LATE ORDOVICIAN CONODONTS FROM THE PRAGUE BASIN, BOHEMIA

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Ferretti, A. 1998. Late Ordovician conodonts from the Prague Basin, Bohemia. *In:* H. Szaniawski (ed.), Proceedings of the Sixth European Conodont Symposium (ECOS VI). — *Palaeontologia Polonica* **58**, 123–139.

A conodont fauna is reported for the first time from the Late Ordovician of Bohemia. Two different levels of the Králův Dvůr Formation, both well known for their brachiopod and trilobite associations, produced poor and fragmentary conodont material, which nevertheless can be interpreted as Ashgill in age. The material most closely resembles the fauna of southern Europe, but there are also similarities to the Anglo-Baltic conodont associations. A special conodont extraction technique, suitable for argillaceous-calcareous mixed sediments, is described.

K e y w o r d s : Conodonta, Ordovician, Bohemia.

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Received October 1996, accepted December 1997

INTRODUCTION

In the Ordovician, the Prague Basin (Barrandian) was a small linear depression situated in a marginal part of the Gondwana continent (HAVLÍČEK 1981; ŠTORCH and MERGL 1989). It is thought to have been composed of separate blocks and/or microplates (ŠTORCH 1990). Up to 2500 m thick, shale-dominated sequences, with sporadic sandstone intercalations, were deposited in the basin as a response to both tectonic movements (HAVLÍČEK 1980) and eustatic sea-level changes (CHLUPÁČ and KUKAL 1988).

The Upper Ordovician formations (Králův Dvůr Formation and Kosov Formation) and the continuous sedimentary record across the Ordovician/Silurian boundary crop out in numerous sections (Fig. 1). Brachiopods and trilobites are common. Gastropods, ostracodes, cystoids, rare graptolites, bivalves and conulariids have also been reported. Two horizons in the lower part of the Kosov Formation have recently been interpreted as glaciomarine diamictites (BRENCHLEY and ŠTORCH 1989; BRENCHLEY *et al.* 1991). Black Silurian graptolitic shales overlie the Ordovician strata.

The peculiar nature of the Ordovician fauna, mostly reflecting shallow water conditions, as compared to coeval occurrences elsewhere, led SPJELDNAES (1961) and HAVLÍČEK (1974, 1982) to include Bohemia in the cold-water "Mediterranean Province". This province, corresponding to the "*Selenopeltis* Province" of WHITTINGTON and HUGHES (1972), was periodically influenced by warm-water episodes (HAVLÍČEK 1989). The Perunica microcontinent, a separate unit between Gondwana and Baltica, was recently proposed by HAVLÍČEK and FATKA (1992) to stress once more the unique character of the fauna from the Prague Basin. Difficulties in correlating the Prague Basin formations to the British Standard Scale, caused by graptolite paucity and differences in benthic assemblages, were partially overcome with the creation of new chronostratigraphic units for the upper part of the Ordovician. HAVLÍČEK and MAREK (1973) introduced the "Královdvor" and "Kosov" Series as time equivalents of the Králův Dvůr and Kosov Formations respectively. FATKA *et al.* (1995) recently reinterpreted them in terms of "stages" that correspond approximately to the Ashgill Series. Nevertheless, difficulties in referring to the standard stratigraphic scale still remain.

Lower Ordovician conodont faunas were already described by ŠPINAR *et al.* (1965), DZIK (1984) and ZUSKOVÁ (1993). Even though the material investigated here is poorly preserved and the total number of recovered specimens is small, this conodont collection is the first ever reported from the Late Ordovician of the Prague Basin and it comes from an unusual type of lithology. The conodont fauna described here is housed in the paleontological collections at the Department of Earth Sciences of the University of Modena (Italy) under repository numbers IPUM 24964–25020.

Acknowledgements. — My sincere thanks go to Petr ŠTORCH (Geological Institute – Academy of Sciences of Prague) for providing the material and the always precise answers to my questions and for the critical reading of the manuscript. Enrico SERPAGLI (University of Modena) is acknowledged for constructive comments and assistance during all stages of this study and for improving the text. Christopher R. BARNES (University of Victoria) provided important suggestions and critically read the manuscript. Jerzy DZIK expertly revised the final version of this paper. Claudio GENTILINI (University of Modena) produced the S.E.M. photographs and is deeply thanked.

This research was funded by C.N.R. and M.U.R.S.T. grants (resp. E. SERPAGLI).

STRATIGRAPHIC FRAMEWORK

The Králův Dvůr Formation is represented by 25–200 m of clayey shales or claystones with silt admixture (HAVLÍČEK 1981; ŠTORCH and MERGL 1989). An "Iron Ore Horizon" with silicate or carbonate ooids is locally present at the base of the formation (HAVLÍČEK and FATKA 1992). The *Dedzetina macrostomoides* brachiopod community, similar to the *Foliomena* Community, occurs in the middle part of the formation and reflects deep water conditions (benthic assemblage 4 to 5; HAVLÍČEK 1982) (Fig. 2). Above and below, the *Rafanoglossa* Community is reported. It corresponds to benthic assemblage 6 (HAVLÍČEK 1982; BRENCHLEY and ŠTORCH 1989). The younger of these occurrences is in carbonate nodules among clayey shales (level A1 of ŠTORCH and MERGL 1989). This level includes a poor but well preserved deep-shelf fauna of trilobites, minute bivalves, gastropods, nautiloids and rare brachiopods of the *Rafanoglossa leiskowiensis* Community. Shales

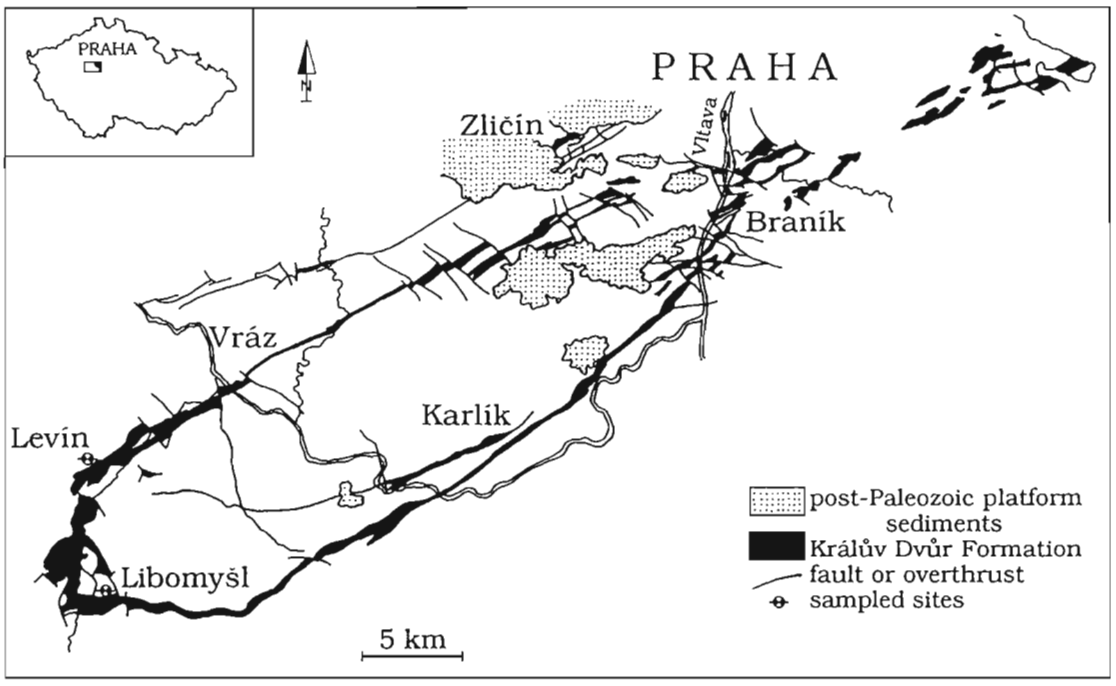

Fig. 1
Location map and extension of the Králův Dvůr Formation in the Prague Basin (modified after ŠTORCH and MERGL 1989).

immediately above provided graptolites indicative of the *Scalarigraptus angustus* Horizon of the *D. anceps* Zone (ŠTORCH 1989). About 3 m below the top of the Králův Dvůr Formation, a thin (max. 10 cm) calcareous layer with abundant sessile organisms is present (B1 level of ŠTORCH and MERGL 1989 or "Perník Bed" of BRENCHLEY and ŠTORCH 1989). The ratio between carbonate and clay content is variable (55% at Libomyšl, 45% at Levín; ŠTORCH and MERGL 1989). This level contains a rich fauna of trilobites and small isolated brachiopods of the *Proboscisambon* Community (benthic assemblage 5 to 6; ŠTORCH and MERGL 1989). The fauna again resembles the *Foliomena* Community (HAVLÍČEK 1982; HAVLÍČEK and MERGL 1982; COCKS and RONG 1988; BRENCHLEY and ŠTORCH 1989; ŠTORCH and MERGL 1989) and indicates deep, cold-water environments (COCKS and RONG 1988). Ostracodes, gastropods, blastoids and cystoids are also present. This high-diversity community disappears abruptly and is replaced by a low diversity *Mucronaspis* fauna (benthic assemblage 5 to 4; ŠTORCH and MERGL 1989), including also ostracodes, bivalves, brachiopods, conulariids and a monospecific graptolite assemblage. The graptolite, identified as *Glyptograptus* cf. *ojsuensis* is indicative of the upper part of the *D. anceps* Zone and/or the *Paraorthograptus pacificus* Subzone (ŠTORCH 1990). This *Mucronaspis* level is reported from silty mudstones and shales that start few centimeters immediately above the Perník Bed and extend upwards (levels B2 and C of ŠTORCH and MERGL 1989). No guide graptolites to prove the Rawtheyan age of the upper Královdvor have been found so far, and this age is suggested mainly on the basis of changes in the benthic assemblage composition (ŠTORCH 1989). The early Hirnantian glacio-eustatic regression is, in fact, reflected in other areas elsewhere by the sudden appearance of shallow marine sandy facies and the spreading of the monotonous *Hirnantia* and *Mucronaspis* faunas (ŠTORCH 1990). The Rawtheyan/Hirnantian boundary is therefore placed within the few meters of shales that separate the Perník Bed from the first glacio-marine episode at the base of the overlying Kosov Formation (ŠTORCH 1990). This unit, 40–150 m thick, has at its base two diamictitic levels, separated by 1–2 m of shales. The levels provided facetted pebbles and dropstones (beautifully illustrated from the Levín Section; ŠTORCH 1990: p. 228) interpreted as deposits of seasonal ice (BRENCHLEY and ŠTORCH 1989). Three meters above the first glacio-marine evidence, thin bedded sandstones recording the peak of the first phase of the Hirnantian regression occur. A true *Hirnantia* fauna, represented by the *H. sagittifera* Community, is present in the uppermost part of the Kosov Formation (MAREK 1963; MAREK and HAVLÍČEK 1967; ŠTORCH 1986; FATKA *et al.* 1995). The fauna is associated with the index graptolite *Glyptograptus bohemicus* (ŠTORCH 1986). About 10–20 cm above, the Silurian starts with black graptolitic shales assigned to the *Akidograptus ascensus* Zone (= lower part of *Parakidograptus acuminatus* Zone; ŠTORCH 1990).

MATERIAL AND METHODS

Two different levels of the Králův Dvůr Formation were investigated (Fig. 2). Six samples were collected from the calcareous nodules (level A1; ŠTORCH and MERGL 1989) intercalating to shales belonging to the lowermost part of and/or just underlying the *angustus* Horizon from the middle part of the Králův Dvůr Formation at Levín. Nine samples (2 from Lybomyšl, 7 from Levín) were collected from the Perník Bed (= level B1; ŠTORCH and MERGL 1989), about 10 m above the previous samples.

Normal acid treatment was mostly ineffective, especially for the samples collected from the Perník Bed. A technique generally reserved in our laboratory for disaggregating slightly indurated sediments with high clay content was partially applied. Samples were slightly crushed (if big pieces were present) and placed in small quantity in plastic beakers. They were then covered with the detergent "NeoDesogen", a perfumed yellowish solution of 10% alkyldimethylbenzylammonium chloride (produced by Ciba Geigy S.p.A.-Origgio, Varese, Italy) used in the medical field as a fungicide and bactericide. Samples were soaked for several days and occasionally stirred with a plastic stick. The disintegration was very slow with a mild effervescence observable with naked eye. When the reaction was complete, the samples were transferred to larger plastic buckets and treated with a solution of acetic or formic acid to remove the calcareous fraction. The resulting residue was wet-sieved. The insoluble sample was completely dried at room temperature. Sometimes, the drying was accelerated by mild heating. Only when perfectly dessicated, was the material returned again to fresh NeoDesogen and a new cycle was started. The entire process of disintegration could take as much as several weeks. The abundant residues were finally concentrated in heavy liquid using sodium polytungstate.

A similar technique had been described by ZINGULA (1968) with Quaternary "O" compound, but his process involved boiling while this method is at room temperature.

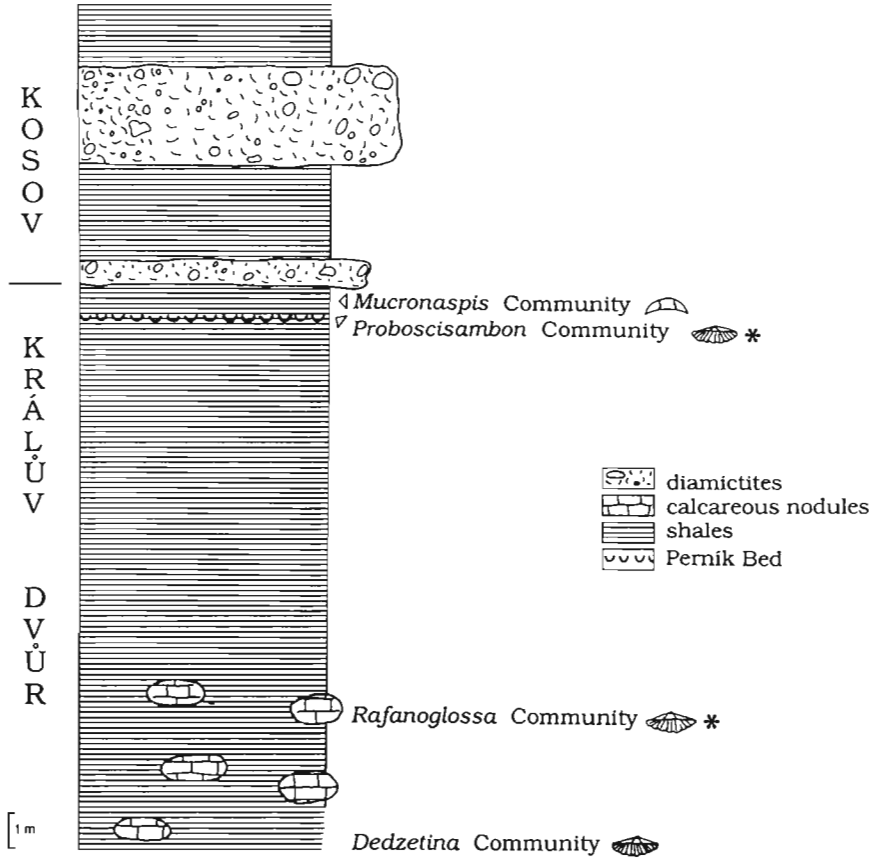

Fig. 2
Stratigraphic column of the Late Ordovician exposed at Levín (modified after BRENCHLEY and ŠTORCH 1989); * denotes sampled level.

The fossil fauna recovered in the acid residue, associated with conodonts, is dominated by well preserved silicified ostracodes (the first such finding from the Ordovician of Bohemia), often complete with the two valves still connected and with their spines preserved. They are now under study by Miroslav KRŮTA (Geological Institute – Academy of Sciences, Prague). Other common elements are juvenile gastropods with numerous pyritized molds, sponges and sponge spiculae (sometimes pyritized), trilobite fragments, brachiopods, chitinozoans, bivalves, bryozoans and the phosphatic sclerites of the problematic paleoscolecid *Milaculum*. Pyrite is also common in some samples (e.g., BO 5) with both crystals and framboids present. Among the two studied levels, the fauna coming from the Perník Bed appears more abundant and diverse.

The conodont collection was isolated from 15 samples with a total weight of approximately 22 kg. Over 400 conodont elements were recovered. Conodont abundance is extremely variable within the same level, but it is certainly much higher in the Perník Bed. The absolute abundance ranges from as little as 1.4 elements to as much as 15 elements per kilogram in the calcareous nodules and from as little as 8.7 elements to as much as 70.3 elements per kilogram in the Perník Bed. The fauna consists of only very small individuals and consequently the 63× microscope enlargement has been necessary for picking the residue. Most of the elements are poorly preserved and fragmentary, which makes specific determination difficult. The conodont Color Alteration Index (CAI) value is 3, indicating heating temperatures in the range of 110–220° (EPSTEIN *et al.* 1977).

THE CONODONT ASSEMBLAGE

The Bohemian material under study includes 13 multielement species representing 11 genera, 8 of which are left in open nomenclature. The list and abundance of the species are given in Table 1. The fragmentary preservation of the material and the incompleteness of many apparatuses make premature any detailed interpretation on the fauna abundance. Nevertheless, when considering the fauna as a whole, elements of *Scabbardella altipes* (HENNINGSMOEN, 1948) (30%) and *Sagittodontina* cf. *robusta* KNÜPFER, 1967 (22%) predominate. In contrast, species such as *Icriodella* sp. and *Birksfeldia*? sp. are represented by very few specimens.

The fauna from the Perník Bed is more diverse than that from the calcareous nodules. It marks the appearance of relatively abundant elements of *Sagittodontina* cf. *robusta* as well as other species such as *Plectodina* aff. *tenuis* (BRANSON *et* MEHL, 1933) and *Istorinus erectus* KNÜPFER, 1967, mostly represented by single elements. Furthermore, the **M** element of *Amorphognathus* aff. *lindstroemi* (SERPAGLI, 1967) is here reported.

BIOSTRATIGRAPHY

All **Pa** elements of *Amorphognathus* from both the calcareous nodules and the Perník Bed are broken, preventing specific determination. A single **M** element of *A.* aff. *lindstroemi* was recovered in the Perník assemblage. No complete diagnosis of the apparatus structure of this species has ever been given and the Bohemian material is too scarce to attempt one. Furthermore, it cannot be definitely excluded that this collection might contain also *A. ordovicicus* (BRANSON *et* MEHL, 1933). For all **P** and **S** elements of the genus *Amorphognathus* the open nomenclature is preferred.

A. lindstroemi has been reported in the upper Keisley Limestone (most likely Rawtheyan in age) from the north of England (ORCHARD 1980) and in the Ashgill of the Italian Carnic Alps (SERPAGLI 1967). *A.* aff. *lindstroemi*, found among the Bohemian fauna, does not appear to have developed the typical features of *A. lindstroemi* completely and could therefore represent an early evolutionary stage of this lineage. "Holodontiform" elements similar to the **M** element of *A.* aff. *lindstroemi* were found at the base of an Ashgillian section (Shoalshook Formation at Whitland) in Wales (BARNES and FERRETTI in preparation).

Hamarodus europaeus (SERPAGLI, 1967) seems to appear in the Rawtheyan in Great Britain (ORCHARD 1980; SWEET and BERGSTRÖM 1984) as well as in many southern European areas of northern Gondwana (FERRETTI 1992). Nevertheless, this species is already reported from the *Amorphognathus superbus* Zone

Table 1
Detailed composition of the Bohemian conodont fauna; * denotes overestimated material, as mainly composed by fragments; ° denotes samples from Libomyšl (all the others are from Levín).

	Calcareous nodules						Perník Bed									
	BO 1	BO 2	BO 3	BO 4	BO 5	P 1	S 1°	S 2°	S 3	S 4	K 1	K 2	K 3	P 2	PB 1	total
Amorphognathus sp.																
Pa*		1		2			4	8	10	8	1		7	10	6	57
Pb							2	1	4				1	1	1	10
Sa				2					2					2		6
Sb				1				1		1				1		4
Sc											1				1	2
A. aff. *lindstroemi*																
M									1							1
Birksfeldia? sp.																
Pb									1							1
Dapsilodus mutatus			1					1	1							3
Hamarodus europaeus																
Pb			1						1							2
M								1	2				2	2		7
Sb										1						1
Sc				1	1			1	1		1	1				6
Hamarodus cf. *europaeus*																
M				1										1		2
Icriodella sp.																
Pa									1							1
Pb						1										1
Istorinus erectus										1						1
Nordiodus italicus																
M				1												1
Plectodina aff. *tenuis*																
Pa										1						1
Pb										1						1
Protopanderodus sp.											1					1
Sagittodontina cf. *robusta*																
Pa							4	4	31	10	5	1	6	10	12	83
Sa													3			3
Sb									3					1		4
*Scabbardella altipes**	3		1	11		2	13	6	34	8	5	3	16	13	10	125
"carniodiform" element	2		1	3					5	1			1	1		14
Gen. et sp. indet.				1												1
Indet. fragments	4		3	1	1		5	5	19	10	5	2	9	8	4	76
																415
Weight	1.3	0.7	0.7	1.6	1.2	1.3	1.7	1.5	1.65	1.35	1.6	0.8	1.45	1.7	3.3	21.85

(ranging then into the following *A. ordovicicus* Zone) in the Scandinavian-Baltic-Polish region (STOUGE and RASMUSSEN 1996) and from the *Hamarodus europaeus* Zone of south-central China, dated as Caradocian by AN (1987).

Sagittodontina robusta, represented possibly only in the Perník assemblage, has been so far reported from the Early Ashgill of Europe and north Africa (BERGSTRÖM and MASSA 1992).

The mutual occurrence of *Sagittodontina* cf. *robusta* and *Istorinus erectus* would indicate an Early Ashgill age for the investigated fauna, but it is also possible that the Bohemian material might extend the range of these species into younger time-intervals.

PALEOBIOGEOGRAPHY

Several studies have emphasized the peculiar nature of the Late Ordovician Bohemian fauna and tried to locate the Prague Basin paleogeographically. HAVLÍČEK and FATKA (1992) recently positioned the basin as a separate microcontinent, called Perunica, in a temperate region bounded by the North Gondwana region to the south and the Anglo-Baltic region to the north. The Prague Basin was dominated by Mediterranean-type faunas and had marine connections with Baltica already in the Early Ordovician (DZIK 1984). This biogeographic pattern reappeared in Královdvor and Kosov times reflecting both a narrowing of the Tornquist and the Rheic seas as well as climatic amelioration (HAVLÍČEK and FATKA 1992). Within the high-diversified deep-water *Proboscisambon* Community of the Perník Bed, some trilobites suggest the invasion of new, warmer water elements coming from the Anglo-Scandic Province (ŠTORCH and MERGL 1989).

Even if conodont absence in the underlying Ordovician sediments prevents any comparison with coeval conodont associations from other regions, the Bohemian conodont fauna reported here still has strong Mediterranean affinity, bearing typical components of the Mediterranean Province conodont fauna such as *Sagittodontina* cf. *robusta* and *Istorinus erectus*. Furthermore, *S. robusta* appears restricted to high-latitude areas which occupied a sub-polar position in the Late Ordovician (SWEET 1988). Nevertheless, genera like *Birksfeldia* and *Plectodina*, common in Great Britain and in the Carnic Alps, and present in the studied collection with scarce elements, indicate the existence of a connection with these regions.

SYSTEMATIC PALEONTOLOGY

The poor preservation of the fauna prevents a detailed morphological and taxonomic discussion, therefore only essential comments are given here. Synonymy is limited to first morphospecies description, first apparatus reconstruction and most recent reports. Orders and families are mostly from SWEET (1988).

Order **Belodellida** SWEET, 1988?
Family **Ansellidae** FÅHRÆUS *et* HUNTER, 1985?
Genus *Hamarodus* VIIRA, 1974

Type species: *Distomodus europaeus* SERPAGLI, 1967.

Hamarodus europaeus (SERPAGLI, 1967)
(Pl. 1: 11–17)

1955. *Microcoelodus*? sp.; RHODES: p. 133, pl. 10: 15, 19, 22.
1955. *Cordylodus elongatus* RHODES; RHODES: p. 135, pl. 7: 5–6.
1959. *Oistodus* sp. n.; LINDSTRÖM: p. 440, pl. 3: 13.
1959. *Cordylodus* sp. n.; LINDSTRÖM: p. 438, pl. 3: 34–36.
1964. ?*Neoprioniodus brevirameus* sp. n.; WALLISER: p. 47, pls 4: 5, 29: 5–10.
1964. ?*Roundya prima* sp. n.; WALLISER: p. 71, pls 4: 6, 31: 1, 2.
1966. *Oistodus breviconus* BRANSON *et* MEHL; HAMAR: p. 63, pl. 1: 19, text-fig. 4 (11).
1966. N. genus and sp. n.; HAMAR: p. 77, pl. 3: 8–10, text-fig. 5 (5a, b).
1967. *Distomodus europaeus* sp. n.; SERPAGLI: p. 64, pl. 14: 1–6.
1967. *"Oistodus" niger* sp. n.; SERPAGLI: p. 79, pl. 20: 1–7.
1967. *Oistodus abundans* BRANSON *et* MEHL; KNÜPFER: p. 34, pl. 5: 4.
1976. *Hamarodus europaeus* (SERPAGLI); DZIK: p. 435, text-fig. 36 (a–g).
1994. *Hamarodus brevirameus* (WALLISER); DZIK: p. 111, pl. 24: 14–19, text-fig. 31a.
1997. *Hamarodus europaeus* (SERPAGLI); FERRETTI and BARNES: p. 22, pl. 3: 1–14.

Remarks. — *Hamarodus europaeus* is moderately abundant in the fauna. **Pb** elements badly preserved and encrusted, but one (Pl. 1: 11) shows terminal denticulation of the anterior and upper keels. **M** elements always broken and present only in the Perník Bed. **S** elements common in many samples.

Occurrence. — Upper Middle and Late Ordovician of Europe and China.

Hamarodus cf. *europaeus* (SERPAGLI, 1967)
(Pl. 2: 13a, b)

Description. — **M** element whose basal margin of the only complete face is in lateral view (Pl. 2: 13b) convex in its basal and median part and concave only in the posterior part.

Remarks. — SERPAGLI (1967: pl. 20: 4a–d) figured some specimens which had these features only on one face, while the other side of the element had a basal margin that was also concave basally.

These elements are probably a variant of the **M** elements of *Hamarodus europaeus*.

Family **Dapsilodontidae** SWEET, 1988

Genus *Dapsilodus* COOPER, 1976

Type species: *Distacodus obliquicostatus* BRANSON *et* MEHL, 1933.

Dapsilodus mutatus (BRANSON *et* MEHL, 1933)
(Pl. 2: 15)

1933. *Belodus? mutatus* sp. n.; BRANSON *et* MEHL: p. 126, pl. 10: 17.
1959. *Acodus inornatus* sp. n.; ETHINGTON: p. 268, pl. 39: 11.
1959. *Distacodus procerus* sp. n.; ETHINGTON: p. 275, pl. 39: 8.
1967. *Acodus curvatus* BRANSON and BRANSON; SERPAGLI: p. 41, pl. 6: 3a–c.
1967. *Acodus mutatus* (BRANSON *et* MEHL); SERPAGLI: p. 41, pl. 6: 1a, b, 6 a, b.
1967. *Acontiodus procerus* (ETHINGTON); SERPAGLI: p. 46, pl. 9: 6–11.
1980. *Dapsilodus mutatus* (BRANSON *et* MEHL); ORCHARD: p. 20, pl. 5: 6, 15, 16, 21.
1994. *Dapsilodus mutatus* (BRANSON *et* MEHL); DZIK: p. 64, pls 11: 24–26, 31–35, 14: 8, 9, text-fig. 6d.
1997. *Dapsilodus mutatus* (BRANSON *et* MEHL); FERRETTI and BARNES: p. 23, pl. 3: 15–19.

Material. — The Bohemian collection includes rare specimens of this species, one found in the calcareous nodules and two in the Perník Bed.

Occurrence. — Middle–Late Ordovician of Europe and North America.

Order **Prioniodontida** DZIK, 1976

Family **Balognathidae** HASS, 1959

Genus *Amorphognathus* BRANSON *et* MEHL, 1933

Type species: *Amorphognathus ordovicica* BRANSON *et* MEHL, 1933.

Amorphognathus aff. *lindstroemi* (SERPAGLI, 1967)
(Pl. 1: 10 a–c)

aff. 1967. *Goniodontus lindstroemi* sp. n.; SERPAGLI: p. 41, pl. 16: 1–4.
aff. 1980. *Amorphognathus lindstroemi* (SERPAGLI); ORCHARD: p. 16, pl. 4: 28.

Description. — A species of *Amorphognathus* in which the "holodontiform" **M** element bears a small denticle on the outer-lateral flange of the cusp. The oral edge of posterior process extends as a sharp carina along the posterior face of the denticle. Cusp biconvex in oral view.

Remarks. — ORCHARD (1980: p. 16) observed that the "barb-like denticle", located on the "antero-lateral face of the cusp" and aborally directed, "is the only feature which may currently be used to distinguish" *A. lindstroemi* from *A. ordovicicus*. The Bohemian element differs from that definition in having the denticle which is oriented laterally and not aborally. Similar features were observed in "holodontiform" elements at the base of an Ashgillian sequence in Wales (BARNES and FERRETTI in preparation), which seem to occur just earlier than definitive **M** elements of *A. lindstroemi*.

A. aff. *lindstroemi* reported by ORCHARD (1980) from the Late Rawtheyan Cystoid Limestone of the north of England has a less developed denticle and the oral ridge of posterior process seems to run along the base of the cusp.

A. lindstroemi co-occurs with *A. ordovicicus* in the Italian Carnic Alps (SERPAGLI 1967) and in Sardinia (FERETTI and SERPAGLI work in progress). No definite criteria for recognizing the *Amorphognathus* species with only extra-"holodontiform" elements have been so far proposed. A waiting for an unequivocal definition of RHODES' material from the Keisley Limestone, this species is named after the "holodontiform" element.

Occurrence. — *A. lindstroemi* is known from the Ashgill of Carnic Alps, Great Britain and ?Bohemia.

Amorphognathus sp.
(Pl. 1: 1–9)

Remarks. — **Pa** elements are represented by broken isolated or rarely coupled processes; their number in Table 1 is overestimated as representing fragments. Small **Pb** elements, both in sinistral and dextral form, were found only in the Perník Bed. **S** elements are rare and often encrusted.

Genus *Birksfeldia* ORCHARD, 1980

Type species: *Birksfeldia circumplicata* ORCHARD, 1980.

Birksfeldia? sp.
(Pl. 2: 9)

Material. — One small incomplete **Pb** element, found in the Perník Bed, is assigned to this genus in open nomenclature.

Genus *Sagittodontina* KNÜPFER, 1967

Type species: *Sagittodontina robusta* KNÜPFER, 1967.

Sagittodontina cf. *robusta* KNÜPFER, 1967
(Pl. 2: 1–8)

cf. 1967. *Sagittodontina robusta* sp. n.; KNÜPFER: p. 38, pl. 8: 3a, b, 4.
1982. *Sagittodontina*? sp.; PARIS *et al.*: pl. 2: 12, 13, pl. 4: 3, 5, 7, 8.
cf. 1983. *Sagittodontina bifurcata* KNÜPFER; BERGSTRÖM: fig. 4.
cf. 1990. *Sagittodontina robusta* KNÜPFER; FUCHS: p. 206, pl. 5: 1–8, pl. 7: 1.
cf. 1992. *Sagittodontina robusta* KNÜPFER; BERGSTRÖM and MASSA: p. 1338, pl. 1: 6–14, 17.
cf. 1997. *Sagittodontina robusta* KNÜPFER; FERRETTI and BARNES: p. 30, pl. 4: 1–23.

Remarks. — *Sagittodontina* cf. *robusta* is the second most abundant species of the fauna, but reported only from the Perník Bed. It is mostly represented by anterior processes of **Pa** elements having up to five large denticles. Cusp has lateral keeled margin extending almost all the way to its apex and which extends distally as a thin short adenticulate process slightly twisted towards the posterior process. Specimens are identical to those illustrated by PARIS *et al.* (1982: pls 2: 12, 13, 4: 3, 5, 7, 8) from the Rosan Formation of France.

On the basis of new material from the Kalkbank limestone of Thuringia documenting the *Amorphognathus ordovicicus* Zone, FERRETTI and BARNES (1997) were able to revise the apparatus reconstruction of this species. When compared to the Thuringian collection (pl. 4: 2–3) and to unpublished materials from Spain, the corresponding **Pa** elements from those two localities appear slightly different in having an outer-lateral process which is approximately perpendicular to the anterior process and, sometimes, denticulated.

One platform-like incomplete posterior process (Pl. 2: 6) bears two convergent rows of denticles. **S** elements are rare and badly preserved.

Occurrence. — *S. robusta* is known in the Late Ordovician of Germany, Spain, France, Libya and ?Bohemia.

Family **Icriodellidae** SWEET, 1988

Genus *Icriodella* RHODES, 1953

Type species: *Icriodella superba* RHODES, 1953.

Icriodella sp.
(Pl. 2: 16, 17)

Remarks. — A single fragment of a Pa anterior process with an oblique ridge connecting denticles and a poorly preserved ?**Pb** element are tentatively assigned to this genus.

Family **Plectodinidae** SWEET, 1988

Genus *Plectodina* STAUFFER, 1935

Type species: *Prioniodus aculeatus* STAUFFER, 1930.

"Plectodina" aff. *tenuis* (BRANSON *et* MEHL, 1933)
(Pl. 1: 19)

aff. 1975. *Plectodina furcata tenuis* (BRANSON *et* MEHL); SWEET *et al.*: p. 42, pl. 2: 9–11, 14–17.
1980. *Plectodina* aff. *tenuis* (BRANSON *et* MEHL); ORCHARD: p. 23, pl. 2: 6.
aff. 1988. *Plectodina tenuis* (BRANSON *et* MEHL); NOWLAN *et al.*: p. 28, pl. 11: 11, 12, 15.

Description. — A small "ozarkodiniform" **Pa** element in the early growth stage and a **Pb** fragment were recovered. The former (Pl. 1: 19) has denticles that are strongly compressed laterally and are basally discrete. The basal cavity extends beneath the processes and flares almost symmetrically beneath the cusp. Anterior and posterior processes are sub-equal in length, the first being only slightly longer but bearing an equal number of denticles.

Remarks. — Similar **Pa** elements were reported as representing early small growth stages by ORCHARD (1980) in the Pusgillian of the north of England. The single Bohemian specimen was compared directly with early growth stages of the morphospecies *"Ozarkodina alpina"* SERPAGLI, 1967 of the Carnic Alps collection. Anterior and posterior process are at about 180°, a feature also observed in the Italian material, even if with a certain variability. However, in the Italian material the anterior process, sometimes similar in dimension to the posterior process, always bears more denticles and, at least in adult forms, is definitely longer.

SWEET *et al.* (1975) distinguished within *"Plectodina" furcata* (HINDE, 1879) two contemporaneous but geographically separated subspecies: *"P." furcata inclinata* (GLENISTER, 1957) with the posterior process of "ozarkodiniform" elements "conspicuously shorter" than the anterior process and *"P." furcata tenuis* (BRANSON *et* MEHL, 1933) with the two processes being of "essentially the same length". In addition, the "trichonodelliform" elements have respectively long, denticulated posterior processes or short ones lacking denticles or rarely bearing more than one or two small denticles. A third stock could have been represented by *"P." alpina* (SERPAGLI, 1967), tentatively revised by SWEET and BERGSTRÖM (1984), whose "ozarkodiniform" element has an anterior process definitely longer than the posterior one and "trichonodelliform" element with short and adenticulate posterior process. Only further studies and additional collecting will clarify the relation between these species. Note that Early Silurian species included by SWEET (1988) in *"Plectodina"*, i.e., *"P." hassi* (POLLOCK *et al.*, 1970), and *"P." oldhamensis* (REXROAD, 1967), appear to have "ozarkodiniform" elements with an anterior process longer than the posterior one and "trichonodelliform" elements lacking a true posterior process (MCCRACKEN and BARNES 1981).

Occurrence. — Middle–Late Ordovician of North America and Europe (Great Britain and Bohemia).

Order **Protopanderodontida** SWEET, 1988
Family **Protopanderodontidae** LINDSTRÖM, 1970

Genus *Protopanderodus* LINDSTRÖM, 1971

Type species: *Acontiodus rectus* LINDSTRÖM, 1955.

Protopanderodus sp.
(Pl. 2: 20)

Remarks. — A single incomplete specimen having a pair of costae, with the anterior more pronounced, on a lateral face which i slightly concave anteriorly and then subplanar, and an acostate convex face. Anterior keel well developed and deflected at its base towards the inner side.

Genus *Scabbardella* ORCHARD, 1980

Type species: *Drepanodus altipes* HENNINGSMOEN, 1948.

Scabbardella altipes (HENNINGSMOEN, 1948)
(Pl. 2: 10–12)

1948. *Drepanodus altipes* sp. n.; HENNINGSMOEN: p. 420, pl. 25: 14.

1980. *Scabbardella altipes* (HENNINGSMOEN); ORCHARD: p. 25, pl. 5: 2–5, 7, 8, 12, 14, 18, 20, 23, 24, 28, 30, 33, 35, text-fig. 4C.
1994. *Scabbardella altipes* (HENNINGSMOEN); DZIK: p. 64, pl. 11: 36–39, text-fig. 6e.
1997. *Scabbardella altipes* (HENNINGSMOEN); FERRETTI and BARNES: p. 34, pl. 1: 17–22.

Remarks. — *Scabbardella altipes* is the dominant species in the Bohemian collection and is common in both the calcareous nodules and the Perník Bed.

Occurrence. — Late Ordovician of Europe, Libya and North America.

Order unknown
Family unknown
Genus *Istorinus* KNÜPFER, 1967

Type species: *Istorinus erectus* KNÜPFER, 1967.

Istorinus erectus KNÜPFER, 1967
(Pl. 2: 14)

1967. *Istorinus erectus* sp. n.; KNÜPFER: p. 31, pl. 1: 4–6.
1967. *Istorinus postdentatus* sp. n.; KNÜPFER: p. 31, pl. 1: 10.
1967. *Istorinus recurvus* sp. n.; KNÜPFER: p. 32, pl. 1: 7–9.
1967. *Drepanodus disymmetricus* sp. n.; KNÜPFER: p. 26, pl. 2: 1–3.
1967. *Drepanodus humilis* sp. n.; KNÜPFER: p. 27, pl. 2: 4–6.
1992. *Istorinus erectus* KNÜPFER; BERGSTRÖM and MASSA: p. 1338, pl. 1: 15, 16.
1997. *Istorinus erectus* KNÜPFER; FERRETTI and BARNES: p. 34, pl. 5: 13–20.

Remarks. — FERRETTI and BARNES (1997) found complete specimens of *Istorinus erectus* in the German Kalkbank limestone and recognized three main morphotypes. A single small element, with sharp anterior and posterior margins and bearing a denticle on one side of cusp occurs in the Perník Bed.

Occurrence. — Late Ordovician of Germany, France, Spain, Libya and Bohemia.

Genus *Nordiodus* SERPAGLI, 1967

Type species: *Nordiodus italicus* SERPAGLI, 1967.

Nordiodus italicus SERPAGLI, 1967
(Pl. 1: 18a, b)

1967. *Nordiodus italicus* sp. n.; SERPAGLI: p. 77, pl. 19: 7a–12c.
1967. *Nordiodus proclinatus* sp. n.; SERPAGLI: p. 78, pl. 19: 1a–6c.
1967. *"Oistodus" rhodesi* sp. n.; SERPAGLI: p. 81, pl. 19: 13a–18d.
1984. *Nordiodus italicus* SERPAGLI; SWEET and BERGSTRÖM: p. 85.

Material. — A single small, poorly preserved, **M** element is present.

Occurrence. — Late Ordovician of Spain, Carnic Alps and Bohemia.

"carniodiform" element
(Pl. 2: 18, 19)

Remarks. — Small denticulated bars, sometimes slightly flexed, having a cusp in a sub-median position. As no complete specimens are present, the morphological nomenclature is preferred, but this does not exclude the possibility that they may represent elements of *Eocarniodus gracilis* (ORCHARD, 1980).

Gen. et sp. indet.
(Pl. 2: 21)

Remarks. — Incomplete element having a prominent triangular cusp, slightly flexed posteriorly. A costa runs laterally and extends into a lateral process. Posterior and anterior processes with three thin denticles oriented towards the cusp. Some of these features resemble those of *S.* cf. *robusta*, but denticles are here more slender and sharp and lateral process is denticulated.

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LATE ORDOVICIAN CONODONTS FROM THE PRAGUE BASIN, BOHEMIA

PLATE 1

Amorphognathus sp. 131

1, 2. Oral views of **Pa** elements IPUM 24964 and IPUM 24965, samples BO4 and P2, both × 120.
3–5. Outer-lateral views of **Pb** elements IPUM 24966, IPUM 24967, and IPUM 24968; samples K3, S3, and S3; × 135, × 95, and × 105 respectively.
6. Lateral view of **Sa** element IPUM 24969; sample BO4; × 115.
7. Lateral view of **Sb** element IPUM 24970; sample S2; × 150.
8, 9. Lateral views of **Sc** elements IPUM 24971 and IPUM 24972; samples PB1 and K1; both × 125.

Amorphognathus aff. *lindstroemi* (SERPAGLI, 1967) 130

10. Posterior (a), anterolateral (b), and oral (c) views of **M** element IPUM 24973; sample S3; × 195, × 195 and × 215 respectively.

Hamarodus europaeus (SERPAGLI, 1967) 129

11. Lateral view of **Pb** element IPUM 24974; sample BO3; × 65.
12–14. Lateral views of **Sc** elements IPUM 24975, IPUM 24976, and IPUM 24977; samples S2, BO5, and BO4; × 125, × 95, and × 135 respectively.
15. Lateral view of **Sb** element IPUM 24978; sample S4; × 135.
16, 17. Lateral views of **M** elements IPUM 24979 and IPUM 24980; samples P2 and K3; both × 85.

Nordiodus italicus SERPAGLI, 1967 133

18. Lateral views (a, b) of **M** element IPUM 24981; sample BO4; × 165.

"Plectodina" aff. *tenuis* (BRANSON *et* MEHL, 1933) 132

19. Lateral view of **Pa** element IPUM 24982; sample S4; × 195.

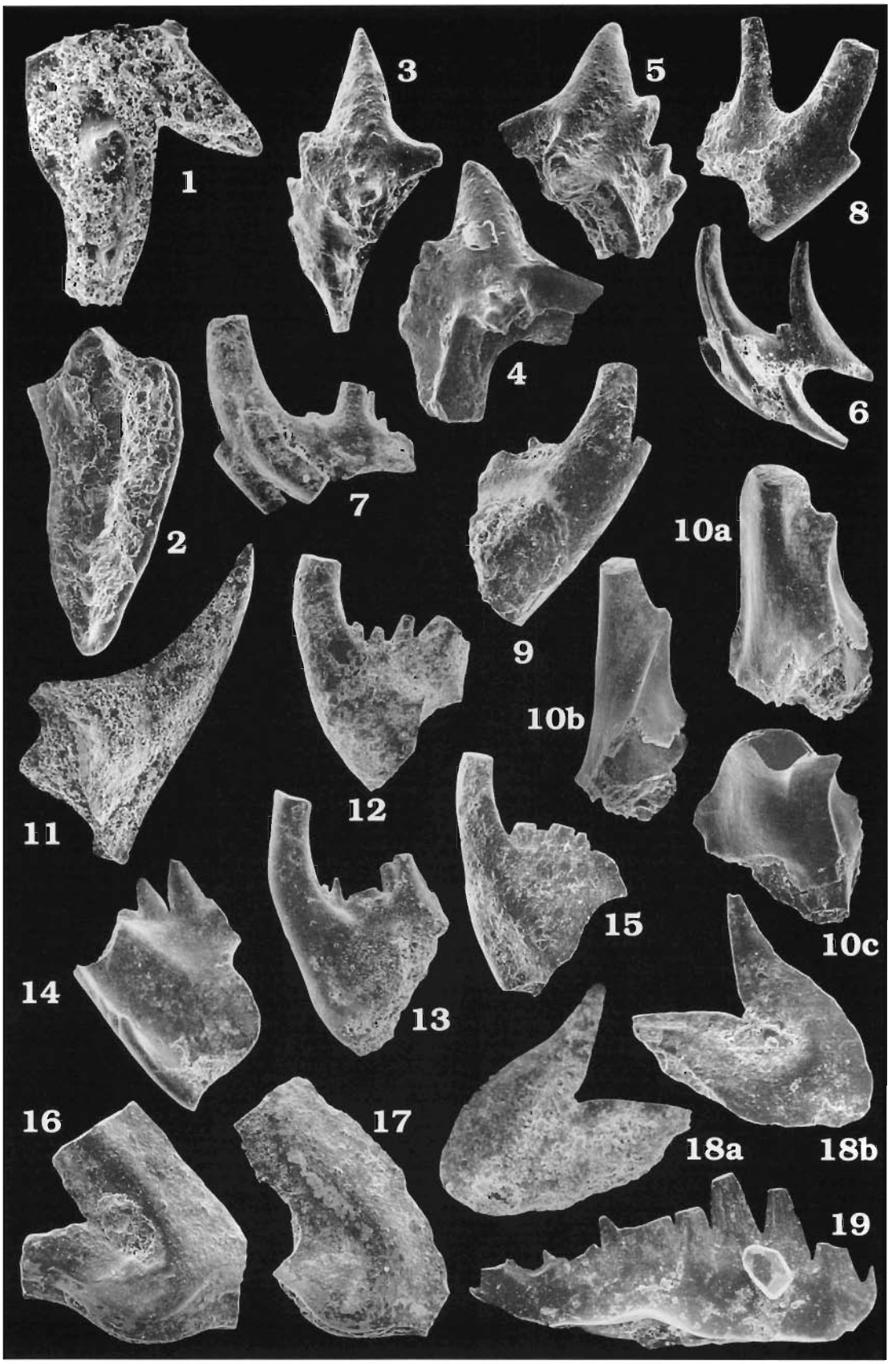
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PLATE 2

Sagittodontina cf. *robusta* KNÜPFER, 1967 131

1–6. Lateral views of **Pa** elements IPUM 24983, IPUM 24984, IPUM 24985, IPUM 24986, IPUM 24987, and IPUM 24988; samples S3, S3, S4, P2, P2, and PB1; × 135, × 150, × 135, × 175, × 140, and × 165, respectively.

7, 8. Lateral views of **Sb** elements IPUM 24989 and IPUM 24990; samples S3 and P2; both × 150.

Birksfeldia? sp. 131

9. Lateral view of **Pb** element IPUM 24991, sample S3, × 165.

Scabbardella altipes (HENNINGSMOEN, 1948) 132

10–12. Lateral views of elements IPUM 24992, IPUM 24993, and IPUM 24994; samples P1, BO4, and BO4; × 75, × 80, and × 120 respectively.

Hamarodus cf. *europaeus* (SERPAGLI, 1967) 130

13. Lateral views (a, b) of **M** element IPUM 24995; sample BO4; × 85.

Istorinus erectus KNÜPFER, 1967 133

14. Lateral view of element IPUM 24996; sample S4; × 235.

Dapsilodus mutatus (BRANSON *et* MEHL, 1933) 130

15. Lateral view of element IPUM 24997; sample BO3; × 170.

Icriodella sp. 131

16. Lateral view of ?**Pb** element IPUM 24998; sample P1; × 95.

17. Oral view of **Pa** element IPUM 24999; sample S3; × 165.

"carniodiform" element 133

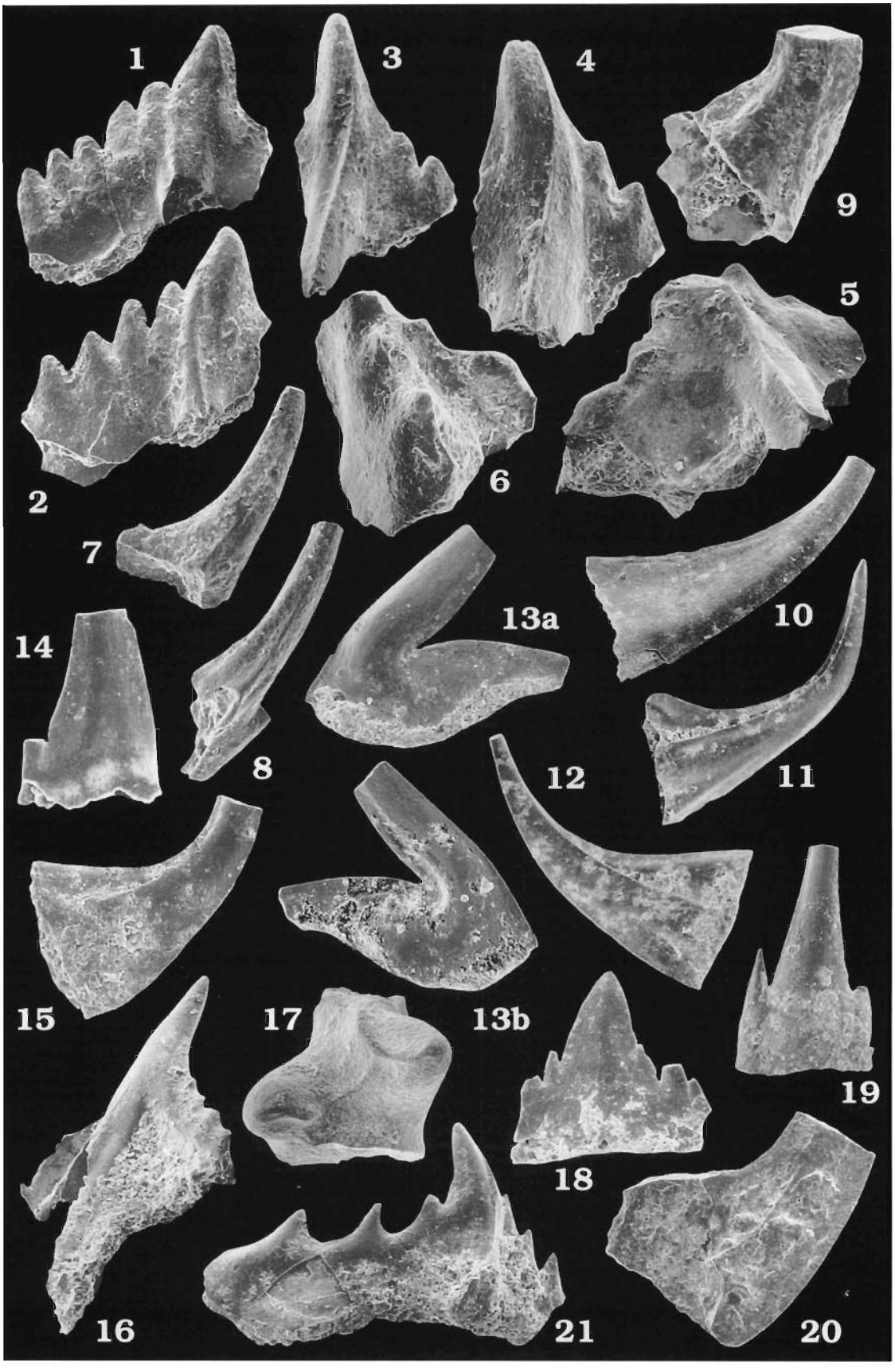
18, 19. Lateral views of elements IPUM 25000 and IPUM 25001; samples BO1 and BO4; × 220 and × 95 respectively.

Protopanderodus sp. 132

20. Lateral view of element IPUM 25002; sample K1; × 65.

Gen. et sp. indet. 133

21. Lateral view of element IPUM 25003; sample BO4; × 130.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13b
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