

The early Viséan (Carboniferous) conodonts from the Saoura Valley, Algeria

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ABSTRACT:

NEMYROVSKA, T.I., PERRET-MIROUSE, M.-F. & WEYANT, M. 2006. The early Viséan (Carboniferous) conodonts from the Saoura Valley, Algeria. *Acta Geologica Polonica*, **56** (3), 361-370. Warszawa.

The present study reports on conodonts from the El Hariga Formation (lower Viséan) of the Saoura Valley, Algeria. This formation overlies the Hassi Sguilma Formation with the latest Tournaisian conodont assemblage with *Scaliognathus anchoralis* and it is overlain by the Mazzer Formation with the mid-Viséan conodont fauna with *Gnathodus bilineatus*. The conodont assemblage of the El Hariga Formation contains the latest Tournaisian gnathodontids and the Viséan *Pseudognathodus* and unornamented early Viséan species of *Lochriea*. A new species, *Lochriea saharae*, a probable earliest representative of *Lochriea* is described. Its relationships to *L. cracoviensis*, *L. commutata* and *Bispathodus stabilis* are discussed.

Key words: Viséan, Carboniferous, Conodonts, Saoura Valley, Algeria, Biostratigraphy, Taxonomy.

INTRODUCTION

The aim of this paper is to present data on conodonts from the El Hariga Formation of the Saoura Valley, Algerian Sahara, which was regarded as early Viséan in age on the basis of ammonoids (PAREYN 1960-1961; LEMOSQUET & PAREYN 1985; LEMOSQUET, CONRAD & MANGER 1985). The third author of the present paper was not able to zone the Viséan of the Saoura Valley by means of conodonts at that time (WEYANT 1985) but also sup-

posed the El Hariga Formation to belong to the lower, if not the lowest Viséan.

After the first reports on the Carboniferous conodonts of LYS & SERRE (1957) and REMACK-PETITOT (1960), large collections have been made from various areas located north of the Reguibat Shield and the Hoggar, including the Bechar Basin. The conodont succession of the Bechar Basin, from the Tournaisian through the early Moscovian, is the reference sequence for comparison with the faunas from other Saharan areas (WEYANT 1985). The El

Hariga Formation of the Saoura Valley, which is located to the south of the Bechar Basin, contains abundant and diverse conodont faunas, three levels with ammonoids, and corals and brachiopods in the uppermost beds of the formation.

GEOLOGICAL SETTING AND BIOSTRATIGRAPHY

The study area is located to the north-west of Beni-Abbes on the west bank of Wadi Saoura,

which separates the dune-fields of the Grand Erg Occidental in the east from the very flat Hamada du Guir-plateau stretching to the west (Text-fig. 1).

The Viséan starts in the Saoura Valley with the El Hariga Formation, which consists of a rather monotonous sequence of red and greenish shales with very scarce intercalations of thin siltstone and limestone layers. Outcrops are visible over a limited area about 20 km long. The overall strike of the rocks is NW-SE, and the dip ranges from 3 to 5° northeast. The thickness of the El Hariga

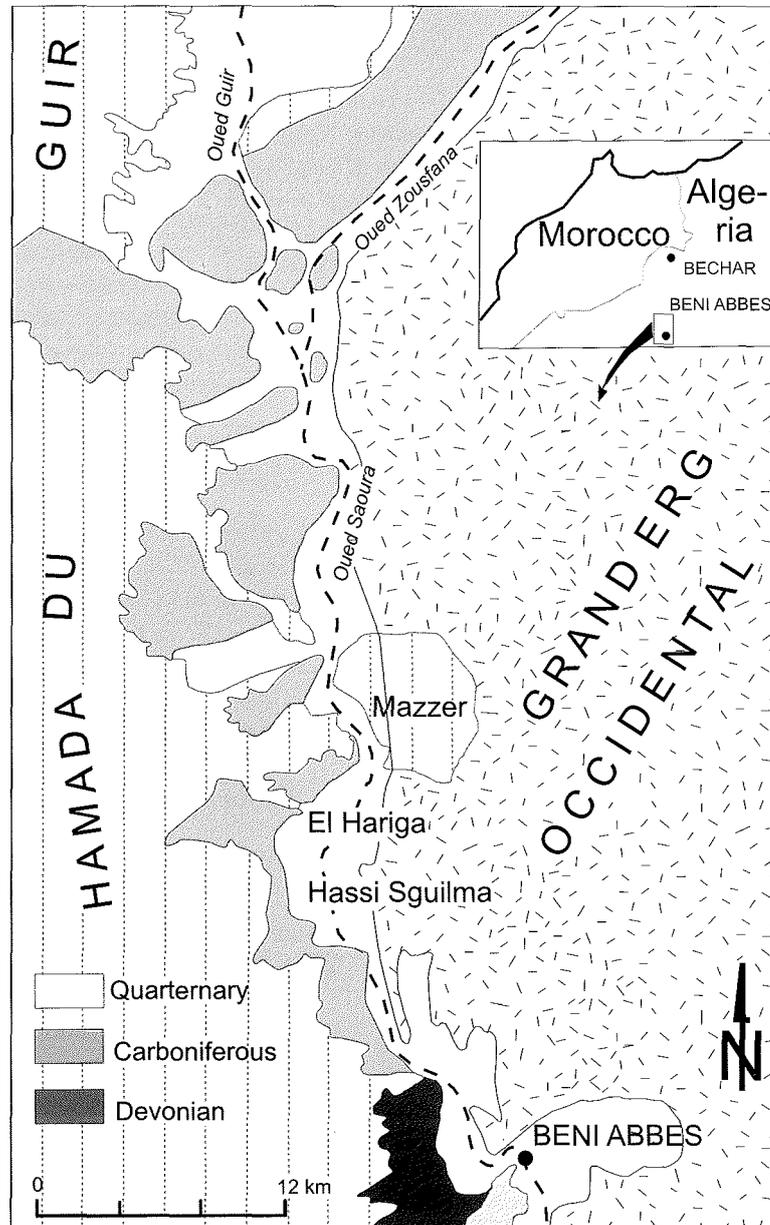


Fig. 1. Location of the investigated area on the simplified geological map of the Saoura Valley, Algeria

Formation according to PAREYN (1961, p. 43) is up to 750 m, but this may be an overestimate.

The conodont samples and the ammonoids were not collected from the same outcrops but from outcrops situated relatively close to one another. The individual limestone beds that were sampled for conodonts are difficult to follow laterally, the outcrops being frequently interrupted and hidden by constantly wandering alluvial deposits. For the same reason there will always remain some uncertainty concerning: 1) precise identification of the beds from which ammonoids were collected by PAREYN in the mid-1950s, and 2) whether they can be correlated with any of those which yielded conodonts two decades later. Therefore the ammonoid occurrences are not shown in Text-fig. 2.

The El Hariga Formation overlies the brown sandstones and quartzites and shales of the Hassi Sguilma Formation, the last thin carbonate layer of which contains the conodonts *Scaliognathus anchoralis* BRANSON & MEHL and *Pseudopolygnathus pinnatus* VOGES of the latest Tournaisian. This age was supported by LEMOSQUET & MANGER, who noted that "the Hassi Formation is characterised by the appearance of the goniatites *Pericyclus* and *Merocanites* along with the climax of *Muensteroceras*" (LEMOSQUET & al. 1985). From the upper part of the Hassi Formation above the limestone bed with *Scaliognathus anchoralis* PAREYN (1961) described a diverse *Fascipericyclus*-*Ammonellipsites* zonal fauna (PAREYN's S1b level) which indicates an earliest Viséan age (RILEY, personal communication, 2001).

The lower part of the El Hariga Formation was assigned to the earliest Viséan *Pseudognathodus homopunctatus* conodont Zone whereas the upper part was considered as belonging to the *Gnathodus bilineatus* Zone (WEYANT 1985). Within the El Hariga Formation PAREYN (1961) distinguished three levels with ammonoids. The lower two levels (S2a and S2b) contain the *Beyrichoceras*/*Bollandoceras* zonal fauna (*Merocanites*, *Beyrichoceratoides* and *Muensteroceras*, acme and subsequent disappearance of *Merocanites*, extinction of *Muensteroceras*, presence of *Nautellipsites*) and are early Viséan in age (PAREYN 1961; LEMOSQUET, CONRAD & MANGER 1985; KORN, personal communication, 2000, and RILEY, personal communication, 2001). The third ammonoid assemblage – S2c or the upper part of the El Hariga Formation, is characterised

by the appearance of the earliest representatives of the *Goniatites* fauna with spiral striae. It contains *Maxigoniatites saourensis* PAREYN (*Goniatites maxima saourensis* PAREYN 1961) and, according to KORN (personal communication, 2001), is mid-Viséan or even earliest late Viséan in age.

The El Hariga Formation is overlain by the basal crinoidal limestone beds of the Mazzer Formation with *Gnathodus bilineatus* (ROUNDY) and late Viséan benthic organisms. SEMENOFF-TIAN-CHANSKY & al. (1975) reported the lithostrotoniid corals *Siphonodendron* gr. *martini* and *S.* gr. *pauciradiale* sp. A from the top of the El Hariga Formation. LEGRAND-BLAIN (personal communication, 2003) found the spiriferid brachiopod *Frechella fascicostata* in the uppermost beds of the formation.

CONODONTS

Fourteen conodont samples were taken from the limestone beds of the El Hariga Formation (Text-fig. 2). Each sample was 1 to 1.5 kg. They yielded 916 conodont elements, an average 60-70 elements/kg.

The platform elements outnumber the ramiforms: 537 platform elements and 379 ramiforms were registered.

The conodont faunas from the El Hariga Formation contain well preserved specimens of the genera *Gnathodus*, *Pseudognathodus* and *Lochriea*. As in the other Carboniferous sequences all over the world, *Gnathodus* appears in the late Tournaisian in the Saoura Valley, and includes a much larger number of species than *Lochriea*, and *Pseudognathodus*, which started in the Viséan. *Gnathodus* and *Lochriea* go through the Viséan and Serpukhovian and become extinct near the mid-Carboniferous boundary. The range of the *Pseudognathodus* species is restricted here to the Viséan.

The *Gnathodus* species dominate throughout the succession. *Gnathodus semiglaber* BISCHOFF, *Gn. pseudosemiglaber* THOMPSON & FELLOWS and *Gn. delicatus* BRANSON & MEHL, known from the underlying Hassi Sguilma Formation (late Tournaisian), occur in the El Hariga Formation. *Gn. pseudosemiglaber* is most abundant in the El Hariga Formation (108 specimens in 14 samples)

but not as abundant as in the Hassi Sguilma Formation (1439 specimens in 4 samples). It overlaps *Gn. bilineatus* in the lowermost part of the overlying Mazzer Formation (Text-fig. 2). *Gn. semiglaber* and *Pseudognathodus homopunctatus* (ZIEGLER) are common. *Gnathodus texanus* ROUNDY was found rather rarely in the lowest limestone beds of the El Hariga Formation together

with M elements of *Lochriea* and Pa elements of the new species of *Lochriea* – *L. saharae* sp. nov.

Small numbers of Pa elements bearing morphological features transitional between *Bispathodus stabilis* (BRANSON & MEHL) and *Lochriea cracoviensis* (BELKA) and *Bi. stabilis* and *L. saharae* sp. nov., as well as *Mestognathus beckmanni* BISCHOFF were also found. Abundant ramiform elements found in the El

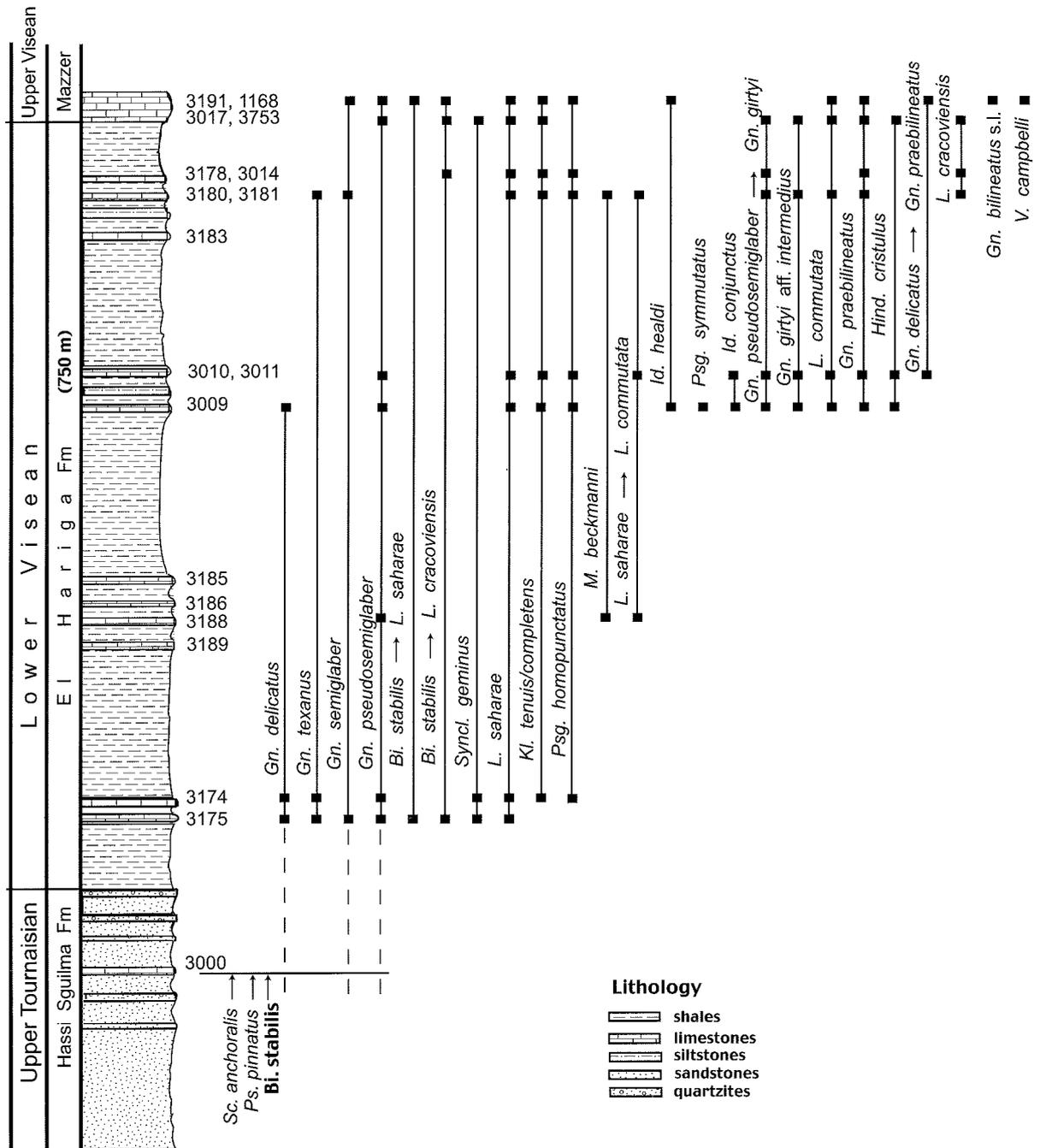


Fig. 2. Distribution chart of the conodonts through the El Hariga Formation, Saoura Valley, Algeria

Hariga Formation and basal beds of the Mazzer Formation are assigned to the multi-element species *Kladognathus tenuis/completens* (BRANSON & MEHL), emend. REXROAD, *Syncladognathus geminus* (HINDE), *Hindeodus cristulus* (YOUNGQUIST & MILLER) and *Idioprioniodus healdi* (ROUNDY).

The upper part of the El Hariga Formation is characterised by the first appearance of *Gnathodus praebilineatus* BELKA (rare), *Gnathodus girtyi* HASS (early subspecies), transitional forms between *Gn. pseudosemiglaber* and *Gn. girtyi* as well as *L. commutata* (BRANSON & MEHL) and *L. cracoviensis* BELKA. *Gn. pseudosemiglaber* and *L. saharae* sp. nov. are common in the upper part of the El Hariga Formation. *Lochriea* species are more abundant in the overlying Mazzer Formation (169 specimens in 5 samples) than in the El Hariga Formation (79 specimens in 14 samples). This is in contrast to *Pseudognathodus homopuctatus* (ZIEGLER) and *Psg. symmutatus* (RHODES, AUSTIN & DRUCE), which are less common in the Mazzer Formation (32 specimens in 5 samples) than in the El Hariga Formation (80 specimens in 14 samples). The first rare *Gn. bilineatus* and *Vogelgnathus campbelli* (REXROAD) were recorded in the lowest beds of the Mazzer Formation.

The conodont association of the El Hariga Formation contains a number of simple unornamented early *Lochriea* species with intermediate forms between them as well as between them and their probable ancestor *Bi. stabilis*. These transitional forms between Pa elements of *Bi. stabilis* and *L. commutata* were recorded already in other areas (MEISCHNER & NEMYROVSKA, 1999). As we regard the *Lochriea* lineage to be important for Viséan stratigraphy, we have tried in this paper to define the early species of that genus more precisely, paying particular attention to the earliest *Lochriea* species in the El Hariga Formation: *L. cracoviensis*, *L. commutata* and the new species *L. saharae*.

Well known and widespread in the Viséan and Serpukhovian, conodonts of the genus *Lochriea* display a great variety in their platform ornamentation, ranging from totally unornamented to sculptured ones with nodes or ridges (MEISCHNER, 1970; HIGGINS, 1975; NEMIROVSKAYA & al. 1994; SKOMPSKI & al. 1995). The morphological trends within the genus *Lochriea* from unornamented to sculptured forms with rich ornamentation are of stratigraphical importance. One of the first ornamented *Lochriea* – *L. nodosa* BISCHOFF, is a mark-

er-species of the latest Viséan conodont zone, and the strongly ornamented species *L. zieglerei* NEMYROVSKA, PERRET & MEISCHNER (or *L. cruciformis* CLARKE) is proposed to serve as marker-species for the identification of the Viséan/Serpukhovian boundary in Eurasia (SKOMPSKI & al. 1995, NEMYROVSKA 1999, NEMYROVSKA, 2005). After being widespread through the Viséan and Serpukhovian, *Lochriea* species became extinct together with the other Mississippian conodonts by the mid-Carboniferous boundary.

MEISCHNER (1970) and later HIGGINS (1975), PARK (1983), BELKA (1985) and MEISCHNER & NEMYROVSKA (1999) cited *Bispathodus stabilis* as a root stock of *Lochriea*. *L. commutata* was mentioned already by MEISCHNER (1970) as the most conservative species spanning the interval of the Viséan and Serpukhovian. During its evolution it gave rise to many species with an ornamented cup (SKOMPSKI & al. 1995). Pa elements of *L. commutata* as well as of all the succeeding species of *Lochriea* are characterized by broadly ovate and slightly asymmetrical cups positioned at the posterior end of the elements. The denticles of the blade and carina are fused and those of the carina may be widened laterally. The Pa element has an almost rectangular shape in lateral view.

L. cracoviensis is a short-ranged species and its descendants are not known. The cup of its Pa element is located not at the posterior end of the element but slightly shifted anteriorly. The laterally widened denticles crown not only its carina but also the posterior part of the free blade.

Bispathodus stabilis (BRANSON & MEHL), which is morphologically similar to the early simple *Lochriea* species, also represents a conservative species, first recorded in the late Devonian. It was subdivided into two morphotypes by ZIEGLER, SANDBERG & AUSTIN (1974). *Bi. stabilis* Morphotype 2 is regarded as a more advanced form of *Bi. stabilis* with the basal cavity already shifted posteriorly; it occurs in the Mississippian, and might be an ancestor of *Lochriea*. Its last occurrence in the Saoura Valley sections is in the Hassi Sguilma Formation underlying the El Hariga Formation.

In spite of the morphological similarities between the Pa elements of *Bi. stabilis* Morphotype 2 and *L. commutata* and the presence of intermediate morphologies, there are essential differences between them:

1. The basal cavity of *Lochriea* is supposed to be positioned at the posterior end of the element; only in the earliest forms can the carina extend beyond the cup posteriorly.
2. The basal cavity in *Lochriea* occupies no more than one third of the element length whereas in *Bi. stabilis* Morphotype 2, even if the cavity is close to the posterior end (which is very rare), it starts at the middle of the element.
3. The basal cavity is generally subcircular to subquadrate in shape and asymmetrical in *Lochriea*, whereas in *Bispathodus stabilis* Morphotype 2 it is oval, elongate and mostly symmetrical. There are also specimens of *Bi. stabilis* with a rather narrow basal cavity.

4. The blade-carina in *Lochriea* consists of denticles, which become wider laterally and are located directly on the flaring of the cup. In *Bi. stabilis* the denticles never tend to be wider laterally and are located on a wider basis below which the flaring of the cup starts.
5. *Bi. stabilis* and *Lochriea* species can be easily distinguished in lateral view. At the anterior end several discrete denticles of *Bi. stabilis* are much higher than the others whereas the lateral profile of early Viséan species of *Lochriea* is almost rectangular.

Pa elements of *L. cracoviensis* are easily distinguished from those of *L. commutata* by their broad carina consisting of laterally expanded denticles, and especially by the broad posterior part of the free blade, close to the cup, which also bears laterally expanded denticles. The denticles can be "expanded to form transverse ridges...., the blade extends beyond the oval-shaped cup at the posterior end" (BELKA 1985). Thus, the differences between the Pa elements of all the *Lochriea* species and those of *L. cracoviensis* are evident: a) the cup (basal cavity) of *L. cracoviensis* is not positioned at the posterior end of the element as it is in other *Lochriea* species; and b) in *L. cracoviensis* both the carina and the posterior part of the free blade are ridged and strongly expanded. The second feature also distinguishes *L. cracoviensis* from *Bi. stabilis*, the blade of which bears simple denticles in contrast to older *Bispathodus* which possess either a ridged blade or a blade with double rows of nodes. However, *L. cracoviensis* resembles older *Bi. stabilis* in the expansion of its ridges onto the posterior part of the blade. The resemblance of the Pa elements of *L. cracoviensis* and *Bi. stabilis* was the reason for BELKA (1985) to consider *L. cracoviensis* as being derived from *Bi. stabilis*.

The availability of forms with intermediate features between the Pa elements of *Bi. stabilis* and *L. cracoviensis* and between those of *Bi. stabilis* and *L. saharae* seems to support the suggestion of the derivation of *Lochriea* from *Bi. stabilis* (Text-fig. 3), in spite of the other elements (Pb, M and S) of *Lochriea* differing from those of *Bispathodus*. Another possibility would be to speculate about the origin of *Lochriea* from *Protognathodus* but there is no evidence on their common multi-element construction.

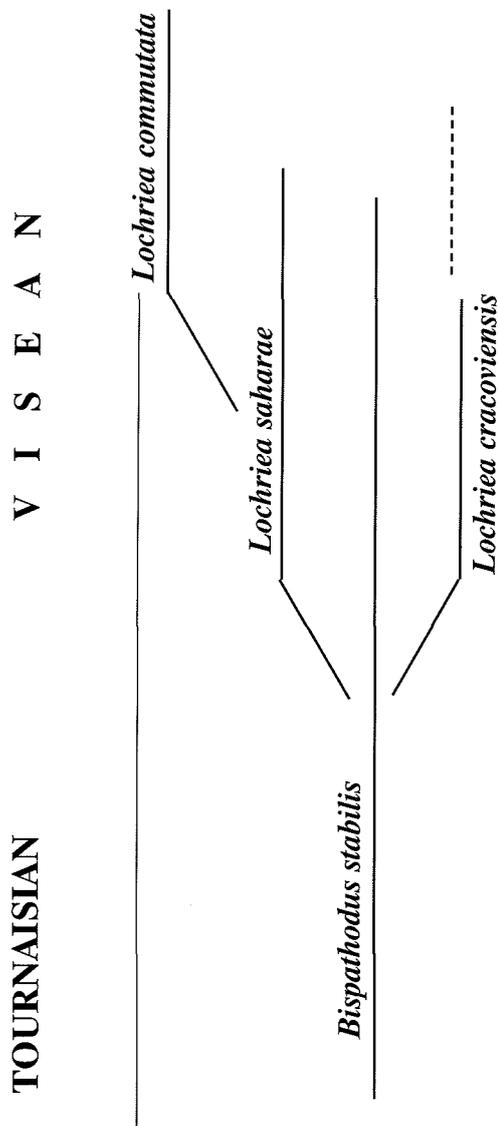


Fig. 3. Hypothetical lineage *Bispathodus stabilis* – *Lochriea saharae* – *L. commutata*

The forms which portray features transitional between those of *Bi. stabilis* and *L. commutata* were found in the lower limestone interbeds of the El Hariga Formation, in the lower/middle Viséan (?) micritic limestones in the French Pyrenees, in the uppermost part of the lower/mid-Viséan of the Rheinisches Schiefergebirge in Germany (MEISCHNER & NEMYROVSKA 1999) and in the Cantabrian Mountains, Palencia, in northern Spain (NEMYROVSKA, 2005). Transitional specimens have also been illustrated from other areas of Europe (see synonymy list of *L. saharae*).

SYSTEMATIC PALAEOONTOLOGY

Figured specimens of the Marcel WEYANT collection are deposited in the Museum d'Histoire Naturelle de Nantes, France.

Genus *Lochriea* SCOTT, 1942

TYPE SPECIES: *Spathognathodus commutatus* BRANSON & MEHL, 1941 (Pa element); *Lochriea montanaensis* SCOTT, 1942 (M element).

Lochriea saharae sp. nov.
(Pl. 1, Figs 6, 10-12, 14-15, 17)

1976. *Lochriea commutata* (BRANSON & MEHL); R.D. NORBY, pl. 11, fig. 6.
1981. *Gnathodus commutatus* (BRANSON & MEHL); I. METCALFE, pl. 7, fig. 6.
1983. *Paragnathodus commutatus* (BRANSON & MEHL); S. PARK, pl. 4, fig. 2.
1990a. *Lochriea commutata* (BRANSON & MEHL); A. RAMOVŠ, pl. 4, fig. 10.
1990b. *Lochriea commutata* (BRANSON & MEHL); A. RAMOVŠ, pl. 1, fig. 7.
1991. *Lochriea commutata* (BRANSON & MEHL); J. STONE, Pl. 4, Figs. 6, 9.
1999. *Bispathodus stabilis* (BRANSON & MEHL) transitional to *Lochriea commutata* (BRANSON & MEHL); D. MEISCHNER & T. NEMYROVSKA, pl. 4, fig. 4.
2002. *Lochriea saharae* nomen nudum; T. NEMYROVSKA & al., p. 47.

HOLOTYPE: Specimen S-10 (Pl. 1, Fig. 10 a-c).

TYPE LOCALITY: Saoura Valley section, Sahara, Algeria.

TYPE HORIZON: Sample 3191, base of the Mazzer Formation, mid-Viséan, base of the *Gnathodus bilineatus* Zone.

DERIVATION OF NAME: After Sahara, Algeria, where it was found.

DIAGNOSIS: Pa elements of *L. saharae* are characterised by an oval or slightly subcircular unornamented cup positioned close to but not at the posterior end of the element. The blade-carina bears mostly simple fused denticles. In lateral view Pa element slightly arched with subrectangular shape common for simple unornamented *Lochriea*.

MATERIAL: 32 specimens.

DESCRIPTION: The blade-carina is made of mostly simple fused denticles. It extends beyond the platform posteriorly. The denticles of the carina can be slightly expanded laterally like in *L. commutata*. The carina is slightly curved posteriorly (some specimens show a considerable curvature). The smooth, unornamented cup is oval to subcircular, symmetrical to slightly asymmetrical; its outer side is commonly wider. Its anterior margin is close to the mid-point of the element or is shifted slightly posteriorly, but the posterior margin of the platform never reaches the posterior end of the element. The Pa element is slightly arched in lateral view. Its anterior end is slightly higher. Both anterior and posterior ends of the element are subrectangular to almost rectangular.

REMARKS: When BRANSON & MEHL (1941) distinguished *Spathognathodus commutatus* they pointed out that the basal cavity "is close to the posterior end of the blade". Subsequent workers, starting from BISCHOFF (1957), did not concentrate on this feature. Only HIGGINS (1975), in accordance with BRANSON & MEHL, mentioned the position of the basal cavity close to the posterior end, but all of his illustrated specimens actually show the cavity located at the extreme posterior end of the blade.

We noticed that the position of the basal cavity

of the forms assigned to *L. commutata* varies from older rocks to younger ones. The basal cavity seems to have shifted posteriorly during evolution in early Viséan time. The shape of Pa elements in lateral view also underwent changes – from slightly arched to subrectangular or rectangular in *L. commutata*. The cavity shape became more subcircular. Thus the early *L. commutata* are closer to *Bi. stabilis* than the later ones. We did not find *L. commutata* with the blade-carina extending posteriorly beyond the platform in the upper Viséan and Serpukhonian deposits, although some specimens with a very prominent carina posteriorly were found even in the lowest Serpukhonian beds (our unpublished records from the Sahara and other areas). We regard the position of the basal cavity to be a very important diagnostic feature and on this basis we distinguish *L. saharae* sp. nov. from *L. commutata*. Even in juveniles of *L. commutata* the basal cavity is always located at the posterior end of the element (Pl. 1, fig. 7). *Lochriea saharae* additionally differs from *L. commutata* in its slightly arched lateral shape.

Lochriea saharae is distinguished from *L. cracoviensis* by the simple carina-blade denticles. The latter can be slightly widened on the carina but never on the posterior part of the blade. *Lochriea cracoviensis* also probably derived from *Bi. stabilis* but it might belong to another lineage. In the El Hariga section, its entry occurs a little later than that of *L. saharae*; in the mid-Arundian of South Wales it was not found at all, but the forms assigned by STONE to *L. commutata* portray the features of *L. saharae* (STONE 1991, pl. 4, fig. 6, 9). Both species, *L. saharae* sp. nov. and *L. cracoviensis*, are the earliest *Lochriea*, but additional sections need to be studied in order to understand better the relationships between them.

Lochriea saharae differs from *Bi. stabilis* in a more subcircular and more asymmetrical and deeper basal cavity located closer to the posterior end of the unit than that in *Bi. stabilis*. It also differs from *Bi. stabilis* in the shape of the blade in lateral view: in the absence of the much higher discrete denticles at the anterior end of the blade in *Bi. stabilis*.

RANGE: *Lochriea saharae* sp. nov. first occurs in the basal beds of the El Hariga Formation together with the other early Viséan conodonts characteristic of the strata younger than the *Scaliognathus anchoralis* Zone. This association consists of abun-

dant *Gnathodus pseudosemiglaber*, less common *Gn. semiglaber*, rather rare *Gn. texanus*, common *Pseudognathodus homopunctatus*, forms transitional between *Gn. pseudosemiglaber* and *Gn. girtyi*, *L. cracoviensis* and the first rare *Gn. praebilineatus*. The conodont assemblage is no younger than early Viséan in age.

At the base of the Mazzer Formation, *L. saharae* sp. nov. is also accompanied by rare *Gn. praebilineatus* and *Gn. bilineatus*, together with more common *L. commutata*. Because of the entry of *Gn. bilineatus* s.l., the conodont association belongs to the early late Viséan.

Although the exact range of *L. saharae* cannot be defined from the material available, its approximate range could be estimated as early- through mid-Viséan. It has not been found so far in the Upper Viséan and Serpukhonian deposits of the Saoura Valley and other areas.

We do not know how exactly to correlate the limestone beds with conodonts in the study area to the three levels with ammonoids of PAREYN. We only know that none of the ammonoid workers who knows the PAREYN collection from the El Hariga Formation, i.e., Nick RILEY, Walter MANGER and Dieter KORN, regard the El Hariga as earliest Viséan. As mentioned above, they consider the lower part of the El Hariga Formation as early Viséan in age and the upper part as early late Viséan (see the chapter "Geological setting and biostratigraphy"). This means that we cannot prove (by means of the other fossils) that *L. saharae* appears in the earliest Viséan. However, because this species show intermediate features between those of *Bi. stabilis* and *L. commutata*, we believe it is the earliest *Lochriea*.

Additional studies are required to prove our suggestions. The data from Central Asia (Tien Shan and the Fergana Valley in particular), where the Viséan is represented by different types of facies: from carbonate platform through slope to basinal facies, are important. The age of some successions in those areas are controlled by ammonoids. The Chinese and the Urals (Russia) sections might be also important in this respect.

OCCURRENCE: Samples 3175, 3174, 3009, 3011, 3180, 3178, 3191; lower Viséan through mid-Viséan; *Gnathodus praebilineatus* Zone through the beginning of the *Gn. bilineatus* Zone.

Acknowledgements

The authors acknowledge Dr. Marie LEGRAND-BLAIN for information and discussions on the Mississippian benthic fossils in the Sahara sections. Tamara NEMYROVSKA is grateful to Drs N. RILEY, D. KORN and W. MANGER for helpful information and discussions on the ammonoids of the Saoura Valley sections. The authors are indebted to Prof. Z. BELKA, the journal referee, for his valuable remarks. This study was made possible by a visiting scientists' grant to the first author, resulting from the Agreement of the cooperation between the University Paul Sabatier, Toulouse, France, and the National Academy of Sciences of Ukraine. IRD and L.M.T.G. (UMR5563-Toulouse) are also thanked for financial support and assistance.

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Manuscript submitted: 25th February 2005

Revision version accepted: 10th May 2006

PLATES 1-6

PLATE 1

- 1a, b, 6, 8, 16 – *Bispathodus stabilis* (BRANSON & MEHL, 1934) transitional to *Lochriea cracoviensis* BELKA, 1985; 1a – S-1, oral view, 1b – the same specimen, denticle microsculpture, × 480, sample 1168; 6 – specimen S-6, oral view, sample 3017; 8 – S-8, oral view, sample 3178; 16a-b – S-16, oral view and microsculpture, × 480, sample 3191.
- 2-3 – *Bispathodus stabilis* (BRANSON & MEHL, 1934) transitional to *Lochriea saharae* sp. nov.; 2 – S-2, oral view, × 80, sample 3175; 3 – specimen S-3, oral view, sample 1168.
- 4 – *Lochriea* cf. ? *saharae* sp. nov.; S-4, oral view, sample 3174.
- 5, 9-11, 13-14 – *Lochriea saharae* sp. nov.; 5 – S-5, oral view, juvenile, sample 3009; 9a-b – S-9, oral and lateral view, sample 3178;
- 10 – S-10, holotype, a – oral view, b – lateral view, c – microsculpture, × 200, sample 3191;
- 11 – S-11, oral view, sample 3191;
- 13 – S-13, lateral view, sample 3011;
- 14 – S-14, lateral view, sample 3753.
- 7, 15 – *Lochriea commutata* (BRANSON & MEHL, 1934); 7 – S-7, 15 – S-15; oral views, sample 3180.
- 12 – *Lochriea saharae* sp. nov. transitional to *L. commutata* (BRANSON & MEHL, 1934); S-12, oral views, sample 3011.

Magnification × 60, when otherwise indicated

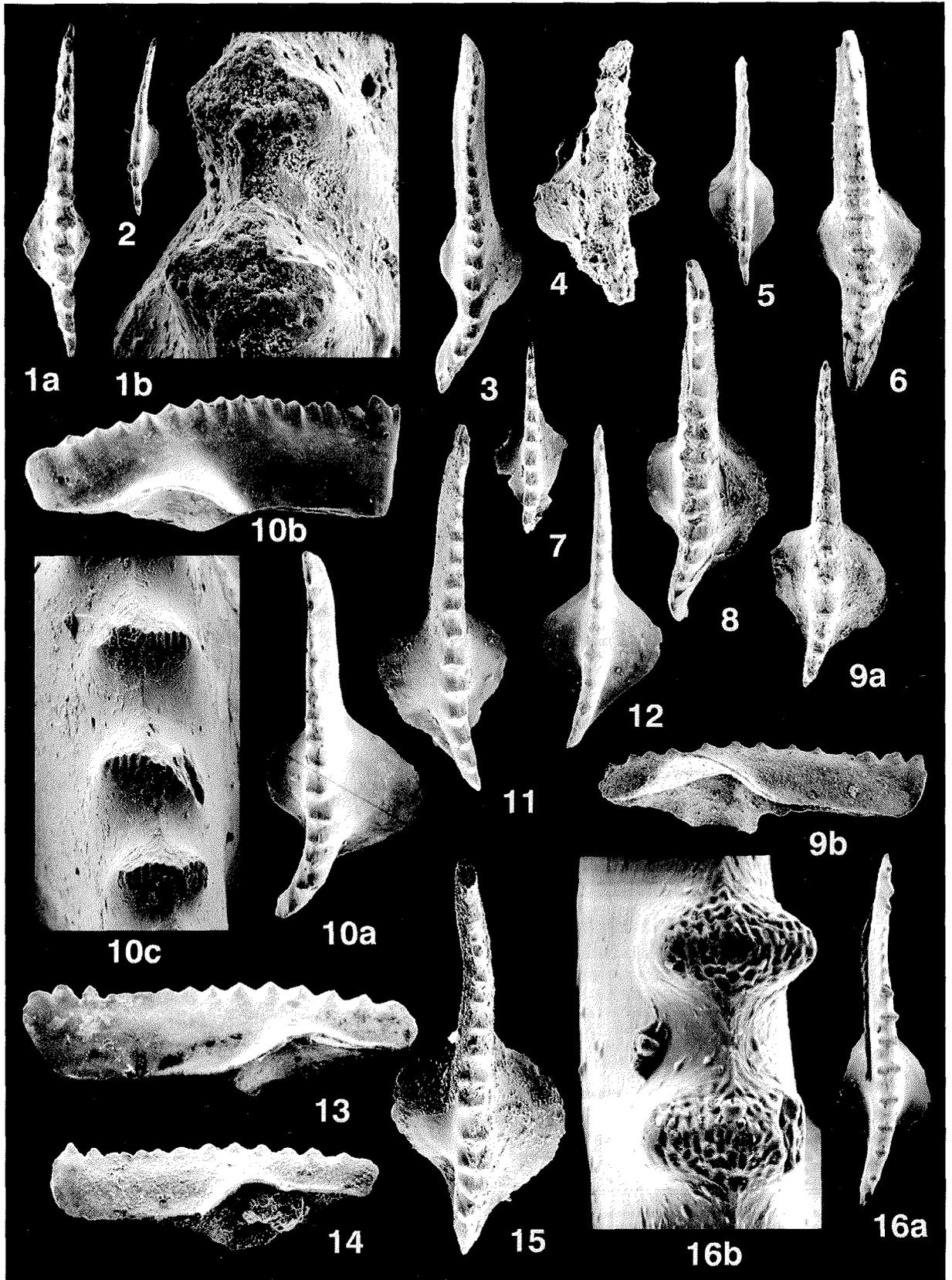


PLATE 2

- 1-2 – *Lochriea cracoviensis* BELKA, 1985; 1 – specimens S-17; a – oral view and b – microsculpture, $\times 300$; 2 – S-18, oral view; both from sample 3180.
- 3-12, 14-15 – *Lochriea commutata* (BRANSON & MEHL, 1934).
Pa elements: 3 – S-19, lateral view, sample 3180; 4 – S-20, oral view, sample 3017.
Pb elements (can be vicariously shared between *L. commutata*, *L. saharae* and *L. cracoviensis*):
- 5-7, 14-15 – DE – *Subbryanthodus subaequalis* HIGGINS, 1961; 5, 7 – S-21 and S-22, sample 3009; 6 – S-23, sample 1168; 14-15 – S-24 and S-25, sample 3191.
M elements (can be vicariously shared between *L. commutata*, *L. saharae* and *L. cracoviensis*):
- 8-9 – DE – *Neoprioniodus singularis* (HASS, 1953); 8 – S-26, sample 3175; 9 – S-27, sample 3191.
S elements (can be vicariously shared between *L. commutata*, *L. cracoviensis* and *L. saharae*):
Sa element:
- 10 – DE – *Hibbardella pennata* Higgins, 1961, S-121, sample 3191.
Sb elements:
- 11-12 – DE – *Hindeodella germana* HOLMES, 1928; 11 – S-28, sample 3191; 12 – S-29, sample 3011.
 13 – *Ozarkodina* sp. 1; 13 – S-30, sample 3011.
- 16, 19-20 – *Ozarkodina* sp. 2; 16 – S-31, sample 3017 (? *Subbryanthodus stipans* REXROAD, 1957); 19 – S-32, sample 3009; 20 – S-33, sample 3191.
 17 – *Pseudognathodus symmutatus* (RHODES, AUSTIN & DRUCE, 1969); 17 – S-34, oral view, sample 3009.
 18 – *Ozarkodina hindei* CLARKE, 1960; 18 – S-35, sample 3009.

Magnification $\times 60$, when otherwise indicated

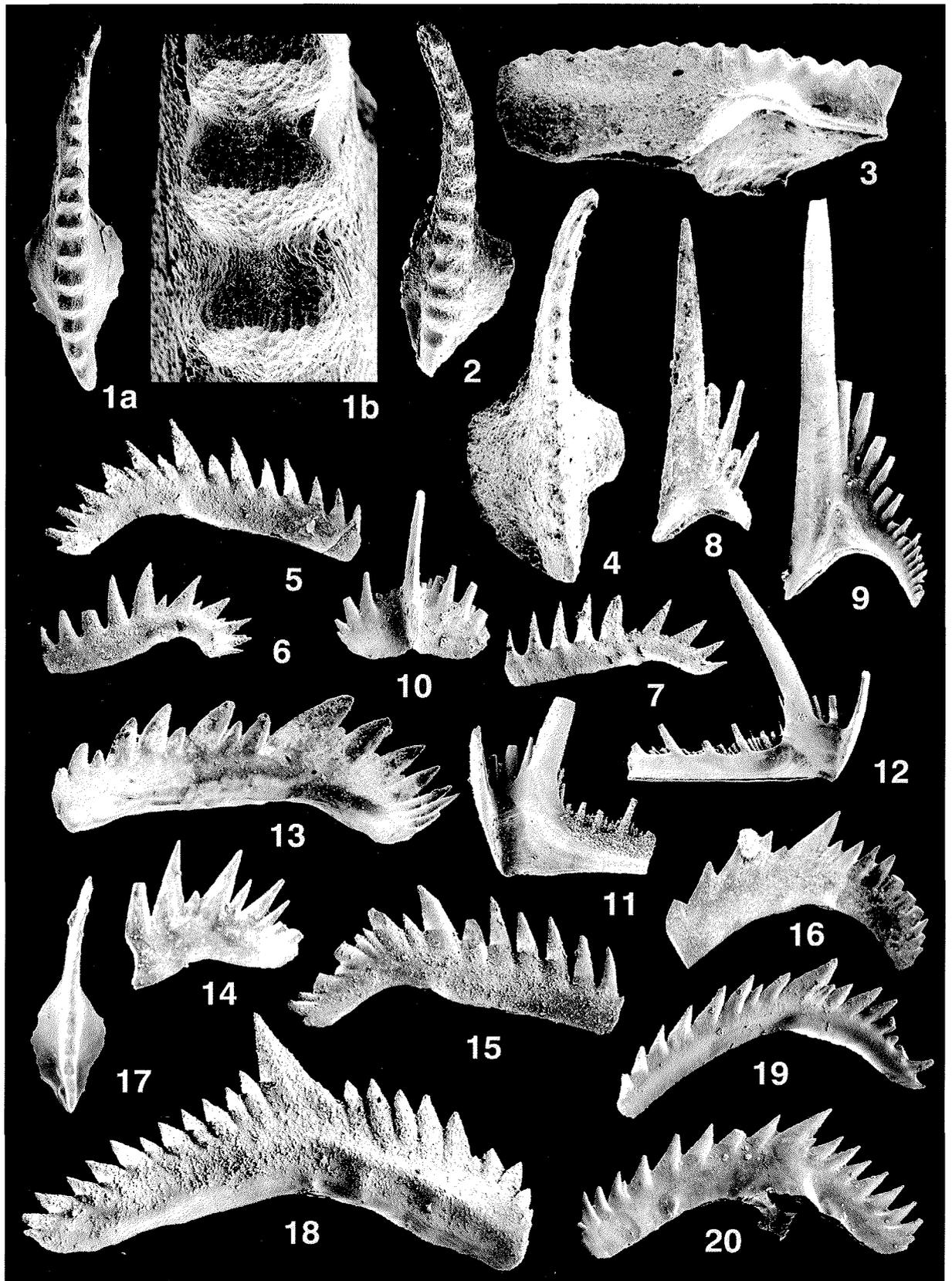


PLATE 3

- 1 – *Gnathodus texanus* ROUNDY, 1926; S-36, sample 3174.
2-8, 10, 14 – *Gnathodus pseudosemiglaber* THOMPSON & FELLOWS, 1970; 2, 6 and 7 – S-37, S-38 and S-39, sample 3175; 3 – S-40 sample 3009; 4 – S-41, sample 3111; 5 – S-42, sample 3191; 8 – S-43, sample 1168; 10 – S-44, sample 3180; 14 – S-45, sample 3180.
9, 11, 18 – *Gnathodus pseudosemiglaber* THOMPSON & FELLOWS, 1970, transitional to *Gn. girtyi* s.l. HASS, 1953; 9 – S-46, sample 3009; 11 – S-47, sample 3011; 18 – S-48, sample 3180.
12, 16 – *Gnathodus semiglaber* BISCHOFF, 1957; 12 – S-49, sample 3175; 16 – S-50, sample 1168.
13, 15, 17, 19 – *Gnathodus girtyi* aff. *intermedius* GLOBENSKY, 1967; 13 – S-51 sample 3011; 15 – S-52 sample 3009; 17, 19 – S-53 and S-54, sample 3191.

Magnification × 60

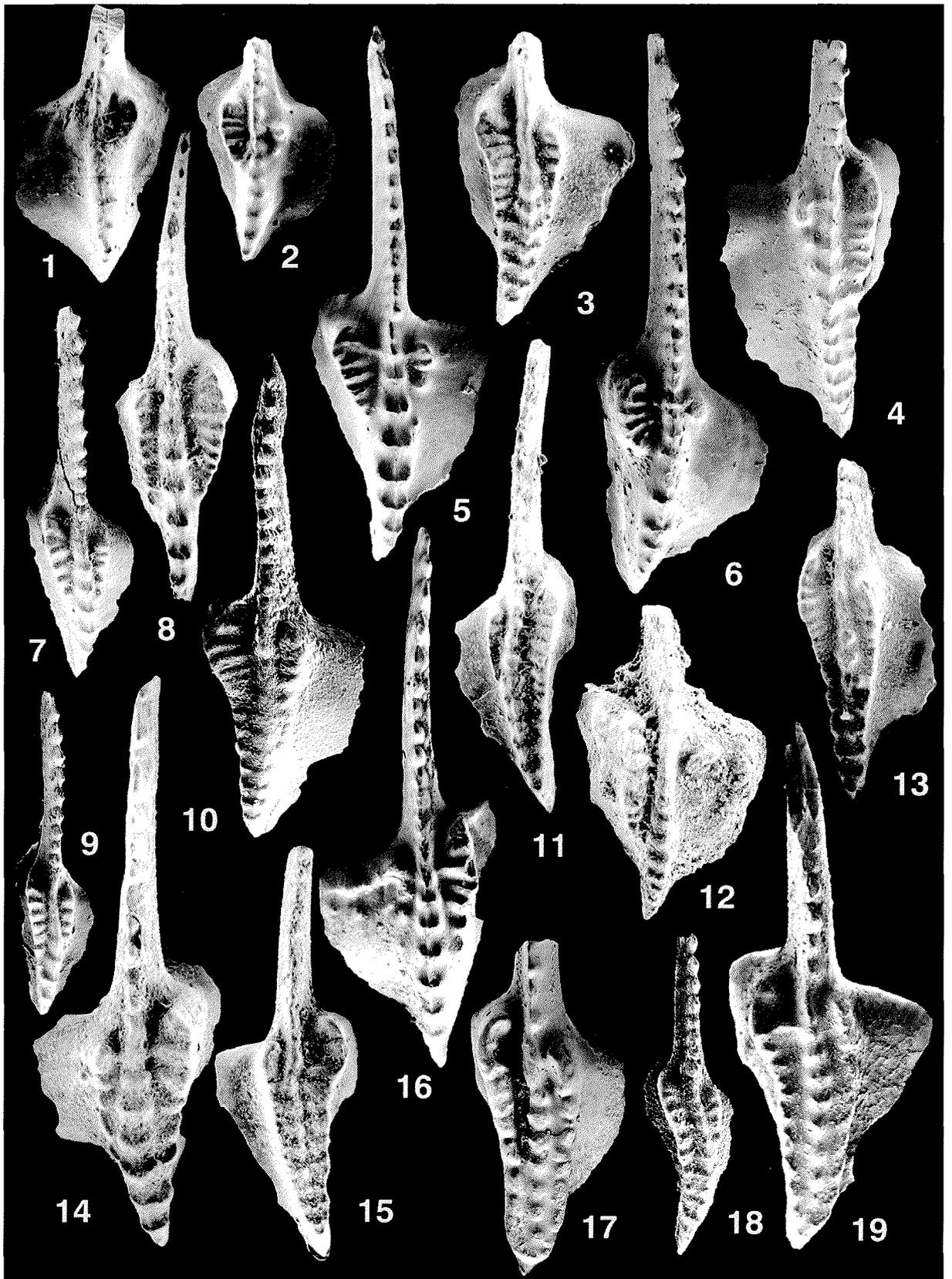


PLATE 4

- 1-5, 7 – *Pseudognathodus homopunctatus* (ZIEGLER, 1960); 1 – S-55, sample 3011; 2, 7a, b – S-56 and S-57, a) oral view, b) microsculpture, $\times 400$, sample 3191; 3, 5 – S-58 and S-59, sample 3180; 4 – S-60, sample 3009.
- 6, 9, 11-13, 15, 20, 22 – *Gnathodus praebilineatus* BELKA, 1985; 6 – S-61, sample 3011, specimen showing trend from *Gn. delicatus* BRANSON & MEHL, 1938; 11, 15, 22 – S-62, S-63 and S-64, sample 3009; 12, 20 – S-65 and S-66, sample 1168, specimen S-66 showing trend from *Gn. semiglaber* BISCHOFF, 1957; 9, 13 – S-67 and S-68, sample 3191, specimens showing trend from *Gn. semiglaber* BISCHOFF, 1957.
- 8 – *Gnathodus joseramoni* SANZ-LÓPEZ, BLANCO-FERRERA & GARCÍA-LÓPEZ, 2004; S-69, sample 3009.
- 10, 14, 17 – *Gnathodus delicatus* BRANSON & MEHL, 1938, transitional to *Gn. praebilineatus* BELKA, 1985; 10, 17 – S-70 and S-71, sample 3011; 14 – S-72, sample 3191.
- 16 – *Mestognathus ?beckmani* BISCHOFF, 1957; S-73, sample 3753;
- 18 – *Gnathodus* sp.; 18 – S-77, sample 3174, specimen showing trend from *Gn. semiglaber* BISCHOFF, 1957.
- 19 – *Gnathodus* aff. *girtyi meischneri* AUSTIN & HUSRI, 1974; S-78, sample 3188.
- 21 – *Gnathodus semiglaber* BISCHOFF, 1957; S-79, sample 3180.
- 23-25 – *Mestognathus beckmani* BISCHOFF, 1957; 23, 24 and 25 – S-74, S-75 and S-76, sample 3188.

Magnification $\times 60$, when otherwise indicated

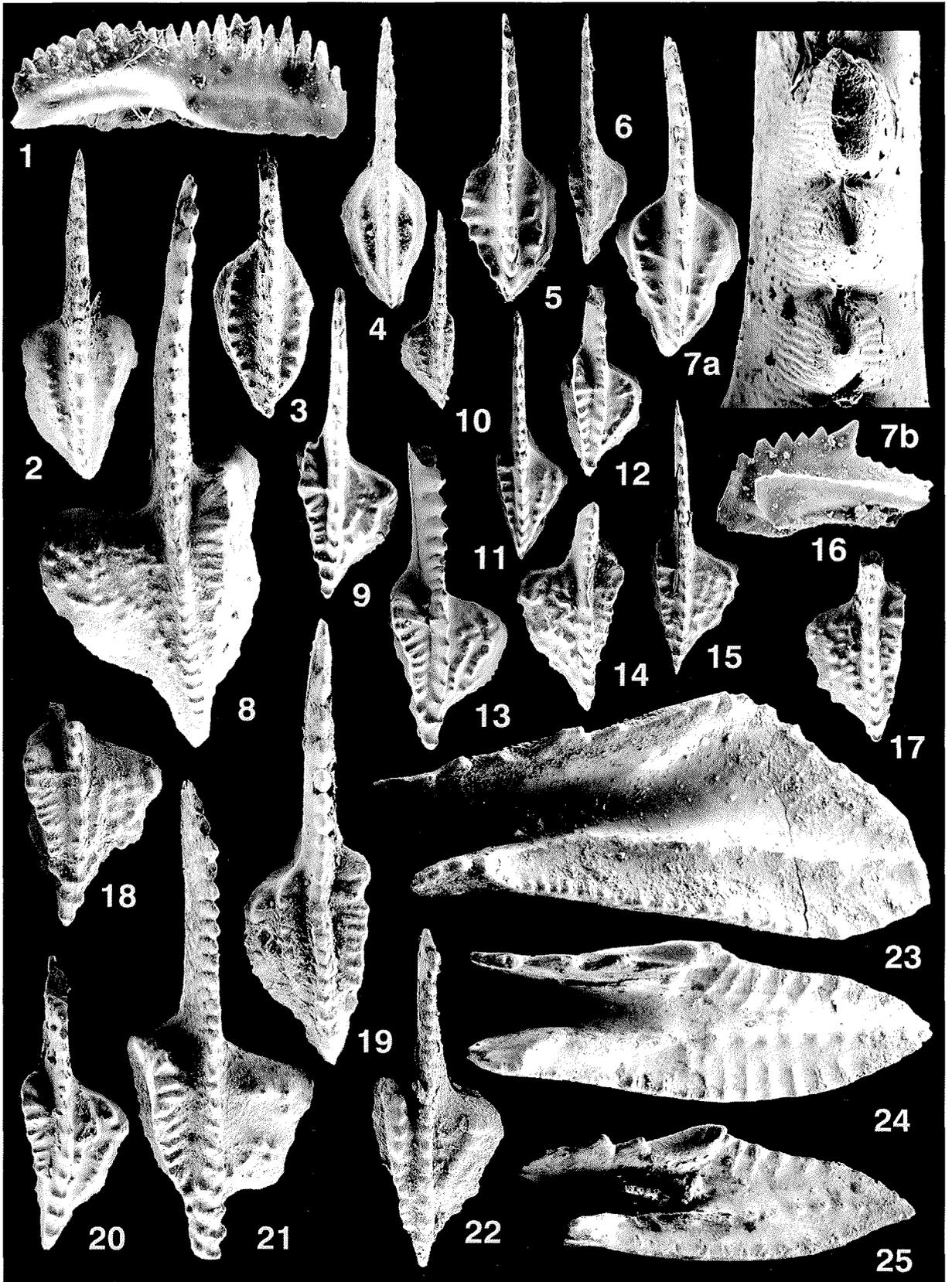


PLATE 5

1-11, 14 – *Kladognathus tenuis/completens* (BRANSON & MEHL, 1941), emend. REXROAD, 1981.

Pa /Pb elements:

1, 3 – DE *Magnilaterella contraria* RHODES, AUSTIN & DRUCE, 1969, specimen S-80, sample 3175 and specimen S-81, sample 3191; 2 – DE *Magnilaterella robusta* REXROAD & COLLINSON, 1963, specimen S-82, sample 3011; 4 – DE *Magnilaterella clarkei* RHODES, AUSTIN & DRUCE, 1969, specimen S-83, sample 3009.

M elements:

8, 11, 14 – DE *Neoprioniodus scitulus* (BRANSON & MEHL, 1940); 8 and 14 – S-84 and S-85, sample 3009, 11: specimen S-86, sample 3174.

Sa elements:

5 – DE *Hibbardella ortha* REXROAD, 1958, specimen S-87, sample 3753, x 60;

6 – DE *Hibbardella milleri* REXROAD, 1958, specimen S-88, sample 1168.

Sc elements:

9 – DE *Ligonodina tenuis* BRANSON & MEHL, 1941, specimen S-89, sample 3191; 7,

10 – DE *Ligonodina levis* BRANSON & MEHL, 1941, 7 – S-90, sample 3009, and 10 – S-91, sample 1168.

16-25 – *Idioproniodus healdi* (ROUNDY, 1926)

Pb elements:

17 – DE *Metalonchodina bidentata* (GUNNELL, 1931), specimen S-92, sample 1168;

12, 15, 19, 20 – DE *Lonchodina furnishi* REXROAD, 1958; 12, 19 – S-93 and S-94, sample 3009; 15 – S-95, sample 3191; 20 – S-96, sample 1168.

M elements:

13 – DE *Neoprioniodus conjunctus* (GUNNELL, 1931), S-97, sample 3009.

Sa elements:

18 – DE *Roundya barnettana* HASS, 1953, S-98, sample 3191.

Sc elements:

17 – DE *Ligonodina roundyi* (HASS, 1953), S-99, sample 3009.

21 – *Subbryanthodus* sp.; S-100, sample 3011.

Magnification × 50

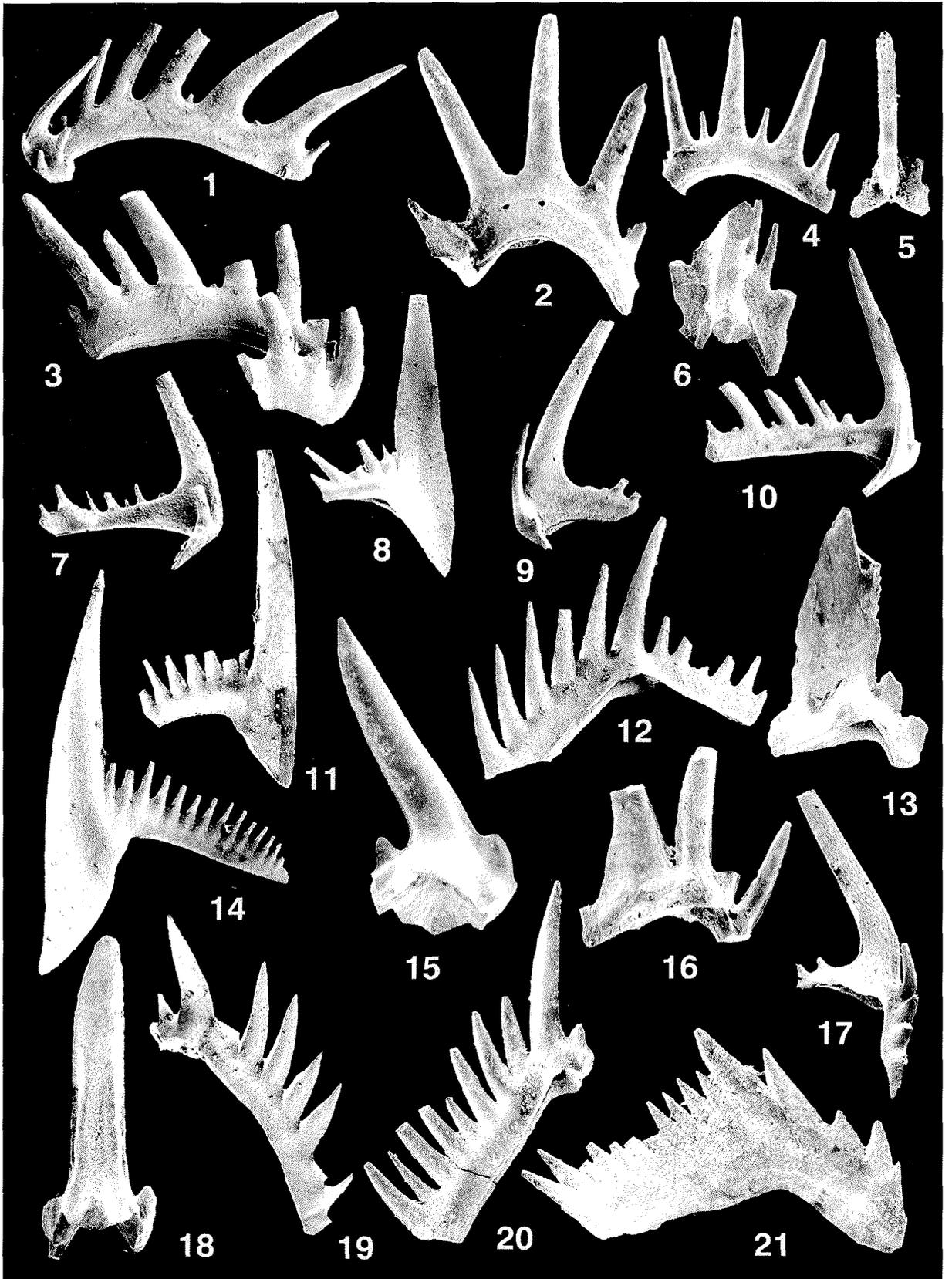


PLATE 6

- 1-3, 5 – *Hindeodus cristulus* (YOUNGQUIST & MILLER, 1949)
Pa elements:
 1, 2 – DE *Hindeodus cristulus* (YOUNGQUIST & MILLER, 1949), 1 – S-101, sample 3011 and 2 – S-102, sample 3009.
M elements:
 3, 5 – DE *Neoprioniodus denticamurus* REXROAD, 1957, 3 – S-103, sample 3011 and 5 – S-104, sample 3017.
- 4, 8-11 – *Syncladognathus geminus* (HINDE, 1900)
Pa elements:
 8 – DE *Hindeodus scitulus* (HINDE, 1900), specimen S-105, sample 3175, × 60.
Pb elements:
 4 – DE *Ozarkodina* cf. *laevipostica* REXROAD & COLLINSON, 1963; S-106, sample 3017.
M elements:
 9, 10 – DE *Apatognathus ? scalena* VARKER, 1967; 9 – S-107 and 10 – S-108, sample 3174;
 11 – DE *Apatognathus ? petila* VARKER, 1967, specimen S-109, sample 3175.
 7, 13 – *Idioprioniodus conjunctus* (GUNNELL, 1931)
S elements:
 7, 13 – DE *Hindeodella ibergensis* BISCHOFF, 1957, 7 – S-110, sample 3009 and 13 – S-111, sample 3011.
 6 – *Hindeodella* sp.; S-112, sample 3011.
 12 – *Hindeodella uncata* (HASS, 1959); S-113, sample 3009.
 14 – *Ligonodina fragilis* HASS, 1952; S-114, sample 3009.
- 15-16 – *Hindeodella hibbardi* COLLINSON & DRUCE, in RHODES, AUSTIN & DRUCE, 1969; 15 – S-115, sample 3017; 16 – S-116, sample 3009.
- 17-18 – *Ozarkodina roundyi* HASS, 1952; 17 – S-117, 18 – S-118, sample 3011.
 19 – *Hindeodella corpulenta* BRANSON & MEHL, 1934; S-119, sample 3009
 20 – *Synprioniodina microdenta* ELLISON, 1941; S-120, **M element** of *Gnathodus* sp., sample 3175.
 21 – Undetermined element; S-122, sample 3009.
 22 – *Lonchodina projecta* (ULRICH & BASSLER, 1926); S-123, sample 3191.
 23 – *Lonchodina* sp.; S-124, sample 3009.

Magnification × 50, when otherwise indicated

