressive-regressive event within the Tornquist Sea area. Tectonic movements near West Gondwana and Perunica possibly associated with rifting opened for the northern direction of a cold high latitudinal ocean current (see Christiansen & Stouge 1999a, b). This event promoted the emigration of the Perunica/Gondwana-derived conodonts to Baltica in the late Volkhov times. The ocean current thus provided a bridge for the conodont species to migrate across the Tornquist Sea and the cold-water 'endemic' *Barrandegnathus bohemicus* was not exclusively constrained to high latitudinal sites.

The cold oceanic current remained active long enough for *B. bohemicus* to colonize the cool and deep-water environments along the southwestern margin of Baltica. Towards the end of Volkhov times this route was closed and the Gondwana and Baltica populations became isolated from each other again.

Available evidence shows that Baltoscandian conodonts (or the Baltic Province) were not constrained to the Baltica continent during early Mid Ordovician times. The Baltoscandian conodont fauna was associated with cool-temperate water carbonate depositional environments (e.g. Lindström 1984a, b). Apparently, cool-water carbonates accumulated on Gondwana i.e. Marocco and on Gondwana derived microcontinents (South China, New Brunswick) as they reached mid-high latitudes. The associated Baltic Province conodont fauna inhabited the continents as these reached or passed through distinct latitudinal and climate belts on the southern hemisphere.

The early Darriwilian conodont faunas from Turkey, New Brunswick and South China are all similar and this suggests that the areas occupied a relatively lower northern position than Perunica did during the lower Mid Ordovician. Apparently major changes in the oceanic current system occurred at this time allowing for cool-water carbonate accumulation at places such as Morocco and Turkey. According to recent palaeogeographical models these areas were situated near the south pole (Cocks & Torsvik 2002, 2004; Fortey & Cocks 2003).

Conclusions

Barrandegnathus originated from west Gondwana and occupied a restricted area within the Tornquist Sea between western Morocco on Gondwana and Perunica, and at high latitudes on the southern hemisphere. *Barrandegnathus* is recorded from the Komstad Limestone and the taxon lived in deep-water shelf environments along the margin of Baltica. It reached Baltica and stayed on its continental margin within a relative short time interval of the early Mid Ordovician (early Darriwilian, late Volkhov).

The immigration of *Barrandegnathus* to southwestern Baltica was probably due to the presence of cold-water oceanic currents (e.g. Dzik 1983a; Christiansen & Stouge 1999a, b). Its arrival to Baltica marks the base of the Darriwilian international Stage of the glo-

bal Middle Ordovician Series (Mitchell & Maletz 1995; Stouge & Nielsen 2003).

Barrandegnathus bohemicus has not been recorded from other Gondwana-derived terranes. However, conodonts with Baltoscandian affinities and contemporaneous to the *Barrandegnathus* fauna appeared near to or along the margin of Gondwana suggesting that faunal communication occurred between Gondwana, peri-Gondwana and Baltica. The Baltic Province conodont fauna also appeared on continents (i.e. Avalonia) that drifted northwards (New Brunswick-Turkey) and southwards (South China). The appearance of Baltic Province conodonts at these places was probably a consequence of the drifting of the palaeocontinents towards mid latitudinal sites with distinct temperate climate belts.

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