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Late Ordovician conodont faunas from southern Sardinia, Italy: biostratigraphic and paleogeographic implications

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ABSTRACT – Conodont faunas recovered from several localities in southwestern and southeastern Sardinia are assigned to the Late Ordovician on the basis of the recovery of Amorphognathus ordovicicus *Branson & Mehl, 1933 and* A. lindstroemi *(Serpagli, 1967). A peculiar* Amorphognathus *species that has been found in slightly older sediments is described. 28 species belonging to 18 genera constitute the conodont collection; elements of* Hamarodus europaeus *(Serpagli, 1967) and* Scabbardella altipes *(Henningsmoen, 1948), together with those of* Amorphognathus, *numerically dominate the fauna. The same dominance was already reported in the "Tonflaserkalk" of the Carnic Alps (Serpagli, 1967). Taxa of the genera* Plectodina, Dichodella, Sagittodontina, Istorinus *and* Icriodina *are described and discussed for the first time for Sardinia. The conodont fauna, composed of about 13000 elements obtained by the processing of about 550 kg of limestones, includes species typical of the Mediterranean Province. Nevertheless, the extreme paucity of its markers* Sagittodontina robusta *Knüpfer, 1967 and* Istorinus erectus *Knüpfer, 1967, which together represent less than one per cent. of the fauna, and the presence of other typical indicators of lower latitude affinity like* Plectodina *and* Dichodella *reveal the mixed character of Sardinian fauna. Together with the Carnic Alps, Sardinia probably occupied an outer position of lower latitudes (compared to the typical north-Gondwanian regions of the circumpolar belt) where faunistic interchange with both the British and Baltic provinces was possible.*

RIASSUNTO – [Faune a conodonti dell'Ordoviciano superiore nella Sardegna meridionale, Italia: considerazioni biostratigrafiche e paleogeografiche] – *Alcune faune a conodonti rinvenute in varie località della Sardegna sudoccidentale e sudorientale sono datate all'Ordoviciano superiore grazie al ritrovamento di* Amorphognathus ordovicicus *Branson & Mehl, 1933* e A. lindstroemi *(Serpagli, 1967). Una particolare specie di* Amorphognathus, *ritrovata in sedimenti leggermente più antichi, è qui descritta. 28 specie appartenenti a 18 generi costituiscono la fauna;* Hamarodus europaeus *(Serpagli, 1967) e* Scabbardella altipes *(Henningsmoen, 1948), assieme ad* Amorphognathus, *rappresentano le forme più diffuse. La stessa dominanza era già stata segnalata nel "Tonflaserkalk" delle Alpi Carniche (Serpagli, 1967). Taxa appartenenti ai generi* Plectodina, Dichodella, Sagittodontina, Istorinus *ed* Icriodina *sono descritti e discussi per la prima volta in Sardegna. Nella fauna a conodonti, costituita da circa 13.000 elementi ottenuti dalla preparazione di circa 550 chilogrammi di calcari, sono presenti specie tipiche della Provincia Mediterranea. Tuttavia, l'estrema scarsità dei suoi rappresentanti più significativi* Sagittodontina robusta *Knüpfer, 1967 ed* Istorinus erectus *Knüpfer, 1967 (che assieme costituiscono meno dell'uno per cento della fauna) nonchè la presenza di indicatori di latitudini più basse, quali* Plectodina *e* Dichodella, *conferiscono un carattere misto alla fauna sarda. Assieme alle Alpi Carniche, la Sardegna occupava probabilmente una posizione più esterna rispetto alla fascia delle regioni tipicamente nord-gondwaniane, ove era possibile un interscambio faunistico con la Provincia Britannica e quella Baltica.*

INTRODUCTION

Ordovician sediments deposited in Southern Europe are mostly constituted by clastic sequences interrupted at the end of the Period by a significant carbonatic episode with variable thickness in different areas. The conodont fauna that has been reported from this horizon represents the cold-water "Mediterranean" fauna of high latitude (Sweet & Bergström, 1984) corresponding to the Mediterranean Province already documented on the basis of other fossil groups (Spjeldnaes, 1961, 1967). This calcareous event is developed also in southern Sardinia (Italy).

Helmcke and Kock (1974), in the attempt to date the porphyroids from the Sarrabus-Gerrei area of southeastern Sardinia, listed (pp. 93-94) a few Ordovician conodonts ("*Amorphognathus* aff. *ordovicicus*, *A.* cf. *tvaerensis*, *Drepanodus altipes*, *Drepanodus* sp. and *Prioniodus* sp.") of which no descriptions or illustrations were provided. Ferretti and Serpagli (1991) and Ferretti (1992) reported Late Ordovician conodonts from a single locality of the Iglesiente in the southwestern part of the island.

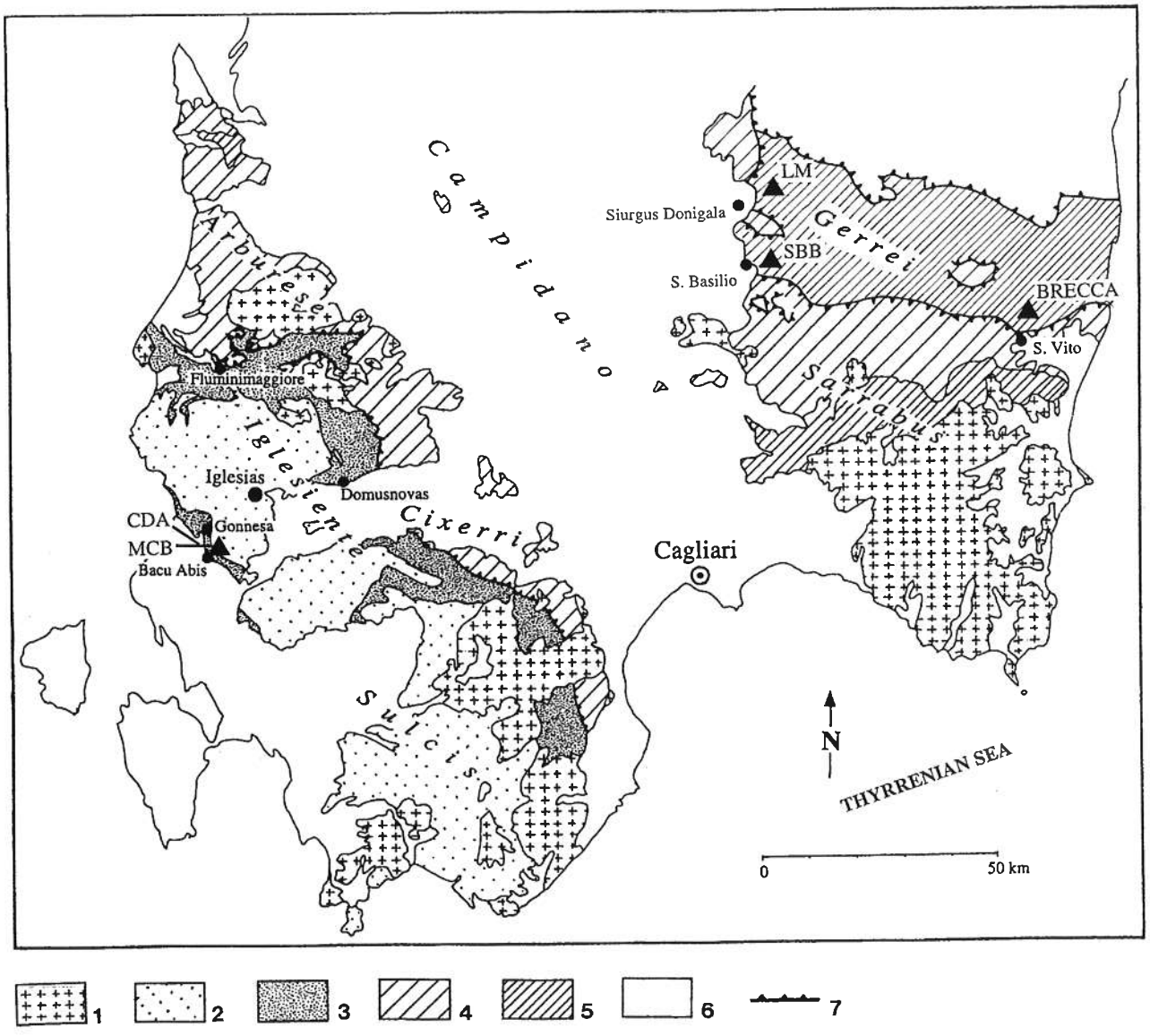
Intensive investigation carried out in the last ten years on all the Ordovician exposed in southern Sardinia has resulted in a considerable amount of new information on the occurrence and distribution of conodonts in the region (Ferretti & Serpagli, 1998). New outcrops were discovered and sampled. Only five of the fourteen areas tested all over southern Sardinia yielded conodont faunas. Some of these results have been preliminary reported in the ECOS VII Sardinia Guide-book (Ferretti *et al.*, 1998a, b, c). In this contribution we present a global consideration of the fauna as a whole.

THE ORDOVICIAN OF SARDINIA

Southwestern and southeastern Sardinia are separated today by the Pliocene to mid-Pleistocene tectonic depression of the Campidano (Text-fig. 1) which replicates the older structure of the Sardinian Graben (=Sardinian rift) of Late Aquitanian to Early Burdigalian Age (Cherchi & Montadert, 1982; Hammann & Leone, 1997). Paleontological and sedimentological studies have mostly dealt with these two areas individually.

Ordovician rocks are abundant in Sardinia and belong either to autochthonous or to allochthonous and/or parautochthonous structural units.

The most important post-Sardic Ordovician autochthonous sequence (1000 m thick) of south-



Text-fig. 1 - Geological sketch map of southern Sardinia showing location of conodont productive Late Ordovician localities (slightly modified after Hammann & Leone, 1997). 1) Hercynian igneous rocks; 2) Presardic autochthonous sequence (Cambrian to Early Ordovician); 3) Postsardic autochthonous sequence (Middle Ordovician to Devonian); 4) Presardic allochthonous (Arburese, Genn'Argiolas and Gerrei nappes) sequence (Cambrian to Early Ordovician); 5) Postsardic allochthonous (Arburese, Genn'Argiolas and Gerrei nappes) sequence (Middle Ordovician to Devonian); 6) Posthercynian; 7) Overthrust.
Conodont localities: CDA) Cannamenda; MCB) Monte Cortoghiana Becciu; LM) Umbrarutta; SBB) Cea Brabetza; BRECCA) Brecca.

western Sardinia is the Iglesiente-Sulcis sequence represented by terrigenous deposits and typical marine sediments in the upper part. Five formations (M. Argentu Fm., M. Orri Fm., Portixeddu Fm., Domusnovas Fm. and Rio S. Marco Fm.), some of which subdivided in members, were introduced by Leone *et al.* (1991). The Late Ordovician has been known for a long time as a rich source of well preserved fossils mostly from the dark-grey very fine sandstones, siltstones and shales, having pyritic and phosphatic nodules towards the top, of the Portixeddu Formation and from the initially arenaceous and subsequently shaley-marly Domusnovas Formation. Brachiopods, bryozoans and echinoderms are dominant, associated with trilobites, ostracodes, gastropods, bivalves, cephalopods, cornulitids, conularids, corals, hyolithids, sponges, chitinozoans, acritarchs and graptolites.

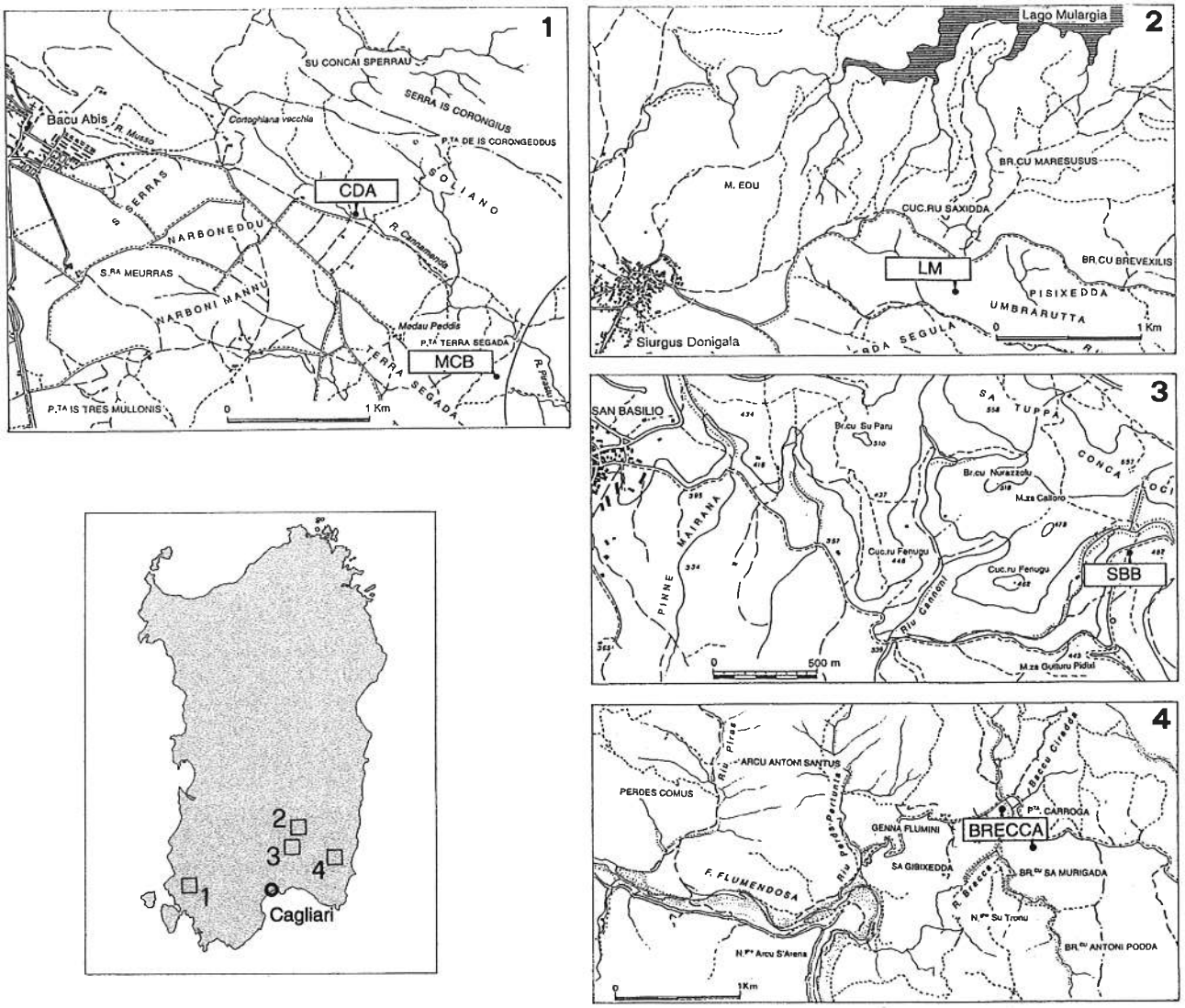
The post-Sarrabese succession of southeastern Sardinia is represented by a lower volcanic and volcanoclastic complex overlain by an Upper Ordovician mainly terrigenous sequence with extremely subordinate limestones (Leone, 1998). Formal lithostratigraphic units were introduced by Barca and Di Gregorio (1980), Loi (1993) and Loi and Dabard (1997) in the Sarrabus area, whereas no formal subdivision of the Ordovician was ever proposed for the Gerrei, owing to the strong variability of subunits and the local facies variations attributed to an extremely variable morphology of the bottom of the basin. Late Ordovician faunas of brachiopods, trilobites, bryozoans, crinoids, cystoids, gastropods, and rare orthocone cephalopods were recovered from the Punta Serpeddì and Tuviois formations in the Sarrabus and from the informal "Rio Canoni shales" (Naud, 1979) in the Gerrei.

The Ordovician succession of the Iglesiente-Sulcis differs from that of southeastern Sardinia mostly in its lack of Middle Ordovician volcanics and in having a thick glaciomarine Hirnantian succession (Leone *et al.*, 1991; Hammann & Leone, 1997). Together with a clearly differing zircon typology and geochemistry (Loi & Dabard, 1997) this would indicate the existence of different sedimentary basins. On the other hand the strong similarities in the tectono-sedimentary development of southwestern and southeastern Sardinia undoubtedly suggest a close original palaeogeographic relationship. Furthermore, the existence in both basins of a complete Cambrian to Lower Ordovician succession and of a Middle Ordovician stratigraphic gap ("Sardic unconformity" of southwestern Sardinia and "Sarrabese unconformity" of southeastern Sardinia) reinforces the similarity with other regions of the North Gondwana "unstable shelf region" (Hammann, 1992; Hammann & Leone, 1997).

LOCATION OF THE INVESTIGATED SECTIONS

The present study focuses on Upper Ordovician rocks exposed at five different localities in western (Cannamenda and Monte Cortoghiana Becciu) and eastern (Brecca, Cea Brabetza and Umbrarutta) Sardinia (Text-figs. 1-2); more specific information on some outcrops may be deduced in Ferretti *et al.* (1998a, b, c). Most localities represent spot limestone occurrences in each outcrop as a result of the strong tectonic activity which affected the island during the Hercynian orogenesis; in addition many units have been biostratigraphically dated for the first time. This study involved repetitive sampling and a huge laboratory background in an often exhaustive attempt to recognize the fossiliferous levels. Only about one-third of the localities tested for conodonts provided elements, and for those, about half of the collected samples proved to be barren.

Sampling in southwestern Sardinia concentrated on the upper part of the Portixeddu Formation (locality Cannamenda) and mostly on the Punta S'Argiola Member at the top of the Domusnovas Formation (localities Cannamenda and Monte Cortoghiana Becciu, both close to the Bacu Abis village). Levels of a dark-grey limestone (bryozoan wackestone to packstone), associated with echinoderm debris and rare brachiopods, are interbedded in siltstones for about 2.5 m at the top of the Portixeddu Formation immediately below the enrichment in phosphatic nodules. A scarce conodont fauna, nevertheless bearing a peculiar *Amorphognathus* species (Pl. 4, figs. 1-4), was there recovered. Bryozoans, brachiopods and chitinozoans were observed in the heavy fractions; rare ostracodes were picked in the light fraction. Brachiopod evidences suggest locating the Caradoc/Ashgill boundary within this part of the unit or immediately below (Leone *et al.*, 1991). A thin barren level of green claystones is followed by red claystones intercalated by green to pink-red calcareous horizons, locally enriched by crinoid fragments. A 4-4.5 cm level of fine-grained pink limestone, exposed in the field in the form of scattered blocks, represents the only conodont productive part of the Punta S'Argiola Member at Cannamenda. A preliminary study on facies control over conodont distribution from this section (only about one-third of the samples were productive) was attempted by Ferretti *et al.* (1998b). The productive limestone is constituted by a wackestone to packstone bearing echinoderm fragments associated with trilobites, bryozoans, sponges and sponge spiculae, brachiopods, gastropods, and very rare small cephalopods. Ostracodes are locally accumulated. Bryozoan-packstones and encrinitic-packstones, as well as mixed bryozoan-echinoderm packstones, were



Text-fig. 2 - Detailed location of conodont localities. CDA) Cannamenda; MCB) Monte Cortoghiana Becciu; LM) Umbrarutta; SBB) Cea Brabetza; BRECCA) Brecca.

completely barren for conodonts (Ferretti *et al.*, 1998b).

Two brachiopod levels and one trilobite horizon were reported by Leone *et al.* (1991) in the Domusnovas Formation, a lower one at the base related to the *Nicolella* fauna (similar to the association of the Portixeddu Formation) and an upper one, with brachiopods and trilobites (attributed to the *Foliomena* fauna) and a cyclopygid trilobite association of deeper water. The Ashgill age of the latter level was proposed on the basis of the trilobite fauna, dominated by *Cyclopige marginata* (Hawle & Corda, 1847) and reinforced by brachiopods of the *Foliomena* fauna and members of the *Proboscisambon* Community.

The exposure of Monte Cortoghiana Becciu, about 1.5 km SE of Cannamenda, represents probably the lateral equivalent of the upper Cannamenda horizon. Only the lower part of a 70 cm calcareous sequence produced a poorly-preserved fauna from a wackestone to packstone almost entirely represented by crinoid debris and rare trilobite fragments, associated with brachiopods and sponges.

Three localities from southeastern Sardinia (Gerrei) produced Ordovician conodont faunas. As previously remarked, no detailed lithostratigraphic classification or formal units have been proposed for the Gerrei and the informal subdivisions of Naud (1979) are here used. Within the fossiliferous upper part of the Ordovician sequence of southeastern Sardinia ("Rio Canoni shales") Naud distinguished two main facies, a typical shaley facies and a sandy calcareous shaley one, apparently associated with red to white cystoid limestones for a total maximum thickness of ten meters (Leone, 1998). Metabasites indicating submarine volcanic activity are locally interbedded (e.g. at San Basilio and Brecca; Leone, 1998).

The area of Brecca, located 4 km N of the S. Vito village, is the original site from which Helmcke and Kock (1974) reported a few conodont elements. The limestone that lies immediately above the porphyroids has been strongly silicified and the search for productive samples has been extremely time consuming. Nevertheless, rare thin layers of grey pure limestone, represented by a packstone of mostly crinoid fragments associated with bryozoans, brachiopods and ostracodes, yielded moderately well preserved conodont faunas. Inarticulate brachiopods were recovered in the heavy fraction. Helmcke and Kock (1974) reported also cystoids and solitary corals.

At the Umbrarutta locality in the Lago Mulargia area, about 3 km from the Siurgus Donigala village, dark grey limestones, mostly composed by echinoderm debris, are locally interbedded with greenish or reddish silty or sandy carbonatic shales sometimes with a typical vacuolar aspect due to the dissolution of fossils. The shales contain benthic fauna with bryozoans (which closely recall the bryozoan fauna of the Portixeddu Formation of southwestern Sardinia; Conti, 1990), crinoids and brachiopods. The limestones have been intensively tested for conodonts, but with no success. A thin dark-red siltitic horizon covers the bryozoan shales and it is overlain by the conodont productive limestone, a light-grey, rarely pinkish or reddish at the base, high-calcium limestone rich in echinoderm debris and weathering to yellowish-grey. The limestone is mostly a micritic mudstone (only rarely wackestone or packstone) with fragmentary echinoderms or bryozoans and rare trilobite fragments.

The Cea Brabetza section is located 3 km from the San Basilio village. A lower coarse-grained arenaceous part (10 m thick) is covered by a 36 m thick succession of fine and coarse-grained calcarenites rich in echinoderm debris interbedded with marly-argillaceous levels. Sampling was mostly restricted to the lower eight meters where the section appeared not tectonically disturbed or decalcified. Limestones are mostly constituted by packstones to wackestones, strongly recrystallized and disturbed. Echinoderm debris is ubiquitous, rare bryozoan fragments are also visible in thin-section.

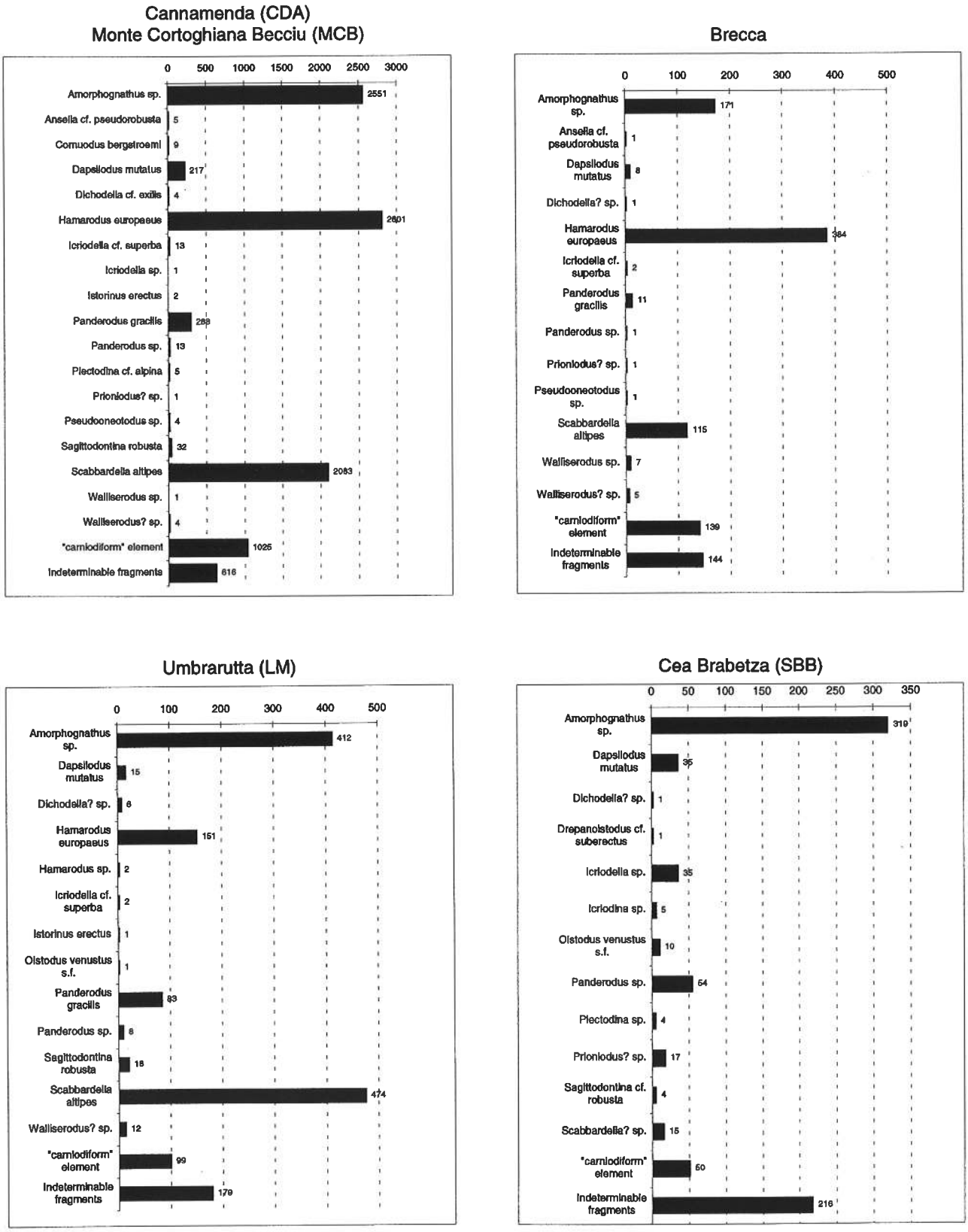
THE ORDOVICIAN CONODONT FAUNAS FROM SARDINIA

Conodonts have been obtained from 52 of 115 samples collected in the five localities. About 550 kg of limestones were processed for conodont recovery with acetic or formic acid. Extremely abundant residues were concentrated with sodium-polytungstate resulting in scarce (e.g. Cannamenda) or large heavy fractions (e.g. Cea Brabetza). A total of about 13000 elements have been recovered and their numerical representation in each sample is summarized in Tab. 1. Preservation is variable in the different sections, but the specimens are mostly fragmentary and encrusted. The material from Cea Brabetza (southeastern Sardinia) is undoubtedly the worst in terms of preservation, whereas the best preserved specimens are from Umbrarutta and some levels of Brecca. The colour alteration index (CAI of Epstein *et al.*, 1977) ranges from 4 to 6, suggesting thermal maturation in the 190-550° C range.

A total of 28 species belonging to 18 genera have been identified. Two of them are reported as morphospecies. This apparently high number of species does not reflect real high diversity of the fauna. In some sections (e.g. Cea Brabetza) the preservation of the material has resulted in an almost ubiquitous open nomenclature as specimens were either too fragmentary or too sparse to allow specific identification. Many genera (e.g. *Istorinus*) are present with only a few elements. Conodont productivity strongly differs in the various areas, as expressed in Tab. 1.

The *A. ordovicicus* Zone of Late Ordovician age has been documented in four localities both in southwestern and southeastern Sardinia. The fauna from these areas is essentially homogeneous throughout the sections, and is numerically dominated by *Hamarodus europaeus*, *Amorphognathus* (*A. ordovicicus* and/or *A. lindstroemi*) and *Scabbardella altipes* (Text-fig. 3). Elements of these taxa constitute together about two-thirds (74 per cent) of the whole assemblage reported in this study. Relatively abundant species are *Panderodus gracilis* (3 per cent) and *Dapsilodus mutatus* (2 per cent). Other species, e.g. *Cornuodus bergstroemi* and *Plectodina* cf. *alpina*, are extremely rare. Species of *Plectodina*, *Dichodella*, *Cornuodus*, *Pseudooneotodus*, *Sagittodontina* and *Istorinus* are described and discussed for the first time for Sardinia. These conodont assemblages belong to the HDS (*Hamarodus europaeus-Dapsilodus mutatus-Scabbardella altipes*) Biofacies of Sweet and Bergström (1984).

The conodont fauna recovered from the Cea Brabetza section differs from the Ordovician associations reported elsewhere in the island. Few elements of *Drepanoistodus* cf. *suberectus* (Branson & Mehl, 1933), *Icriodina* sp. s.f. and *Oistodus venustus* s.f.



Text-fig. 3 - Numbers of individual species recovered from the Sardinian conodont localities here investigated.

Stauffer, 1935 occur only here. *Dapsilodus mutatus* is slightly more abundant (about 5 per cent compared to an average value of 2 per cent in the other outcrops) and is associated with representatives of *Amorpho-gnathus* sp. and *Panderodus* sp. Furthermore, *Icriodella* sp. and *Icriodina* sp. s.f. represent here about 5 per cent. of the fauna. *Hamarodus europaeus* is apparently missing and *Scabbardella* is only questionably present. Owing to the peculiarity of such assemblage, no biofacies definition in the scheme of Sweet and Bergström (1984) is attempted; nevertheless remarkable similarities (mostly the presence of *Icriodina* and the absence of *Hamarodus*) occur with the Ashgill conodont fauna described by Paris *et al.* (1982) in the *Calcaire de Rosan* of northwest France, even if species are present with diverse frequencies.

COMPARISON BETWEEN SOUTHWESTERN AND SOUTHEASTERN SARDINIA

No significant differences in composition appear to exist between conodont faunas of the *A. ordovicicus* Zone recovered from southwestern and southeastern Sardinia. Some species have, in fact, been recovered only from one sector (e.g. *Cornuodus bergstroemi*) but with such sparse elements that it is not possible to establish if this reflects a true absence or simply lack of recovery. The faunas from the two sectors of the island only differ in productivity, the conodont assemblage from southwestern Sardinia being much more abundant (two-thirds of the whole Sardinian fauna here reported has been obtained from the material of southwestern Sardinia, which represents in weight only one-third of the whole productive limestone), and in a slightly different order of abundance of the three main species (*Hamarodus europaeus*, *Scabbardella altipes* and *Amorphognathus* sp.) in the different sampled localities, which nevertheless always mantain a dominant role. In particular, the conodont assemblage from Umbrarutta is dominated by *Scabbardella altipes* (32 per cent) and shows a minor presence of *Hamarodus europaeus* (10 per cent), species which is on the contrary abundant in other areas of southeastern Sardinia (39 per cent at Brecca). Furthermore, the Umbrarutta assemblage is composed of slightly smaller-sized elements and has the highest CAI value in southern Sardinia.

The peculiar features of the Cea Brabetza fauna have been discussed above.

PALEOGEOGRAPHIC REMARKS

"North Africa and South Europe are assigned as a rule to the Mediterranean zoogeographic province which on the whole is a cold-water province of the circum-polar zone; marginal parts of this province may reach the temperate zone" (Havlíček, 1989, p. 79). The benthic fauna is far from uniform, reflecting "latitudinal-climatic control, geographic distribution, and various modes and rates of migrations of individual animal groups" (Havlíček, 1989, p. 80).

As regards conodonts, Late Ordovician provincialism has been thoroughly discussed by Sweet and Bergström (1984) and updated in terms of multielement taxonomy by Bergström (1990b). Three different provinces, Baltic, British and Mediterranean, were recognized by Bergström (1990b) inside the Atlantic Faunal Region, which is characterized by high latitude cool- to cold-water faunas. Whereas the Baltic and British provinces show many similarities, the Mediterranean is a distinctive high-latitude fauna having its markers in *Sagittodontina*, *Istorinus* and *Nordiodus* (Bergström, 1990b; Nowlan *et al.*, 1997). Paleogeographic reconstruction and biostratigraphic relations inside the Mediterranean Province are complicated and continental Europe is often conveniently referred to as a whole unit of high latitude located at the southern hemisphere extremity. Paris (1990), Paris and Robardet (1990) and Robardet *et al.* (1990), mainly using respectively chitinozoans or the evolution of climatic features, attempted a reconstruction of relative positions of many European localities, postulating the existence in North Gondwana of a South Armorican Ocean, as a branch of the Rheic Ocean. Its northern margin was represented by the mid-North Armorican and Central Iberian domains (as an extension of the Moroccan and Saharan platform), the southern one by the Ebro-Aquitanian Domain, by southernmost Europe and Bohemia.

Hammann (1992) reinterpreted the distribution of many early Paleozoic areas of North Gondwana in a shelf to basin transect, recognizing a main stable shelf (including North Africa and the terranes of the Central Iberian Zone and Armorica) and an unstable shelf region (including Pyrenees, Catalonia, Montagne Noire, Sardinia, the Alps, parts of the Carpathians and large parts of Turkey) locating southwestern Sardinia in an outer shelf-to-slope transitional zone. According to the author, the South Armorican Ocean would not have existed, but was simply part of the southern Mid-European Rheic Ocean.

Havlíček *et al.* (1994, p. 24) recenty reinterpreted the Mediterranean Province as a "mosaic of various terranes often largely differing from each other". They established Perunica, including the major part of the Bohemian Massif, as a separate microcontinent in the Ordovician, located between the Gondwanan and North European (Baltic) cratons, and occasionally in communication with Armorica (which, at that time, according to the authors, included Spain, France, Carnic Alps and Sardinia).

The global composition of the conodont fauna recovered in Sardinia is apparently closely similar to

that reported from other areas of the cold-water Mediterranean Province in the Late Ordovician. Nevertheless, the Sardinian fauna differs strikingly from the others in the relative proportion of the species. *Sagittodontina robusta* and *Istorinus erectus* are present in greater abundance from areas interpreted as parts of the Northern Gondwana margin. These two species are widely distributed in Spain and France (e.g. Fuganti & Serpagli, 1968; Hartevelt, 1970; Lindström & Pelhate, 1971; Carls, 1975; Weyant *et al.*, 1977; Hafenrichter, 1979; Paris *et al.*, 1982; Sarmiento, 1990; Ferretti, 1992; Sarmiento & Garcia López, 1993), and are dominant in Thuringia (32 per cent and 19 per cent respectively; Ferretti & Barnes, 1997) and Libya (45 per cent and 6 per cent respectively; Bergström & Massa, 1992). A recent conodont fauna from Bohemia (Ferretti, 1998) is too scarce to allow conclusions, nevertheless, elements of *S.* cf. *robusta* appear to be also well represented there in the Perník Bed conodont collection (22 per cent). *S. robusta* and *I. erectus* are on the contrary almost undetectable in Sardinia (less than 1 per cent.), the former being represented mostly by very rare ramiform elements and the latter by a few specimens. In addition, these two genera have been recently reported with rare representatives also from south Wales (Barnes *et al.*, 1998). Furthermore, typical low-latitude genera that occur fairly widely in the British Province and in the Carnic Alps, like *Plectodina* and *Dichodella*, are also reported in Sardinia, stressing once more the links between these two European areas and their difference with other areas of North Gondwana.

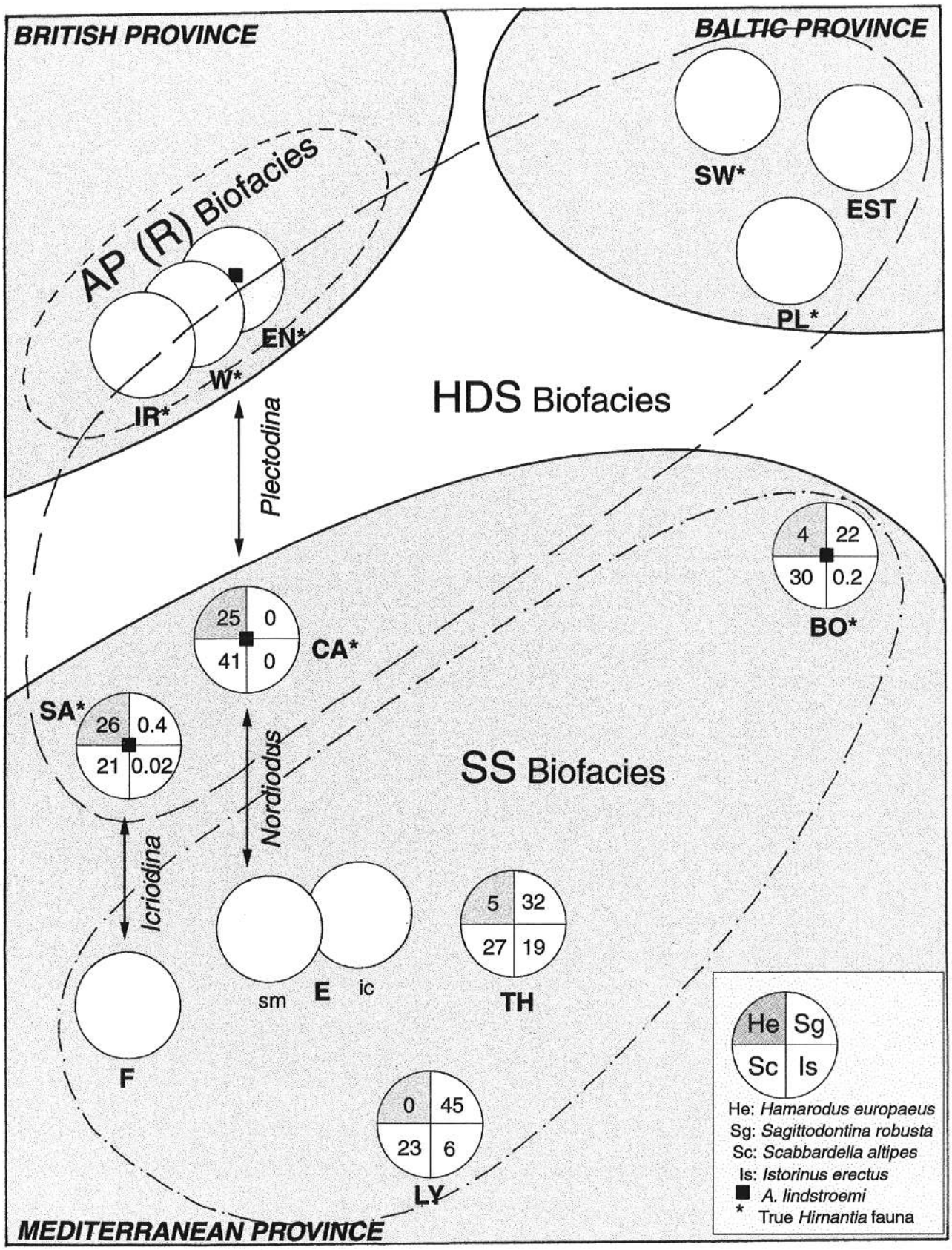
The uniqueness of the Carnic Alps conodont fauna described by Serpagli (1967) was already emphasised by Sweet and Bergström (1984). The great abundance there of *Hamarodus europaeus* (25 per cent) and the presence of typical species like *Plectodina alpina*, *Ansella pseudorobusta*, *Dichodella exilis* and *"Strachanognathus parvus"*, not reported elsewhere in continental Europe, led Sweet and Bergström (1984) include the Carnic Alps, the Baltic Province, part of the British Province and south-central China (Pagoda Limestone) in the HDS (*H. europaeus-D. mutatus-S. altipes*) Biofacies. Other areas of southern Europe and North Africa (Libya, Thuringia, Spain, NW France) were instead attributed to the *S. robusta-S. altipes* Biofacies. Ferretti and Barnes (1997) reinforced this assumption observing that the Carnic Alps have the most diversified fauna in southern Europe and that they had closer relations to more temperate faunas. On the basis of lithological and faunal data, Schönlaub (1992, 1998) inferred for the Southern Alps a paleolatitudinal position at approximately 50° S in the Late Ordovician.

The Sardinian conodont assemblage here described has indeed much in common with the Carnic Alps, having in *H. europaeus* (26 per cent), *Amorphognathus* sp. (including elements of *A. ordovicicus* and *A. lindstroemi*) and *S. altipes* its dominant components (74 per cent of the fauna). Similarly, also rare elements of *Plectodina* cf. *alpina* and *Ansella* cf. *pseudorobusta* are present. The diversity of our fauna is certainly much lower than that of the Carnic collection, and many species are represented by sparse elements and incomplete apparatuses. Furthermore, another typical indicator of that fauna, *Nordiodus italicus*, abundant in the Carnic material (Serpagli, 1967; Bagnoli *et al.*, 1998) and reported also from Sierra Morena in Central Spain (Fuganti & Serpagli, 1968; Ferretti, 1992) has so far not been found in Sardinia. Up to now, the presence of *Nordiodus*, together with the absence of *Rhodesognathus*, would represent the only common features between the Carnic Alps and the Mediterranean Province. Our data would therefore suggest, even for Sardinia, a more external position of lower latitudes inside the Mediterranean Province compared to the other north-Gondwanian regions of the circumpolar belt.

Any faunistic comparison between separate geographic areas within a 4-8 million years interval (estimated duration of the Ashgill Series; Barnes, 1992) gains significance whenever this analysis involves the shortest possible time interval. The recovery of *A. lindstroemi* (Text-fig. 4) in Sardinia and the Carnic Alps (and possibly Bohemia) allows a more precise age definition and reinforces the observations proposed above. This species has so far not been reported in the typical *Sagittodontina-Scabbardella* conodont faunas from Gondwana (Thuringia, Libya, Spain, France) where the corresponding calcareous episode might be slightly older, as already suggested by Sweet and Bergström (1984).

A temperate-boreal water mass was recently suggested by Stouge and Rasmussen (1996) for the faunal assemblage of the HDS Biofacies, which is known from a variety of lithologies and appears to be indifferent to the bottom conditions, occupying a deep shelf to marginal settings.

Text-fig. 4- Possible relationship between Late Ordovician (Ashgill) conodont provinces and biofacies (*sensu* Sweet & Bergström, 1984; Bergström, 1990b) during the *A. ordovicicus* Zone (including also Sardinian data). Circles indicate conodont reports with, whenever possible, relative frequencies of significant conodont taxa. Sites - IR: South Ireland; W: Wales; EN: England; SW: Sweden; EST: Estonia; PL: Poland; BO: Bohemia (numerical data calculated after Ferretti, 1998); CA: Carnic Alps (numerical data computed after Serpagli, 1967); SA: Sardinia (this paper); F: NW France; E: Spain (sm: Sierra Morena, ic: Iberian Chains); LY: Lybia (numerical data deduced after Bergström & Massa, 1992); TH: Thuringia (numerical data calculated after Ferretti & Barnes, 1997). Conodont biofacies - AP (R): *Amorphognathus-Plectodina* (*Rhodesognathus*); HDS: *Hamarodus europaeus-Dapsilodus mutatus-Scabbardella altipes*; SS: *Sagittodontina robusta-Scabbardella altipes*.


BRITISH PROVINCE
BALTIC PROVINCE
AP (R) Biofacies
SW*
EST
PL*
EN*
W*
IR*
HDS Biofacies
Plectodina
4 22 30 0.2
BO*
25 0 41 0
CA*
SA*
26 0.4 21 0.02
SS Biofacies
Nordiodus
Icriodina
sm E ic
5 32 27 19
TH
F
0 45 23 6
LY
MEDITERRANEAN PROVINCE
He Sg Sc Is
He: Hamarodus europaeus
Sg: Sagittodontina robusta
Sc: Scabbardella altipes
Is: Istorinus erectus
A. lindstroemi
* True Hirnantia fauna

In the subsequent Hirnantian stage, the temperate location of both Sardinia and Carnic Alps appears to have persisted, as suggested by the distribution of the well-known latest Ordovician *Hirnantia* fauna. Havlíček (1990) recognized inside this brachiopod fauna two climatic belts, a belt with *Plectothyrella libyca* Havlíček, 1973 and *P. chauveli* Havlíček, 1971 (corresponding to the Bani Province of Rong & Harper, 1988) located in the circumpolar sphere, and a belt with *Plectothyrella crassicostis* (Dalman, 1828) and *Kinnella kielanae* (Temple, 1965) (corresponding to the Kosov Province of Rong & Harper, 1988). The latter represents the "typical *Hirnantia* fauna" and reached the temperate or even the subtropical zone (Rong & Harper, 1988). *P. crassicosta* and *K. kielanae* were reported by Leone *et al.* (1991) in the Rio San Marco Formation of southwestern Sardinia, as well as *K. kielanae* was reported in the Plöcken Formation of the Austrian Carnic Alps (Jaeger *et al.*, 1975; Schönlaub, 1980; Schönlaub *et al.*, 1994). The existence in Bohemia, Sardinia and the Carnic Alps of a true *Hirnantia* fauna was preliminarly underlined by Ferretti and Barnes (1997) who attributed this occurrence to a different latitudinal/ecological response.

All data discussed above are tentatively plotted in Text-fig. 4 (the true *Hirnantia* Fauna being indicated by an asterisk), representing the distribution of the main conodont provinces and biofacies in the *A. ordovicicus* Zone inside part of the Atlantic Faunal Region. Differently from the *Sagittodontina robusta-Scabbardella altipes* Biofacies and from the *Amorphognathus-Plectodina* Biofacies, which would have characterized respectively the Mediterranean and the British Province, the *Hamarodus europaeus-Dapsilodus mutatus-Scabbardella altipes* Biofacies appears at that time to be widespread in all three provinces (British, Baltic and Mediterranean). The British Province was also characterized by the *Amorphognathus-Plectodina* Biofacies (Sweet & Bergström, 1984), as also recently revealed by the preliminary study of Late Ordovician conodonts from south Wales (Barnes *et al.*, 1998) constituted for about two-thirds by elements of *Amorphognathus*, *Plectodina-Aphelognathus* and *Eocarniodus*. Links between the Carnic Alps and the British Province are expressed, among other factors, by the abundance of *Plectodina* inside the faunas (especially the material from the Valbertad Section, Bagnoli *et al.*, 1998). The Carnic Alps are also characterized by a significant development of the genus *Walliserodus*. Relations between Carnic Alps and Central Spain are expressed by the common occurrence of the genus *Nordiodus*. Part of Sardinia (Cea Brabetza) and NW France, furthermore, are linked by the recovery of *Icriodina* (and by the absence of *Hamarodus*). Lybia and NW France are, finally, the only two areas inside the Mediterranean Province where the *A. ordovicicus* fauna does not include so far elements of *Hamarodus*.

EXPLANATION OF PLATE 1

Figs. 1-11 - *Amorphognathus* sp. (*ordovicicus-lindstroemi* Group).
1) lateral view of Pa element, IPUM 25755, sample CDA-CA 5, x 75;
2-3) upper views of Pa elements, IPUM 27498 and IPUM 27499, sample LM 1, x 65 and x 85 respectively;
4) upper view of Pa element, IPUM 25799, sample LM 3, x 95;
5-6) antero-lateral views of Pb elements, IPUM 25801 and IPUM 25758, samples LM 3 and CDA-RO (97), x 90 and x 75 respectively;
7-8) lateral views of Sa elements, IPUM 25804 and IPUM 27500, samples LM 20 and LM 1, x 140 and x 100 respectively;
9) antero-lateral view of Sc element, IPUM 25761, sample CDA-CA 5, x 120;
10-11) lateral views of Sd elements, IPUM 25762 and IPUM 25807, samples CDA-GR (97) and LM 1, x 100 and x 160 respectively.

Figs. 12-14 - *Amorphognathus ordovicicus* Branson & Mehl, 1933.
12-13) postero-lateral views of M elements, IPUM 25763 and IPUM 25764, sample CDA-GR (97), x 100 both;
14) antero-lateral view of M element, IPUM 25765, sample CDA-CA 5, x 110.

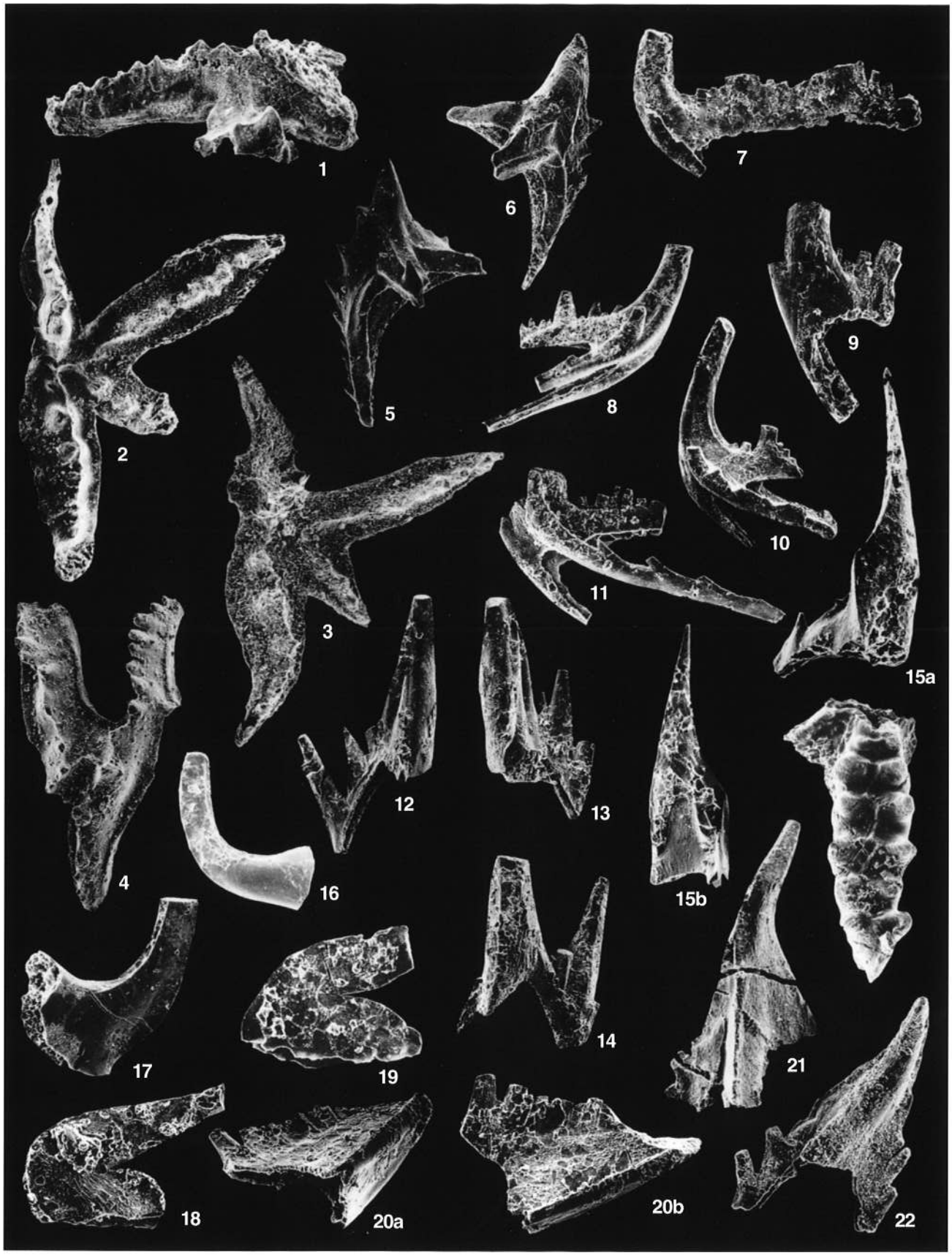
Fig. 15 - *Amorphognathus lindstroemi* (Serpagli, 1967).
15a-b) antero-lateral and postero-lateral views of M element, IPUM 25766, sample CDA-FI (97), x 140.

Figs. 16-17 - *Cornuodus bergstroemi* Serpagli, 1967. Lateral views, IPUM 27501 and IPUM 25788, samples CDA-CA 4 and CDA-CA 5, x 100 and x 140 respectively.

Figs. 18-20 - *Ansella* cf. *pseudorobusta* (Serpagli, 1967).
18-?19) lateral views of M elements, IPUM 25775 and IPUM 27502, samples CDA-CA 4 and BRECCA H 4, x 105 and x 135 respectively:
20a-b) lower-lateral and lateral views of Sa element, IPUM 25774, sample CDA-CA 5, x 115 and x 105 respectively.

Figs. 21-22 - *Icriodella* cf. *superba* Rhodes, 1953.
21) lateral view of Pb element, IPUM 25795, sample CDA-CA 4, x 115;
22) postero-lateral view of Sa element, IPUM 25811, sample LM 18A, x 90.

Fig. 23 - *Icriodella* sp. Upper view of Pa element, IPUM 27503, sample CDA-97 (4), x 75.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SYSTEMATIC PALEONTOLOGY

Orders and families are mostly from Sweet (1988). All figured specimens are deposited in the paleontological collections of the Dipartimento di Scienze della Terra of the University of Modena and Reggio Emilia. Repository numbers from IPUM 25754 to IPUM 26048 denote specimens already illustrated in Ferretti *et al.* (1998a, b, c); numbers from IPUM 27498 to IPUM 27530 are reserved for newly figured material. The conodont fauna from southern Sardinia is composed of the species listed below:

Amorphognathus ordovicicus Branson & Mehl, 1933
A. lindstroemi (Serpagli, 1967)
A. sp. A
Ansella cf. *pseudorobusta* (Serpagli, 1967)
Cornuodus bergstroemi Serpagli, 1967
Dapsilodus mutatus (Branson & Mehl, 1933)
Dichodella cf. *exilis* Serpagli, 1967
Dichodella? sp.
Drepanoistodus cf. *suberectus* (Branson & Mehl, 1933)
Hamarodus europaeus (Serpagli, 1967)
Hamarodus sp.
Icriodella cf. *superba* Rhodes, 1953
Icriodella sp.
Icriodina sp. s.f.
Istorinus erectus Knüpfer, 1967
Oistodus venustus s.f. Stauffer, 1935
Panderodus gracilis (Branson & Mehl, 1933)
Panderodus sp.
Plectodina cf. *alpina* (Serpagli, 1967)
Plectodina sp.
Prioniodus? sp.
Pseudooneotodus sp.
Sagittodontina robusta Knüpfer, 1967
Sagittodontina cf. *robusta* Knüpfer, 1967
Scabbardella altipes (Henningsmoen, 1948)
Scabbardella? sp.
Walliserodus sp.
Walliserodus? sp.
"carniodiform" element *sensu* Ferretti & Barnes, 1997
Indet. fragments

Systematic descriptions have been made only for poorly known taxa that are sufficiently well represented and for taxa to which significant taxonomic contributions can be presented. Illustrations are provided for all taxa; whenever possible, the same element of the apparatus has been figured from material of both southwestern and southeastern Sardinia. Synonymy is limited to references to the first description of morphospecies, first apparatus reconstruction and most recent papers, with special regards to reports from the Atlantic Faunal Region.

Order BELODELLIDA Sweet, 1988?
Family ANSELLIDAE Fåhræus & Hunter, 1985?

Genus HAMARODUS Viira, 1974

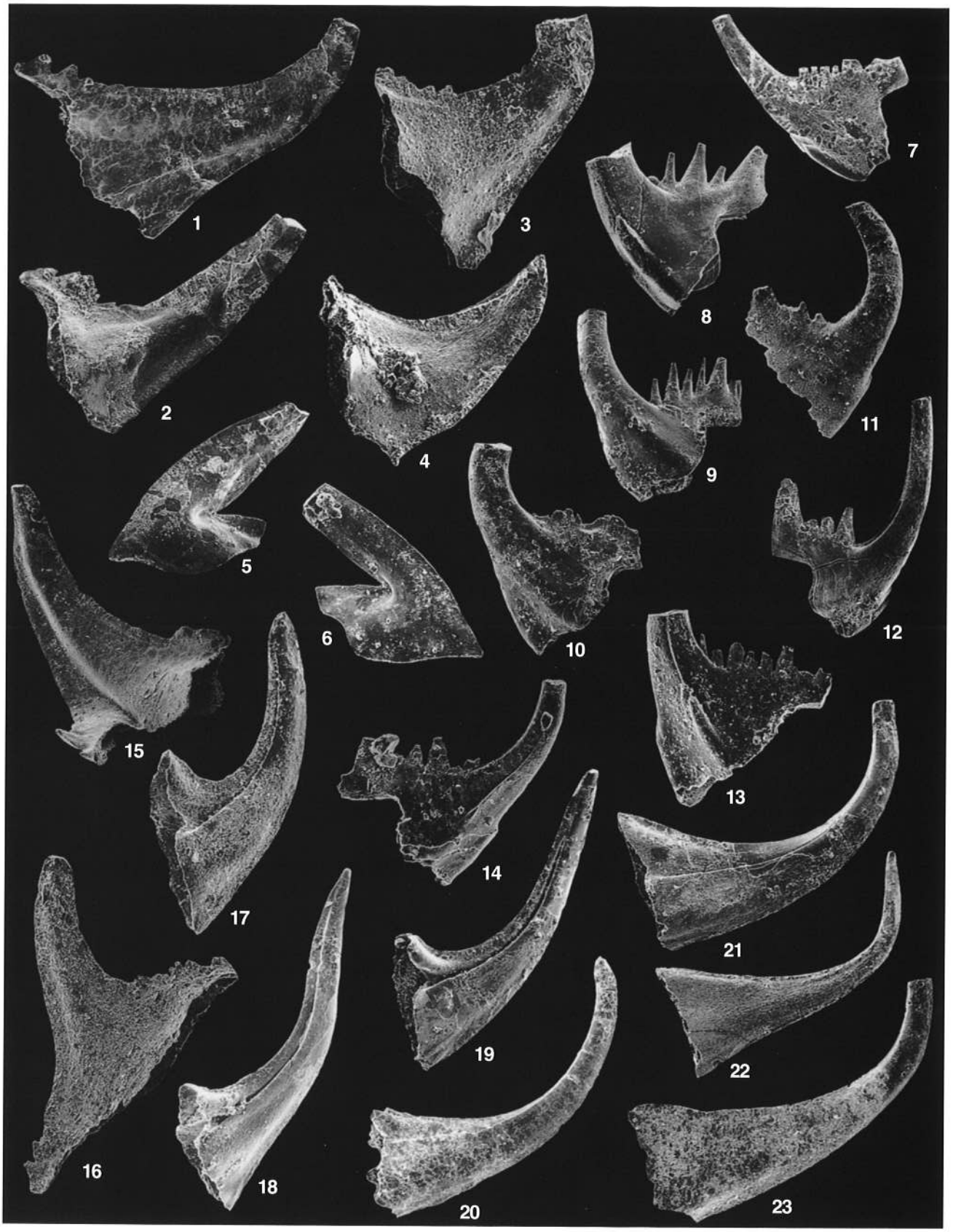
Type species – Distomodus europaeus Serpagli, 1967.

HAMARODUS EUROPAEUS (Serpagli, 1967)
Pl. 2, figs. 1-14

1955 *Microcoelodus* ? sp. RHODES, p. 133, pl. 10, figs. 15, 19, 22.
1955 *Cordylodus elongatus* Rhodes - RHODES, p. 135, pl. 7, figs. 5-6.
1959 *Cordylodus* n. sp. LINDSTRÖM, p. 438, pl. 3, figs. 34-36.
1959 *Oistodus* n. sp. LINDSTRÖM, p. 440, pl. 3, fig. 13.
1964 ?*Neoprioniodus brevirameus* n. sp. WALLISER, p. 47, pl. 4, fig. 5; pl. 29, figs. 5-10.

EXPLANATION OF PLATE 2

Figs. 1-14 - *Hamarodus europaeus* (Serpagli, 1967).
1-2) lateral views of Pa elements, IPUM 25820 and IPUM 25784, samples LM 3 and CDA-CA 5, x 80 and x 70 respectively;
3-4) lateral views of Pb elements, IPUM 25821 and IPUM 25777, samples LM 3 and CDA-CA 5, x 95 and x 70 respectively;
5-6) lateral views of M elements, IPUM 25779 and IPUM 25782, sample CDA-CA 5, x 70 and x 50 respectively;
7-8) lateral views of Sa elements, IPUM 25785 and IPUM 27504, samples CDA-CA 5 and CDA-TR 3 (98), x 100 and x 115 respectively;
9-10) lateral views of Sb elements, IPUM 25786 and IPUM 25817, sample CDA-CA 4 and sample LM 20, x 95 and x 105 respectively;
11-12) lateral views of Sc elements, IPUM 25823 and IPUM 25780, samples LM 1 and CDA-CA 4, x 170 and x 95 respectively;
13-14) lateral views of Sd elements, IPUM 25824 and IPUM 25825, samples LM 1 and LM 3, x 155 and x 135 respectively.
Figs. 15-16 - *Hamarodus* sp.
15) lateral view of Pa element, IPUM 25826, sample LM 1, x 60;
16) lateral view of Pb element, IPUM 25827, sample LM 1, x 75.
Figs. 17-23 - *Scabbardella altipes* (Henningsmoen, 1948).
17-19) lateral views, IPUM 27505, IPUM 27506 and IPUM 25796, samples LM 1, CDA-CA 4 and CDA-CA 5, x 70, x 55 and x 50 respectively;
20-21) lateral views, IPUM 27507 and IPUM 25797, samples LM 3 and CDA-CA 5, x 60 both;
22-23) lateral views, IPUM 25798 and IPUM 27508, samples CDA-CA 5 and LM 1, x 65 and x 60 respectively.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1964 ?*Roundya prima* n. sp. WALLISER, p. 71, pl. 4, fig. 6; pl. 31, figs. 1-2.
1966 *Oistodus breviconus* Branson & Mehl - HAMAR, p. 63, pl. 1, fig. 19; text-fig. 4 (11).
1966 N. genus and n. sp. HAMAR, p. 77, pl. 3, figs. 8-10; text-fig. 5 (5a-b).
1967 *Distomodus europaeus* n. sp. SERPAGLI, p. 64, pl. 14, figs. 1-6.
1967 "*Oistodus*" *niger* n. sp. SERPAGLI, pp. 79-80, pl. 20, figs. 1-7.
1967 *Oistodus abundans* Branson & Mehl - KNÜPFER, p. 34, pl. 5, fig. 4.
1976 *Hamarodus europaeus* (Serpagli) - DZIK, p. 435, text-fig. 36.
1980 *Hamarodus europaeus* (Serpagli) - ORCHARD, p. 21, pl. 4, figs. 22, 25, 29-31.
1985 *Hamarodus europaeus* (Serpagli) - BERGSTRÖM & ORCHARD, pl. 2.5, figs. 4, 7, 12.
1989 *Hamarodus europaeus* (Serpagli) - DZIK, text-fig. 16.
1991 *Hamarodus europaeus* (Serpagli) - FERRETTI & SERPAGLI, pl. 2, figs. 1-6.
1994 *Hamarodus brevirameus* (Walliser) - DZIK, pp. 111-112, pl. 24, figs. 14-19; text-fig. 31a.
1996 *Hamarodus europaeus* (Serpagli) - STOUGE & RASMUSSEN, p. 62, pl. 1, figs. 8, ?9, 10-11.
1997 *Hamarodus europaeus* (Serpagli) - FERRETTI & BARNES, pp. 22-23, pl. 3, figs. 1-14.
1997 *Hamarodus brevirameus* (Walliser) -NOWLAN *et al.*, p. 1533, pl. 1, figs. 18-19.
1998 *Hamarodus europaeus* (Serpagli) - FERRETTI, p. 129, pl. 1, figs. 11-17.
1998a *Hamarodus europaeus* (Serpagli) - FERRETTI *et al.*, pl. 4.1.2, figs. 1-9.
1998b *Hamarodus europaeus* (Serpagli) - FERRETTI *et al.*, pl. 3.1.3, figs. 1-10.
1998 *Hamarodus europaeus* (Serpagli) - BAGNOLI *et al.*, pl. 1.2.2, figs. 7-10.

Remarks – According to Orchard (1980), several elements of Rhodes' material (1955) from the Keisley Limestone belong to the apparatus of this taxon.

Dzik (1994) has renamed this species after the ramiform elements found by Walliser (1964) in the "Bereich I" of the Cellon Section from the Carnic Alps. It is highly probable that the Austrian fauna records the presence of this species so its name should be accordingly changed. However, because Nowlan (1983) and Stouge and Rasmussen (1996) inferred the existence of more than one species of *Hamarodus* during the *A. ordovicicus* Zone and keeping in mind that our material from Umbrarutta reveals unusual distacodiform elements classified as *Hamarodus* sp. (while no significant differences were noticed within the set of ramiform elements), we believe a different nomenclature without new complete collections available from the Cellon level to be premature.

Occurrence – Upper Middle and Late Ordovician of Europe, China and eastern Canada.

HAMARODUS sp.
Pl. 2, figs. 15-16

1998a *Hamarodus* sp. – FERRETTI *et al.*, pl. 4.1.2, figs. 10-11.

Two distacodiform denticulated elements in our fauna apparently differing from the classical Pa and Pb elements of *Hamarodus europaeus* are briefly described.

EXPLANATION OF PLATE 3

Figs. 1-7 - *Sagittodontina robusta* Knüpfer, 1967.
1-2) lateral views of Pa elements, IPUM 25770 and IPUM 27509, samples CDA-RO (97) and LM 1, x 75 and x 110 respectively;
3-4) antero-lateral views of Pb elements, IPUM 25831 and IPUM 25772, samples LM 20 and CDA-CA 20, x 85 and x 75 respectively;
5) lateral view of Sb element, IPUM 25771, sample CDA-CA 20, x 100;
6-7) lateral views of Sd elements, IPUM 25773 and IPUM 25833, samples CDA-RO (97) and LM 3, x 95 and x 125 respectively.

Figs. 8-9 - *Plectodina* cf. *alpina* (Serpagli, 1967).
8) lateral view of Sc element, IPUM 27510, sample CDA-TR 2(97), x 90;
9) lateral view of M element, IPUM 25791, sample CDA-CA 1-2, x 115.

Fig. 10 - *Plectodina* sp. Posterior view of Sa element, IPUM 26036, sample SBB 0, x 75.

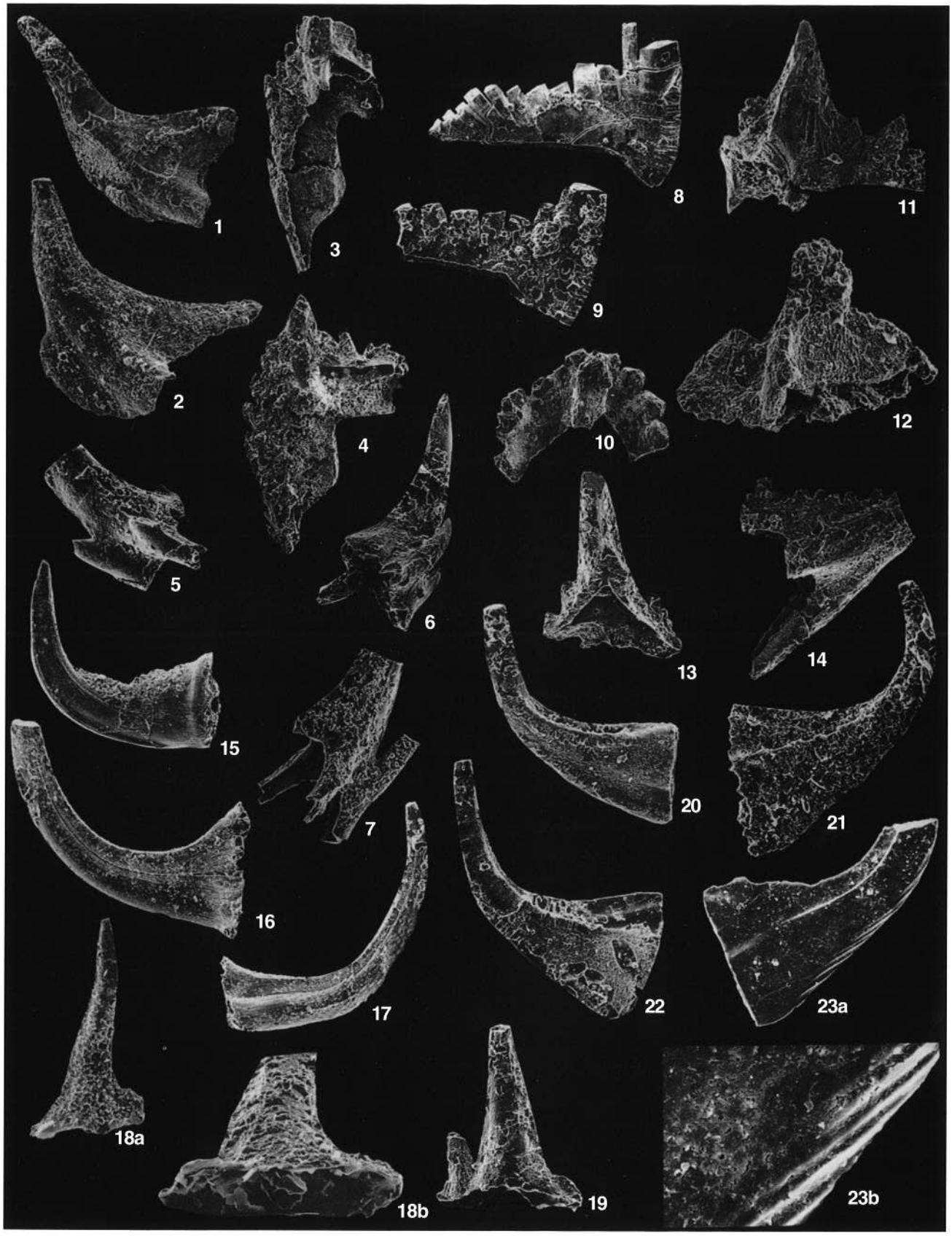
Figs. 11, 13-14 - *Dichodella* cf. *exilis* Serpagli, 1967.
11) lateral view of Pa element, IPUM 27511, sample CDA-CA 5, x 75;
13) postero-lower view of Sa element, IPUM 25789, sample CDA-GR (97), x 145;
14) lateral view of Sb element, IPUM 25790, sample CDA-CA 5, x 100.

Fig. 12 - *Dichodella*? sp. Lateral view of Pa element, IPUM 25812, samples LM 2, x 140.

Figs. 15-17 - *Panderodus gracilis* (Branson and Mehl, 1933). Lateral views, IPUM 25767, IPUM 27512 and IPUM 27513, samples CDA-CA 5, LM 1 and BRECCA H3, x 75, x 90 and x 100 respectively.

Figs. 18-19 - *Istorinus erectus* Knüpfer, 1967.
18a-b) lateral and close lower views, IPUM 27514, sample LM 1, x 130 and x 280 respectively; note the integral profile of the basal cavity of fig. 18b;
19) lateral view, IPUM 25769, sample CDA-CA 1-2, x 115.

Figs. 20-23 - *Dapsilodus mutatus* (Branson & Mehl, 1933).
20-22) lateral views, IPUM 27515, IPUM 25809 and IPUM 25793, samples CDA-CA 20, LM 20 and CDA-CA 5, x 125, x 175 and x 125 respectively;
23a) lateral view, IPUM 27516, sample CDA-TR 2 (97), x 160;
23b) detail of the former figure, x 750.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Description – The Pa element is characterized by the strongly twisted antero-basal part and by a pronounced anterior keel running almost to the top of the cusp. Basal profile extremely sinuous. The Pb element is characterized by a well developed anteriorly directed anticusp, whose anterior margin forms an angle of about 130° with the posterior one. Basal profile quite regular, less flared in its median part than that of the equivalent Pb elements of *H. europaeus*.

Occurrence – Late Ordovician of southern Sardinia (Italy).

Family DAPSILODONTIDAE Sweet, 1988
Genus DAPSILODUS Cooper, 1976

Type species – Distacodus obliquicostatus Branson & Mehl, 1933.

DAPSILODUS MUTATUS (Branson & Mehl, 1933)
Pl. 3, figs. 20-23

1933 *Belodus? mutatus* n. sp. BRANSON & MEHL, p. 126, pl. 10, fig. 17.
1959 *Acodus inornatus* n. sp. ETHINGTON, p. 268, pl. 39, fig. 11.
1959 *Distacodus procerus* n. sp. ETHINGTON, p. 275, pl. 39, fig. 8.
1967 *Acodus curvatus* Branson & Branson - SERPAGLI, p. 41, pl. 6, fig. 3a-c.
1967 *Acodus mutatus* (Branson & Mehl) - SERPAGLI, p. 41, pl. 6, figs. 1a-b, 6 a-b.
1967 *Acontiodus procerus* (Ethington) - SERPAGLI, p. 46, pl. 9, figs. 6-11.
1980 *Dapsilodus mutatus* (Branson & Mehl) - ORCHARD, p. 20, pl. 5, figs. 6, 15-16, 21.
1990a *Dapsilodus mutatus* (Branson & Mehl) - BERGSTRÖM, pl. 2, figs. 1-2; pl. 3, fig. 14; pl. 4, fig. 8.
1994 *Dapsilodus mutatus* (Branson & Mehl) - DZIK, p. 64, pl. 11, figs. 24-26, 31-35, pl. 14, figs. 8-9, text-fig. 6d.
1997 *Dapsilodus mutatus* (Branson & Mehl) - FERRETTI & BARNES, pp. 23-24, pl. 3, figs. 15-19.
1998 *Dapsilodus mutatus* (Branson & Mehl) - FERRETTI, p. 130, pl. 2, fig. 15.
1998a *Dapsilodus mutatus* (Branson & Mehl) - FERRETTI *et al.*, pl. 4.1.1, figs. 10-11.
1998b *Dapsilodus mutatus* (Branson & Mehl) - FERRETTI *et al.*, pl. 3.1.3, figs. 16-17.
1998c *Dapsilodus mutatus* (Branson & Mehl) - FERRETTI *et al.*, pl. 1.1.1, figs. 19-21.
1998 *Dapsilodus mutatus* (Branson & Mehl) - BAGNOLI *et al.*, pl. 1.2.1, figs. 10-11.

Remarks – Only one element of our fauna revealed the antero-aboral striations described by Orchard (1980) in his collection from the Keisley Limestone. The morphospecies *Oistodus venustus* s.f. Stauffer, 1935, regarded as a possible M element, is scarcely present only in one locality (Cea Brabetza).

Occurrence – Middle-Late Ordovician of Europe, North America, China and Libya.

Order PRIONIODONTIDA Dzik, 1976
Family BALOGNATHIDAE Hass, 1959

Genus AMORPHOGNATHUS Branson & Mehl, 1933

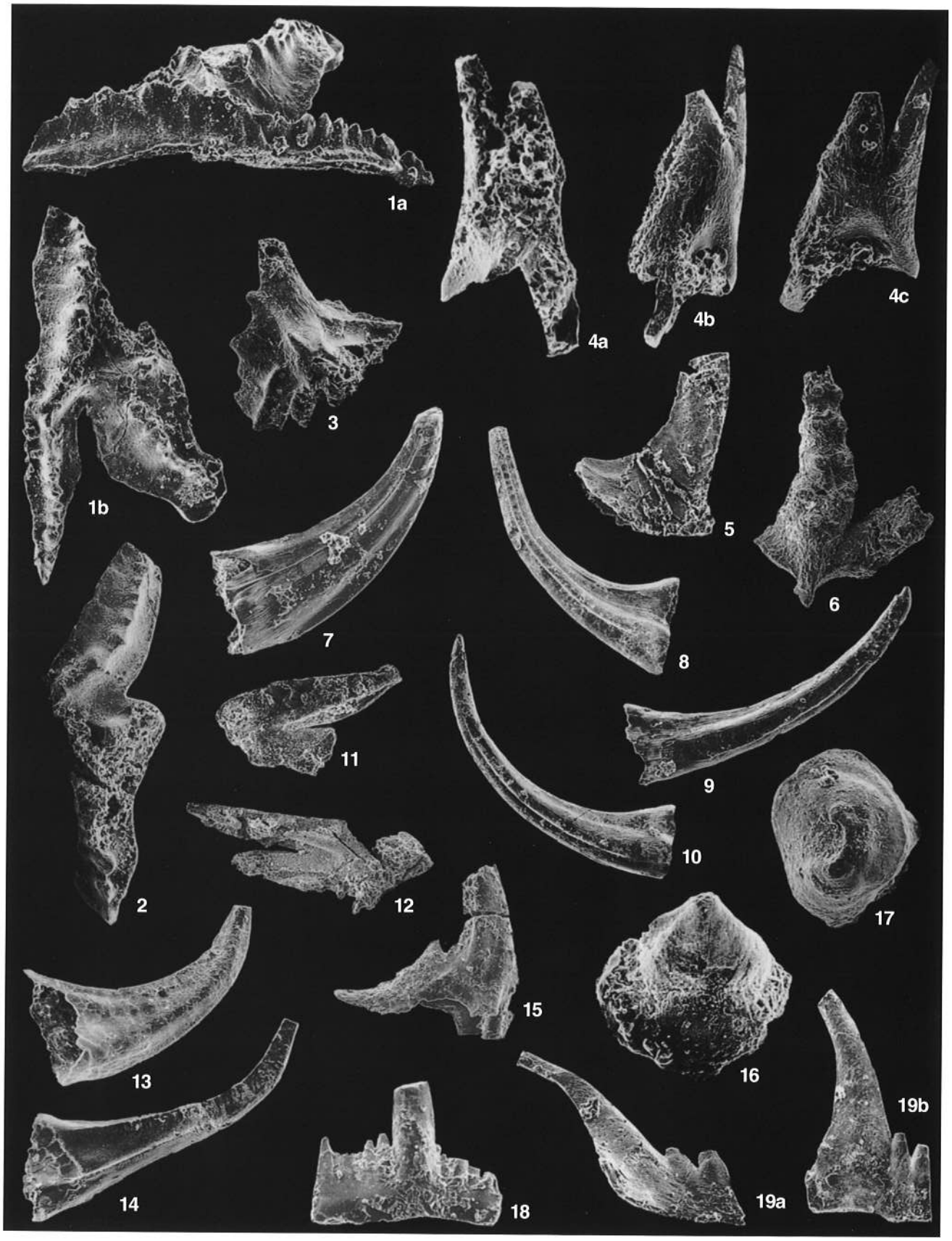
Type species – Amorphognathus ordovicica Branson & Mehl, 1933.

AMORPHOGNATHUS sp. A
Pl. 4, figs. 1-4

Description – Pa elements showing, in oral view, a sinuous pattern of the bar formed by the anterior and posterior processes. The M element, typical of the species, has a long anterior aboral denticle. Anterior aboral process completely contracted. Cusp not completely discrete and slightly recurved posteriorly. The outer lateral edge of cusp seems to bear, at mid-height, an incipient barb-like denticle laterally oriented.

EXPLANATION OF PLATE 4

Figs. 1-4 - *Amorphognathus* sp. A.
1a-b) lateral and upper views of Pa element, IPUM 27517, sample CDA-97 (4), x 80 both;
2) upper view of Pa element, IPUM 27518, sample CDA-97 (5) SX, x 75;
3) lateral view of Pb element, IPUM 27519, sample CDA-97 (5) SX, x 95;
4a-c) posterior, antero-lateral and anterior views of M element, IPUM 27520, sample CDA-97 (4), x 150 all.
Fig. 5 - *Drepanoistodus* cf. *suberectus* (Branson and Mehl, 1933). Lateral view, IPUM 26032, sample SBB 1B, x 145.
Fig. 6 - *Icriodina* sp. s.f. Upper view of Pa element, IPUM 26033, sample SBB 0, x 90.
Figs. 7-10 - *Panderodus gracilis* (Branson & Mehl, 1933). Lateral views, IPUM 27521, IPUM 27522, IPUM 27523 and IPUM 25768, samples CDA-CA 5, BRECCA H4, LM 3 and CDA-CA 4, x 75, x60, x 95, and x 60 respectively.
Figs. 11-12 - *Oistodus venustus* s.f. Stauffer, 1935. Lateral views, IPUM 26046 and IPUM 26047, sample SBB 1, x 95 and x 75 respectively.
Figs. 13-14 - *Walliserodus* sp. Lateral views, IPUM 27524 and IPUM 27525, sample BRECCA H4, x 90 and x 105 respectively.
Fig. 15 - *Prioniodus*? sp. Antero-lateral view, IPUM 27526, sample BRECCA H 4, x 90.
Figs. 16-17 - *Pseudooneotodus* sp. Lateral and upper views, IPUM 27527 and IPUM 27528, samples MCB (B) and BRECCA C, x 160 and x145 respectively.
Figs. 18-19 - "carniodiform" element *sensu* Ferretti & Barnes, 1997.
18) lateral view, IPUM 27529, sample CDA-GR (97), x 110;
19a-b) lower and lateral views, IPUM 27530, sample CDA-CA 5, x 125 and x 95 respectively.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LATE ORDOVICIAN CONODONTS OF SOUTHERN SARDINIA	SOUTHWESTERN SARDINIA																				SE SARDINIA				
				CANNAMENDA														BECCIU		BRECCA				
	CDA-97 (4)*	CDA-98 (4)*	CDA-97(5)S2*	CDA-CA 1-2	CDA-BK 1	CDA-CA 20	CDA-BK3	CDA-CA 4	CDA-CA 5	CDA-Z	CDA-RO (97)	CDA-GR (97)	CDA-FI (97)	CDA-A	CDA-5 (96)	CDA-TR (97)	CDA-TR 2 (97)	CDA-TR 3 (98)	MCB-A	MCB-B	BRECCA C	BRECCA H2	BRECCA H5	BRECCA H4	BRECCA BK
Amorphognathus ordovicicus																									
M						1	3	6	15		8	10	13			6	2	3			3				
A. lindstroemi																									
M							1						2					?1							
A. sp. (ordovicicus-lindstroemi Group)																									
Pa*				28	4	55	58	185	315	3	84	132	101			50	71	70	5	49	91	2	6	7	
Pb				16	2	72	26	91	168	2	81	86	46			49	49	49	2	21	34	1		2	
Sa				1	1	11	9	9	17	1	21	24	23			6	14	9		4	7				
Sb				5		6	2	18	22	1	29	15	15			13	14	11	1	1	6				
Sc						7	3	9	15		21	8	13			7	9	7	1		6				
Sd						6	2	'6	9		17	16	7			10	4			1	4		1	1	
A. sp. A																									
Pa*	10	9	5																						
Pb	1		1																						
M	1																								
Sa	1																								
Sd	1																								
Ansella cf. *pseudorobusta*																									
M								2			2													?1	
Sa									1																
Cornuodus bergstroemi								2	1			2	3					1							
Dapsilodus mutatus		1		1		28	8	8	19		28	39	22		1	16	27	9		10	6		1	1	
Dichodella cf. *exilis*																									
Pa									1																
Sa												1	1												
Sb									1																
Dichodella? sp.																									
Pa																					1				
Pb																									
Sa																									
Drepanoistodus cf. *suberectus*																									
Hamarodus europaeus																									
Pa				13		14	14	141	167		25	43	23			6	18	45		22	14	1	1	1	
Pb				5		16	6	33	56		10	18	16			10	6	13		15	2				
M				10	4	71	33	115	240		68	81	58			40	39	71		155	229	1	8	1	
Sa				4	1	10	4	14	25		10	16	18			5	8	8		5	15				
Sb						8	4	9	23		19	9	5			4	10	11		6	15	1			
Sc				10	2	34	21	119	148	1	42	102	120			24	42	73		69	90	2	1		
Sd				1		2	4	4			6	3	2			8	6	2			?1		1		
Hamarodus sp.																									
Pa																									
Pb																									
Icriodella cf. *superba*																									
Pa						3	1	1	3								2	1			2				
Pb								1																	
M						1																			
Sa																									
Icriodella sp.																									
Pa	1																								
Pb																									
Sa																									
Icriodina sp. a.f.																									
Pa																									
M																									
Istorinus erectus				1							?1														
Oistodus venustus a.f.																									
Panderodus gracilis				11		57	23	30	27	2	51	24	4			25	26	8			6		3	2	
Panderodus sp.	4	1												1						7			1		
Plectodina cf. *alpina*																									
Pa											?1														
M				1																					
Sb																	1								
Sc																	2								
Plectodina sp.																									
Pa																									
M																									
Sa																									
Prioniodus? sp.		1																						1	
Pseudooneotodus sp.																				4	1				
Sagittodontina robusta																									
Pa						2			?1		3						2								
Pb						1										2									
M							?1									2									
Sa						3																			
Sb						1					2					3									
Sd						2			1		2					1	3								
Sagittodontina cf. *robusta*																									
Pb																									
Sa																									
Sb																									
*Scabbardella altipes**				56	5	284	135	313	360	1	230	203	99			102	153	80		62	97	10	8		
Scabbardella? sp.																									
Walliserodus sp.											1													7	
Walliserodus? sp.						2		2													5				
"carniodiform" element	1	2				52	35	68	82		132	157	200			62	81	78	1	74	135		3	1	
Indet. fragments	2	2	1	31	1	23	18	149	97		7	112	37			19	51	23	10	33	138		3	1	2
total/sample	22	16	7	194	20	772	411	1335	1814	11	901	1101	828	1	1	470	640	573	20	538	908	18	37	26	2
weight (kg)	4,4	17,25	3,5	6	3	1,6	3	3,15	4,7	2,15	12,3	3,6	1,1	1,7	5,085	2,1	2,75	1,9	3,485	2,635	10,85	4,2	4,6	2,035	5,15

Tab. 1 - Numerical distribution of conodonts in productive samples from southern Sardinia. Note that the symbol * denotes overestimated

SOUTHEASTERN SARDINIA																															
CEA BRABETZA															UMBRARUTTA																
BRA 89	SBB 0	SBB 1	SBB 1B	SBB 1C	SBB 2	SBB 3	SBB 3W	SBB 3K	SBB 3Y	SBB 3X	SBB 3A	SBB 3E	SBB 4	LM 1	LM 2	LM 3	LM 4	LM 17	LM 17A	LM 17B	LM 18	LM 18A	LM 19	LM 20	LM 21	LM 22	LATE ORDOVICIAN CONODONTS OF SOUTHERN SARDINIA	total/species
														2	3	4	1							1			*Amorphognathus ordovicicus*	
																											M	81
																											A. lindstroemi	
		71									71																M	6
																											A. sp. (*ordovicicus-lindstroemi* Group)	
	9	67	19	2	2	1	9	5	2		53	5	1	75	44	50	8	2	5	3		1	6	38	71	1	Pa°	1725
1	2	21	7	2		1	3	4	3		13	2		34	22	32	3	1		1	74		4	9			Pb	966
	2	8	1	1				1	1		4	1		9	2	1	1							3			Sa	192
		10	5				2		1		4			4	4	6	1						1	4			Sb	201
	1	7	3				1				10	1		7	3	1											Sc	140
		8	2				2	1	1		5			2	3	2	2							1			Sd	113
																											A . sp. A	
																											Pa°	24
																											Pb	2
																											M	1
																											Sa	1
																											Sd	1
																											Ansella cf. *pseudorobusta*	
																											M	5
																											Sa	1
																											Cornuodus bergstroemi	9
	2	13	2	1			1	2		76	4	4		8			1							6			*Dapsilodus mutatus*	275
																											Dichodella cf. *exilis*	
																											Pa	1
																											Sa	2
																											Sb	1
																											Dichodella? sp.	
															1									1			Pa	3
		1												2													Pb	3
														1	1												Sa	2
			1																								*Drepanoistodus* cf. *suberectus*	1
																											Hamarodus europaeus	
														12		6	2	2					1	2		1	Pa	574
														4		5							1				Pb	216
														10	2	21		2	1	1			4	2			M	1267
														4		3							2				Sa	152
														1		2	1						1	1			Sb	130
														17	1	18		2			1	1	4	3			Sc	947
														6		3							1				Sd	50
																											Hamarodus sp.	
														1													Pa	1
														1													Pb	1
																											Icriodella cf. *superba*	
																			1								Pa	14
																											Pb	1
																											M	1
																						1					Sa	1
																											Icriodella sp.	
	4	13	3				3		71		5																Pa	30
		2	2																								Pb	4
		2																									Sa	2
																											Icriodina sp. s.f.	
	4																										Pa	4
		71																									M	1
														1													*Istorivus erectus*	3
		9								71					1												*Oistodus venustus* s.f.	11
														8	23	14		11	17	10							*Panderodus gracilis*	382
	3	24	8				1	2		3	11	1	1		4							3		1			*Panderodus* sp.	76
																											Plectodina cf. *alpina*	
																											Pa	1
																											M	1
																											Sb	1
																											Sc	2
												1															*Plectodina* sp.	
		1																									Pa	1
	1	1																									M	1
		16									1																Sa	2
																											Priontodus? sp.	19
																											Pseudooneotodus sp.	5
																											Sagittodontina robusta	
														2		1		1					1	1			Pa	14
																							2	1			Pb	6
														1													M	4
																	1										Sa	4
														2													Sb	8
														3		2											Sd	14
							1																				*Sagittodontina* cf. *robusta*	
																											Pb	1
		71									1																Sa	2
		71																									Sb	1
														160	2	206	32	4	3	2	2	3	19	38		3	*Scabbardella altipes**	2672
		8	2					1	2		2																*Scabbardella?* sp.	15
																											Walliserodus sp.	8
															1	1				1	1		7	1			*Walliserodus?* sp.	21
		10	6			1	6	2	1		24			47	6	10	12		2			1	9	12			"caniiodiform" element	1313
	3	57	29	3		1	13	11	7	7	83	1	1	61	44	8	6	7	7	1	2	3	18	17		5	Indet. fragments	1155
1	31	282	90	9	2	4	42	29	19	17	221	16	3	485	167	396	71	32	36	19	10	13	81	142	1	10	**total/sample**	12893
2,3	14,8	27,5	11,59	4	5,5	4,7	2,795	4	7,6	3,835	27,57	4,5	6	39,16	7	3,2	2,8	1,59	5	3,6	8,7	3,9	6,7	8,86	3,5	3,35		

material, and the symbol ° refers to material from the Portixeddu Formation of southwestern Sardinia.

Discussion – A definite denticle anterior to the cusp is preserved in the M element of the genus *Rhodesognathus* but the cusp of our element has not the reclined aspect typical of that genus and, in spite of the scarce fauna, other elements recovered in the same sample clearly belong to the genus *Amorphognathus*.

The M element outlined above clearly differs from all other *Amorphognathus* M elements so far reported and the elements here described possibly belong to a new species.

The horizon from which the Sardinian material was recovered is close to the Caradoc/Ashgill boundary according to brachiopod and trilobite evidences (Leone *et al.*, 1991). A documented *A. ordovicicus* conodont fauna is recovered from a calcareous horizon slightly above.

Occurrence – Late Ordovician of southern Sardinia (Italy).

Genus DICHODELLA Serpagli, 1967

Type species – Dichodella exilis Serpagli, 1967.

DICHODELLA cf. EXILIS Serpagli, 1967
Pl. 3, figs. 11, 13-14

cf. 1967 *Dichodella exilis* n. sp. SERPAGLI, p. 63, pl. 29, figs. 9-10.
cf. 1967 *Gothodus? sellii* n. sp. SERPAGLI, p. 71, pl. 13, figs. 1-2.
cf. 1967 *Hibbardella caudata* (Walliser) - SERPAGLI, p. 72, pl. 22, figs. 4-5.
cf. 1967 *Prioniodus ethingtoni* n. sp. SERPAGLI, p. 92, pl. 25, figs. 1-9.
1998b *Birksfeldia* cf. *circumplicata* Orchard - FERRETTI *et al.*, pl. 3.1.3, figs. 13-14.
cf. 1998 *Dichodella exilis* Serpagli - BAGNOLI *et al.*, pl. 1.2.1, figs. 18-20.

Remarks – Bagnoli *et al.* (1998), studying material from a new Late Ordovician section of the Italian Carnic Alps, equivalent to the conodont association reported by Serpagli (1967), recently considered *Dichodella exilis* s.f. Serpagli, 1967 as the Pa element of the apparatus reconstructed by Orchard (1980) and named *Birksfeldia*. In addition to the elements of the apparatus proposed by Orchard, fully supported by the Carnic collection, the morphospecies *Prioniodus ethingtoni* Serpagli, 1967 could be also included in the apparatus as the Pb element.

Occurrence – Late Ordovician of Carnic Alps and Sardinia (Italy), Sweden and Great Britain.

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