BULLETIN DE L'INSTITUT ROYAL DES SCIENCES NATURELLES DE BELGIQUE SCIENCES DE LA TERRE, 81: 5-25, 2011
BULLETIN VAN HET KONINKLIJK BELGISCH INSTITUUT VOOR NATUURWETENSCHAPPEN AARDWETENSCHAPPEN, 81: 5-25, 2011

Extinctions, survival and innovations of conodont species during the Kačák Episode (Eifelian-Givetian) in south-eastern Morocco

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WALLISER, O. & BULTYNCK, P., 2011 – Extinctions, survival and innovations of conodont species during the Kačák Episode (Eifelian-Givetian) in south-eastern Morocco. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, **81**: 5-25, 4 figs, 4 pls, Brussels, November 30, 2011 – ISSN 0374-6291.

Abstract

For the first time the complete conodont fauna from the GSSP for the base of the Givetian at Jebel Mech Irdane in the Tafilalt (SE Morocco) is described. The conodont faunas described by BULTYNCK in 1987 from the Bou Tchrafine ridge in the same area and from the Jebel Ou Driss (Mader, SE Morocco) in 1989 are updated. Many new morphotypes of *Polygnathus linguiformis* and other conodont species are described. *Polygnathus amphora, P. pseudoeiflius* and *Icriodus hollardi* are established as new species.

Keywords: Conodonts, Kačák, Eifelian-Givetian, Morocco.

Résumé

L'entière faune à conodontes trouvée au GSSP pour la base du Givetien et localisée dans le Jebel Mech Irdane du Tafilalt (Sud-Est du Maroc) est décrite pour la première fois. Les identifications des faunes à conodontes du Bou Tchrafine dans la même région décrites par BULTYNCK (1987) ainsi que celles du Jebel Ou Driss dans le Mader (Sud-Est du Maroc) décrite en 1989 sont mises à jour. Des nouveaux morphotypes de *Polygnathus linguiformis* et d'autres espèces de conodontes sont décrits. *Polygnathus amphora, P. pseudoeiflius* et *Icriodus hollardi* sont décrits comme nouvelles espèces.

Mots-clefs: Conodontes, Kačák, Eifelien-Givetien, Maroc.

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† Otto WALLISER passed away late December 2010. The present paper is dedicated to his memory. He was a brilliant geologist-palaeontologist. The last two years we worked together on the conodont faunas described herein.

Introduction

The Global Stratotype Section and Point (GSSP) for the base of the Givetian is located in the Jebel Mech Irdane in the Tafilalt of SE Morocco. The position of the boundary was designated by the Subcommission on Devonian Stratigraphy (SDS) and is based on the first occurrence of the conodont species *Polygnathus hemiansatus* considered to be a direct descendant of *Polygnathus pseudofoliatus*. The boundary level is within the Kačák Episode (WALLISER *et al.*, 1995). Many samples from the Mech Irdane section contain abundant and very diverse conodont faunas, hundreds of specimens per kilogramme. At the time of the discussion of the GSSP for the base of the Givetian the study of the conodont faunas was limited to the evolutionary lineage *P. pseudofoliatus – P. hemiansatus*, as well as *Polygnathus ensensis*, the species considered important for the boundary definition. These species groups were figured in the guide-book for the field meeting of the SDS in the Tafilalt-Mader area in 1991 (WALLISER, *ed.*, 1991).

The conodont faunas are not only rich by the number of specimens but the species also demonstrate a large variability. This allows recognition of different morphotypes in known species or new species that are useful for establishing lineages and for biostratigraphy. The description of these morphotypes and new species is the main purpose of the present paper. The study of the Mech Irdane conodonts is combined with an update of earlier described conodonts from the same time interval in the same region: the Bou Tchrafine section in the N Tafilalt (BULTYNCK, 1987) and the Ou Driss section in the Mader (BULTYNCK, 1989). The position of the three studied sections is shown in Fig. 1.

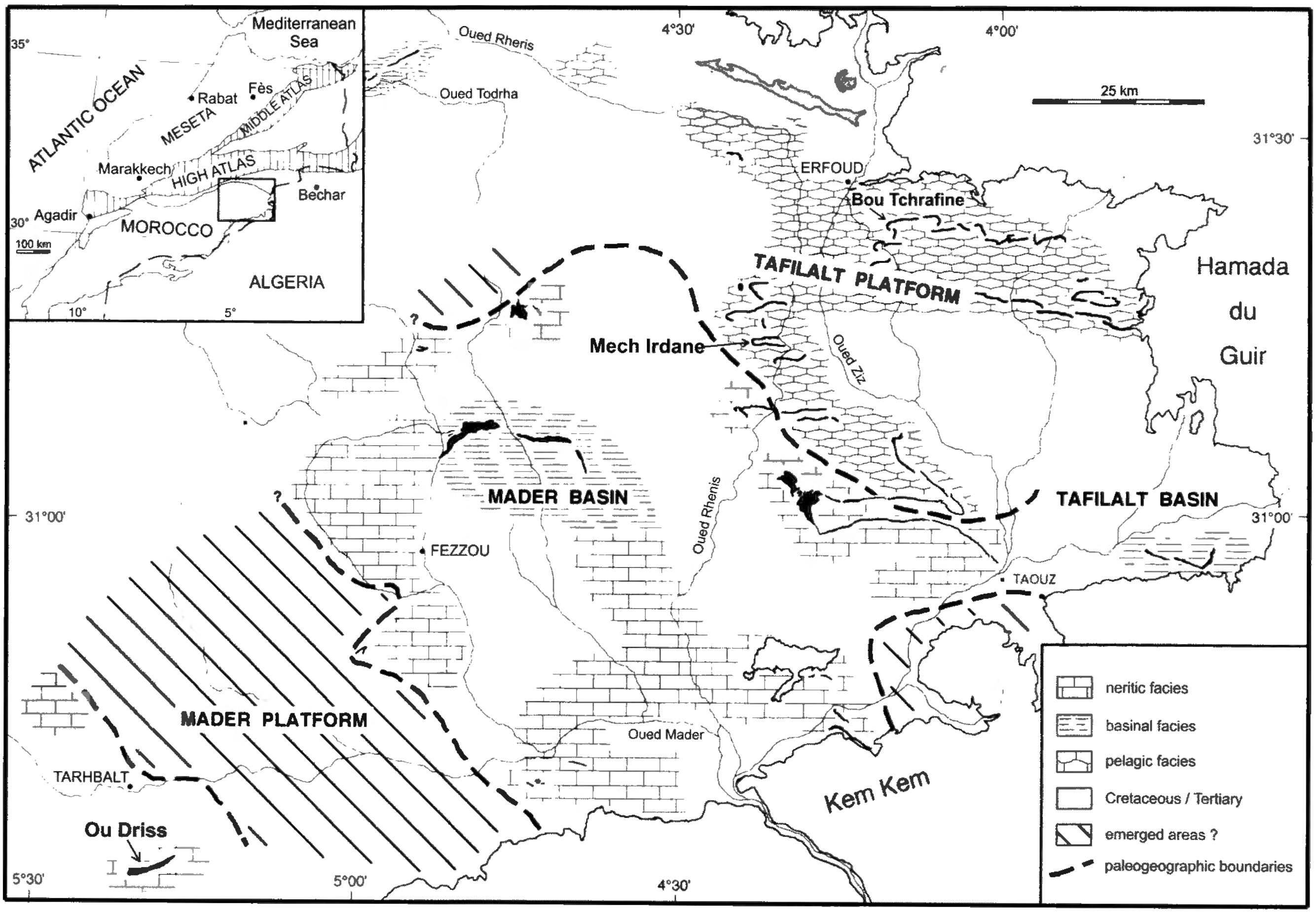

Fig. 1 – Map of the Tafilalt and Mader region with indication of paleogeography during the late Eifelian and early Givetian. The three studied sections, Jebel Mech Irdane, Bou Tchrafine and Jebel Ou Driss East are indicated with arrows.

The Late Eifelian Events (Kačák Episode)

The GSSP for the base of the Givetian is placed in a stratigraphic succession showing a sharp facies change due to an hypoxic perturbation (WALLISER *et al.*, 1995). The terminology for this hypoxic interval caused some confusion in earlier literature. HOUSE (1985) introduced the name Kačák Event, after the Kačák Member or Shale in the Bohemian Massif. It is a black and calcareous shale in which the index tentaculite *Nowakia otomari* occurs. In the uppermost part of the Choteč Limestone just below the Kačák Member the index conodont *Tortodus kockelianus* occurs (CHLUPAC *et al.*, 2000). At the same time WALLISER (1985) proposed the *otomari* Event based on the onset of the dacryoconarid lineage of the species *Nowakia otomari*. Some authors considered that the Kačák Event and the *otomari* Event covered the same period and were synonymous. It was also demonstrated that the Kačák Event was not instantaneous but represents a polyphased biotic crisis (GARCIA-ALCALDE *et al.*, 1990). In order to solve this confusing situation WALLISER (2000) proposed a Kačák Episode with the Late Eifelian 1 Event and the Late Eifelian 2 Event.

In the Mech Irdane section (Fig. 2) the base of the Late Eifelian 1 Event corresponds with the sudden onset of dark shales and can be assigned to the *otomari* Event. During the late Eifelian 2 Event the dark shales become progressively lighter and contain marly and nodular limestones. The Kačák Episode is 0.50 m thick.

In the Bou Tchrafine section (Fig. 3) the base of the Late Eifelian 1 is drawn at a level showing a changeover from light brown shales to gray shales with nodules and two thin limestone beds at the base, samples 15 and 15a. In these limestones occur dark spots with organic matter and concentrations of dacryoconarids, including *Nowakia otomari*. In the Late Eifelian 2 Event the shales and limestone nodules as well as bed 15b show brownish spots due to the presence of hematite and also yield a hematitic fauna. The Kačák Episode is represented by about 2 m of strata.

The Jebel Ou Driss Eastern section (Fig. 4) shows more neritic influences than the two other sections. The base of the Late Eifelian 1 Event can be recognized

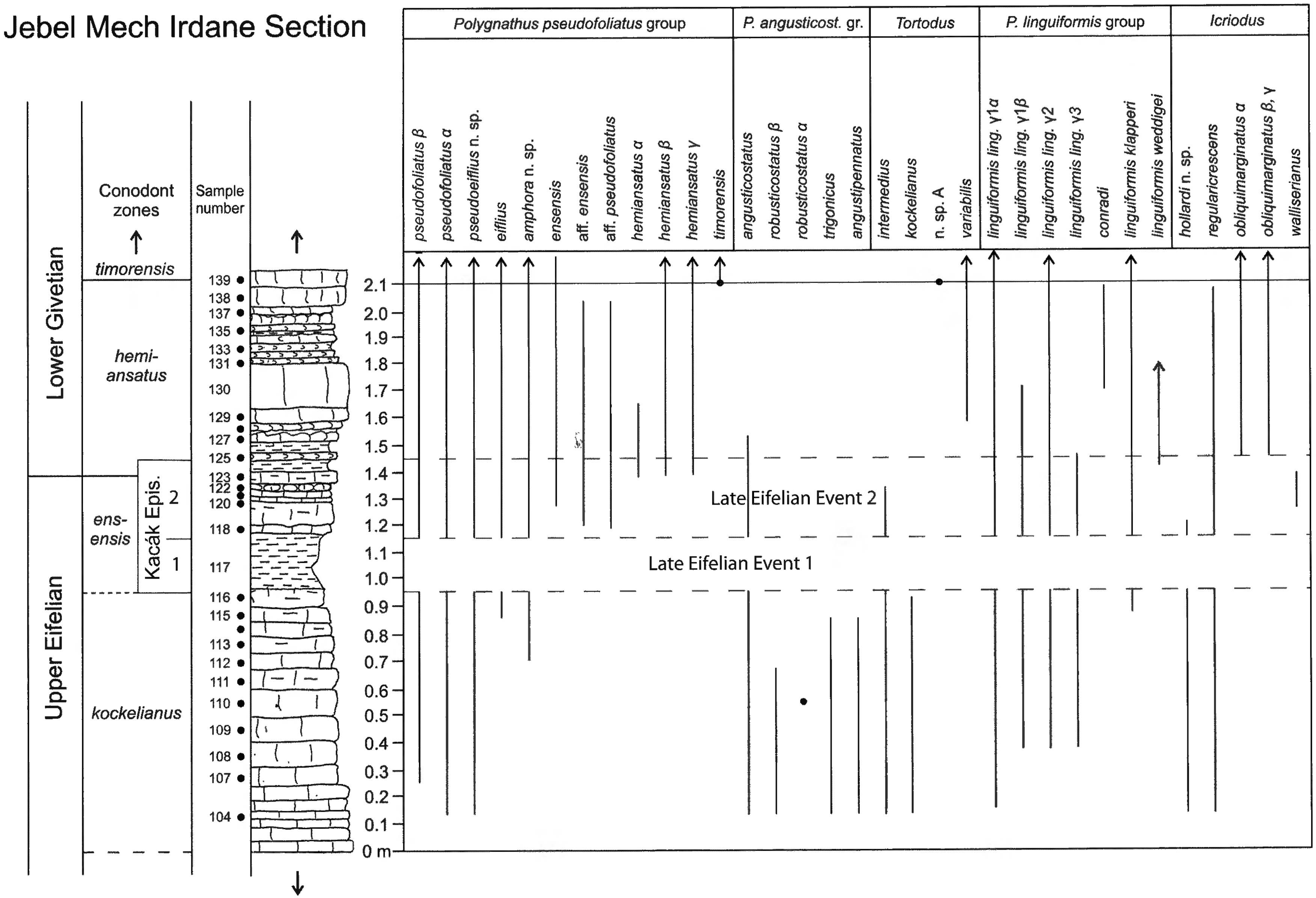

Fig. 2 – Table showing the ranges of conodont species and their morphotypes in the Jebel Mech Irdane section, from the *kockelianus* Zone to the base of the *timorensis* Zone. No conodonts recovered from the interval between samples116 and 118.

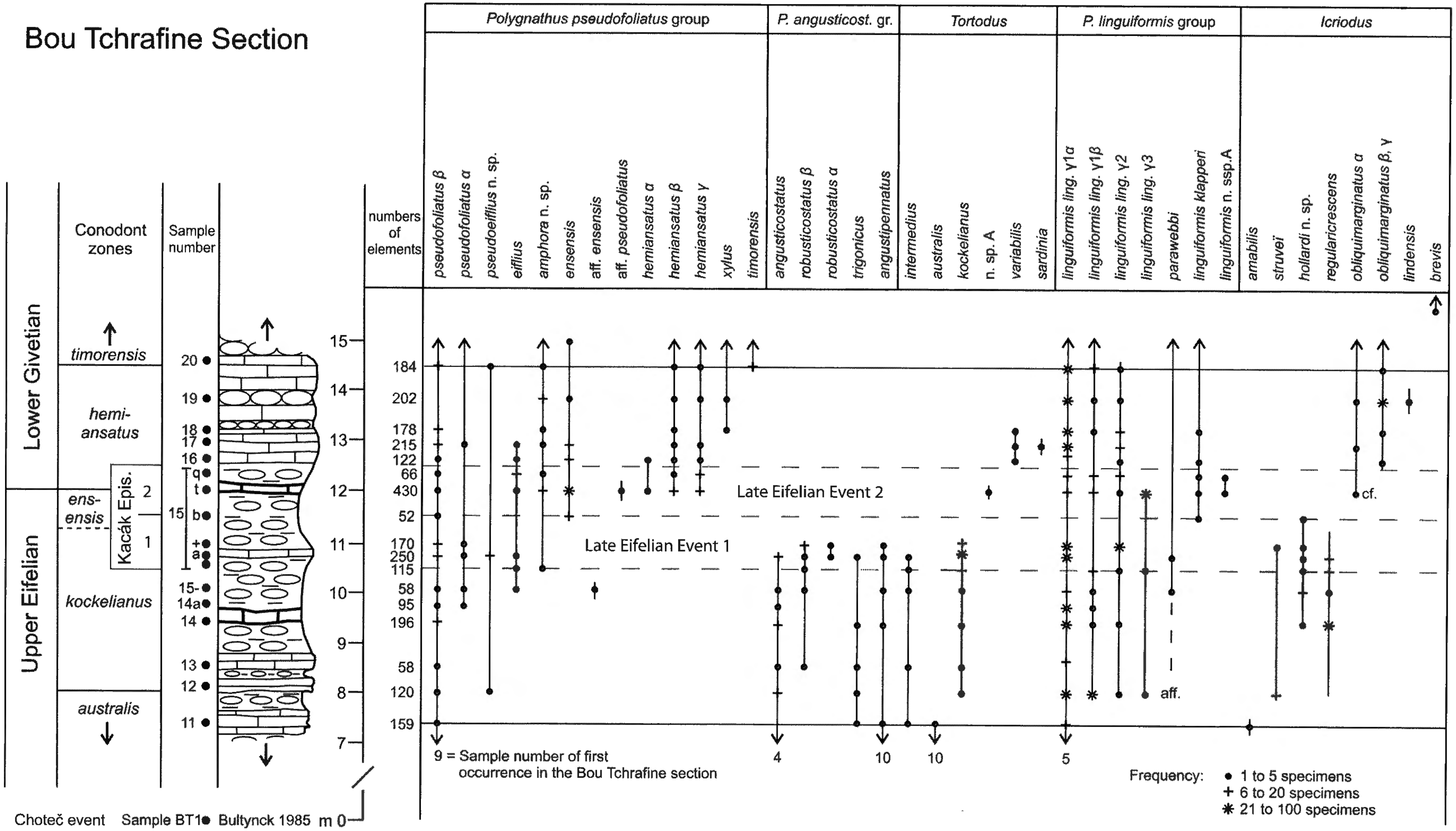

Fig. 3 – Table showing the ranges and frequency of conodont species and their morphotypes in the Bou Tchrafine section from the top of the *australis* Zone to the base of the *timorensis* Zone.

by the sudden colour change of brown-reddish marls to dark gray shales and limestones at the level of bed ODE-8-19 and continuing upward to bed ODE-7-1. Just above occurs a level with four compact limestone beds that forms a characteristic ridge in the Jebel Ou Driss and that is considered to represent the Late Eifelian 2 Event. The total Episode is represented by 2.50 m of strata.

In the three sections the Late Eifelian 1 Event and the lower part of the Late Eifelian 2 Event are assigned, in part or entirely, to the *ensensis* Zone. The uppermost part of the Late Eifelian 2 Event belongs to the *hemiansatus* Zone. The onset of the Kačák Episode may be related to the basal sea level rise of cycle If of JOHNSON *et al.* (1985) that also belongs to the *ensensis* Zone.

Extinction levels

The species of the *Polygnathus angusticostatus* group show a more or less simultaneous extinction level in the three sections (Figs 2-4). However, in the Mech Irdane section and in the Ou Driss E section the extinction level is below the Kačák Episode. In the Bou Tchrafine section it is slightly above the base of the Kačák Episode and also more simultaneous for the different species than in the two other sections. The discrepancy between the Mech Irdane section and the Bou Tchrafine section can be explained by the presence of the interval with dark shales without a conodont record at the base of the Kačák Episode in the former section.

One should also consider that the changeover to dark shales is less pronounced in the Bou Tchrafine section than in the two other sections.

Most *Icriodus* species of the common Eifelian *Icriodus* type (the *I. corniger-struvei* group) that have a rather broad spindle and a rather short posterior extension of the median row denticles behind the spindle, disappear below the Kačák Episode. The last representative, *Icriodus struvei,* disappears slightly below the Kačák Episode after probably giving rise to the *Icriodus arkonensis* group in the Kačák Episode (WEDDIGE, 1977); *Icriodus walliserianus* is the earliest representative. The innovative *Icriodus regularicrescens*, first occurs in the *costatus* Zone and ranges into the Kačák Episode and above, is ancestral to the *Icriodus obliquimarginatus* group in which we recognize three morphotypes α, β and γ. The α morphotype seems to be restricted to the pelagic-hemipelagic facies, the β and γ morphotypes occur also in the neritic facies.

Survival and innovations

The Polygnathus pseudofoliatus group

In the *kockelianus* Zone, below the Kačák Episode, the P. *pseudofoliatus* group is represented in the three sections by *P. pseudofoliatus, P. pseudoeiflius* n. sp., *P. eiflius* and *P. amphora* n. sp. The last mentioned species also occurs in the Plum Brook Shale of Ohio (US), described by SPARLING (1995) as *P. pseudofoliatus* subsp. A. The Plum Brook Shale was assigned by SPARLING to the upper part of the *ensensis* Zone.

The most characteristic innovation in the *P. pseudofoliatus* group took place during the Late Eifelian Event 2 by the initiation of the *Polygnathus hemiansatus* lineage, characterized by the modification of the anterior trough margins. In the earlier species of the *P. pseudofoliatus* group the anterior trough margins are steep and relatively symmetric on the inner and outer side. In the *hemiansatus* lineage the anterior trough margins become strongly asymmetric. The outer anterior through margin is characterized by the development of an outward bowing spoon-like structure and a pointed or linear constriction in the outer platform margin just posterior to the geniculation point. The inner anterior trough margin is only slightly outward bowing and is steep.

In the Mech Irdane section the platform surface of *P. hemiansatus* is strongly ribbed in the interval from bed 123 to bed 129. From bed 131 on, the surface of the platform can be also punctuated and becomes more elongated.

The Polygnathus linguiformis group

Three new morphotypes of *Polygnathus linguiformis linguiformis*, γ_1, γ_2 and γ_3, appear in the upper part of the *kockelianus Zone.* The γ_3 morphotype has a short stratigraphic range and disappears slightly above the Kačák Episode and does not reach the top of the *hemiansatus* Zone. Notable is the presence of *Polygnathus conradi* in the upper part of the *hemiansatus* Zone in the Mech Irdane section. It was decribed by CHATTERTON (1978) from the Eifelian-Givetian boundary interval from a section in the Canadian Northwest Territories. Until now it was not recognized outside this area.

Systematic Paleontology

The different species, based on P_1 elements, are described or discussed in the same order as in the three range charts (Figs 2-4). We distinguish a *Polygnathus*

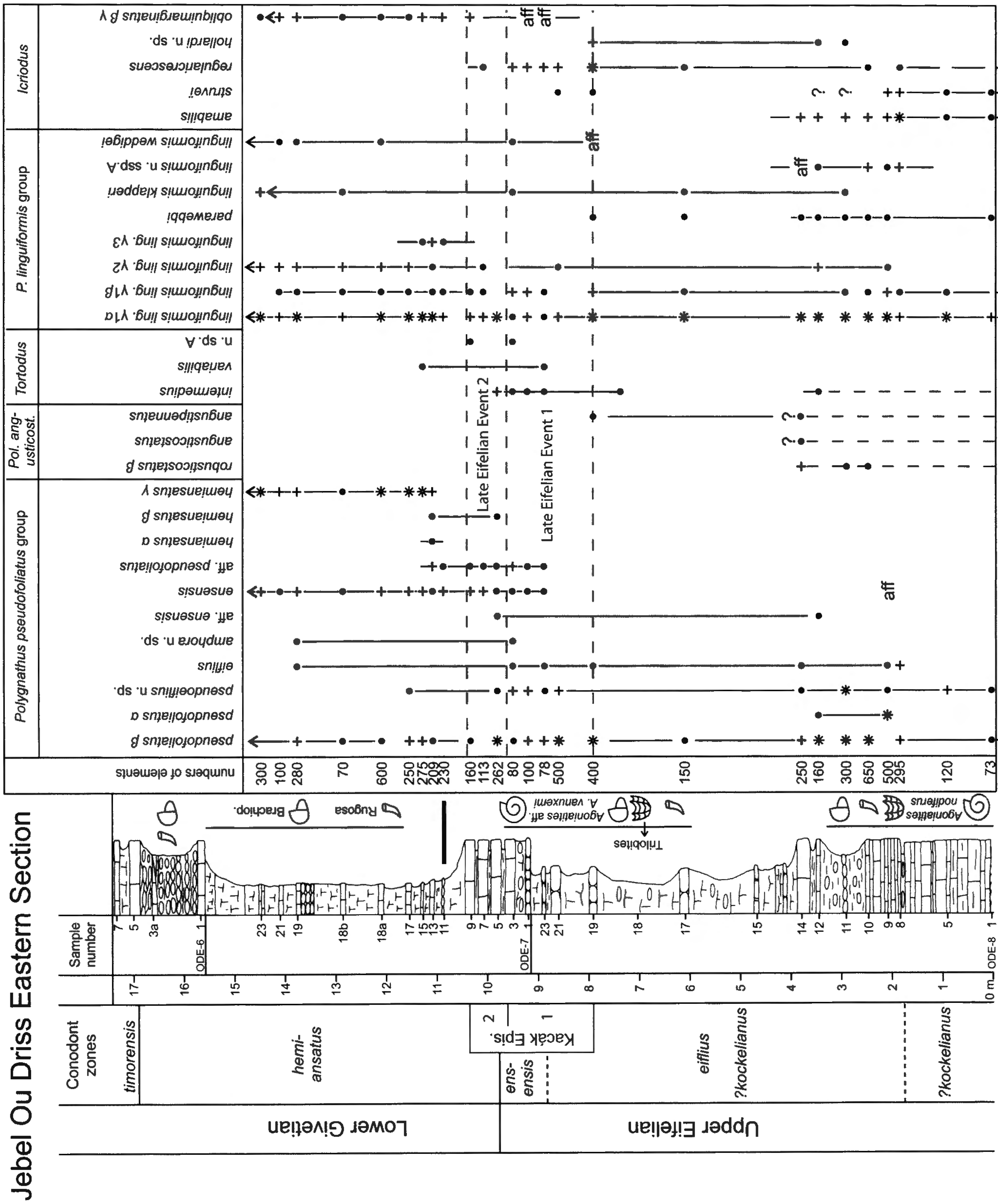

Fig. 4 – Table showing the ranges and frequency of conodont species and their morphotypes in the Jebel Ou Driss Eastern section from the ? *kockelianus* Zone to the base of the *timorensis* Zone. See Fig. 3 for the meaning of the frequency symbols.

Table 1 – Distribution of ostracods in the Hanonet Fm and Trois-Fontaines Fm at the Mont d'Haurs.

MONT D'HAURS	499	500	501	502	503	505	507	508	511	516	521	523	525	527	543	604	608	610	612
Poloniella tertia KRÖMMELBEIN, 1953	●			●	●														
Coryellina? audiarti nov. sp.	●	●	●		●														
Ropolonellus kettneri (POKORNY, 1950)	●		●		●			●											
Tubulibairdia clava (KEGEL, 1933)	●	●	●	●	●	●	●	●	●	●	●	●	●						
Uchtovia abundans (POKORNY, 1950)	?	●		●	●		●				?	●	●	●					
Bairdiocypris rauffi KRÖMMELBEIN, 1952	●	●	●	●	●	●	●		?			●	●	●	●		?	?	
Bufina schaderthalensis ZAGORA, 1968		●	●	●	●	●	●												
Cytherellina perlonga (KUMMEROW, 1953)		●	●	●	●	●						●	●	●					
Bairdia paffrathensis KUMMEROW, 1953		●	●	●	●	●	●	●					●		?			?	
Refrathella struvei BECKER, 1967			●			●													
Jefina romei COEN, 1985?			●			●													
Parabolbinella coeni nov. sp.			●				●												
"Orthocypris" sp. *in* CASIER *et al.* (1995)			●		●	●	●												
Bairdiocypris cf. *symmetrica* (KUMMEROW, 1953)			●		●							●							
Amphissites tener omphalotus BECKER, 1964			●		●		●					?							
Bairdia cf. *carinata* POLENOVA, 1960 *sensu* COEN (1985)			●		●								●						
Samarella cf. *laevinodosa* BECKER, 1964			●						?			●	●	●					
Cavellina haursensis nov. sp.			●		●							●		●					
Urftella adamczacki BECKER, 1970			●							●					●				
Cytherellina? cf. *brassicalis* BECKER, 1965			●	●	●	●		?							●	?			
Cytherellina obliqua (KUMMEROW, 1953)			●	●	●	●		?							●	●			
Poloniella cf. *claviformis* (KUMMEROW, 1953)				●															
Acratia sp. A				●															
Uchtovia kloedenellides (ADAMCZAK, 1968)				●	●		●			●		?		?					
Kozlowskiella sp. C *in* CASIER *et al.* (1994)				?	?		?								●				
Cryptophyllus sp. indet.				●													●		
Marginia cf. *sculpta multicostata* POLENOVA, 1953					●														
Bairdia sp. A					●														
Roundyella patagiata (BECKER, 1964)					●	●													
Bairdia cf. *tischendorfi* BECKER, 1965					●	●	●		?	?									
Parapribylites hanaicus POKORNY, 1950					●							?							●
Microcheilinella affinis POLENOVA, 1955						●						●	●			?	●	?	●
Svantovites primus POKORNY, 1950							●												
Cytherellina? sp. indet.							●												
Bairdiocypris sp. A, aff. *eifliensis* (KEGEL, 1928)							●												
Healdianella sp. A, aff. *budensis* OLEMPSKA, 1979							●	?				?	●	●				●	
Cytherellina sp. A								●											
Baschkirina sp. B *in* CASIER *et al.* (1992)?												●							
Coeloenellina sp. A, aff. *minima* (KUMMEROW, 1953)												●		●					●
Buregia ovata (KUMMEROW, 1953)													●						
Bairdia sp. B													●						
Aparchites sp. A *in* CASIER *et al.* (2010)													●	●					
Fellerites crumena (KUMMEROW, 1953)														●					
Coeloenellina? sp. indet.														●					
Coeloenellina minima (KUMMEROW, 1953)															●				●
Kielciella cf. *fastigans* (BECKER, 1964)															●				
Cavellina macella (KUMMEROW, 1953)																?			
Bairdiacypris antiqua POKORNY, 1950																	●		

important because this one would characterize a new zone of the zonal sequence established on metacopids in the Devonian by CASIER (1979; 2008).

Most of species identified in the Rancennes Quarry are known from other sections in the Dinant Synclinorium, particularly from the Resteigne Quarry (CASIER & PRÉAT, 1990, 1991) and La Couvinoise Quarry (CASIER *et al.,* 1992), in Belgium and also from the Glageon Quarry, in Avesnois (CASIER *et al.,* 1995), France. Close relationship exists also among ostracods from the Aisemont Quarry in the Namur Synclinorium (CASIER & PRÉAT, 2006), Boulonnais in France (MAGNE, 1964; MILHAU, 1988), Eifel in Germany (KUMMEROW, 1953; BECKER , 1964, 1965; GROOS, 1969...), Holy Cross Mountains in Poland (ADAMCZAK, 1968, 1976; OLEMPSKA 1979; ZBIKOWSKA, 1983...), and the Czech Republic (POKORNY, 1950).

Conclusions

The ostracod fauna collected in the upper part of the Hanonet Fm and in the base of the Trois-Fontaines Fm at the Mont d'Haurs, belongs to the Eifelian Mega-Assemblage and is indicative of shallow marine well-oxygenated environments generally close to fair-weather wave base. Only one sample collected at the top of the section studied contains an ostracod assemblage indicative of semi-restricted water conditions (in this sample the monospecific assemblage with the genus *Coeleonellina* prevails), and another sample from the same part of the section, contains Leperditicopid ostracods indicative of lagoonal environmental conditions. Three new species are described: *Coryellina? audiarti* nov. sp., *Cavellina haursensis* nov. sp and *Parabolbinella coeni* nov. sp.

X_{LF} values decrease across the boundary interval between the Hanonet Fm and the Trois-Fontaines Fm and are very weak during the biostromal unit, before reaching the highest X_{LF} values in the restricted lagoonal environment of the Trois-Fontaines Fm. X_{LF} and microfacies curves show a moderate positive correlation in general. This is due to the evolution from a mixed ramp (Hanonet Fm) to a carbonate platform (Trois-Fontaines Fm).

A high-resolution stratigraphic correlation is tentatively proposed here between the Mont d'Haurs section and a 40 km-distant Baileux section where similar MS fluctuations were reported (MABILLE & BOULVAIN, 2008) even if the sediments in the Baileux section are much thicker. The MS signal is strongly controlled by ferromagnetic *s.l.* minerals (mixture of magnetite with significant contribution of a high-coercivity phase, which might be hematite) and paramagnetic grains. The transition from a mixed- to inner-ramp system to a restricted lagoon in the carbonate platform system is accompanied by sea-level fall and an input of coarse-grained ferromagnetic *s.l.* minerals (probably of detrital origin). However, an increasing trend of the S_d and IRM loss parameters is observed across the section with the highest values (together with the X_{LF} values) in the lagoonal sediments of the Trois-Fontaines Fm. These two parameters point to the occurrence of a significant proportion of ultrafine-grained magnetite (close to 30 nm) probably formed during diagenesis. The primary MS signal is thus affected by diagenetic processes, which slightly modified the magnetic signal of the lagoonal limestones after deposition.

Acknowledgments

The research has been supported by the FRFC n° 2.4518.07 project of the Belgian "Fonds National de la Recherche Scientifique (FNRS) and contributes to the IGCP Project No.580 "Application of magnetic susceptibility on Paleozoic sedimentary rocks". The hysteresis analyses were carried out at the Geophysical Centre of the Belgian Royal Meteorological Institute and Simo Spassov is greatly acknowledged for easy access to the laboratory. We thank especially Marie Coen-Aubert for providing of the specimen figured by Michel Coen in his paper on the Givetian ostracods, and designed herein as holotype for the new species *Parabolbinella coeni* nov. sp. She is also thanked for the storing of all figured specimens and types of her deceased husband into the collection of Department of Paleontology of the Royal Belgian Institute of natural Sciences. We appreciate the helpful review of our manuscript by Dr. L. Koptikova (Prague) and Dr. R. Gozalo (Valencia). Finally, we thanks Mr. Rigo who has kindly authorised the access to the section.

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Typescript submitted: November 30, 2010.
Revised typescript received: June 17, 2011

ANNEXE 1

A list of Givetian ostracods figured by COEN (1985) and recently lodged with the collection of the Department of Paleontology of the Belgian royal Institute of natural Sciences. The numbering (IRScNB n° b 54...) is new. Ostracod specimens from the Mont d'Haurs are printed in bold.

b5451. *Kozlowskiella rugulosa* (KUMMEROW, 1953). Pl. 1, Fig. 1;
b5452. *Kozlowskiella rugulosa* (KUMMEROW, 1953). Pl. 1, Fig. 2;
b5453. *Kozlowskiella rugulosa* (KUMMEROW, 1953). Pl. 1, Fig. 3;
b5454. *Kozlowskiella* sp. Pl. 1, Fig. 4;
b5455. *Falsipollex?* sp. Pl. 1, Fig. 5;
b5456. *Tetrasacculus* sp. Pl. 1, Fig. 6a,b;
b5457. *Semibolbina* sp. Pl. 1, Fig. 7a,b;
b5458. *Parapribylites hanaicus* POKORNY, 1950. Pl. 1, Fig. 8a-c;
b5459. *Parapribylites hanaicus* POKORNY, 1950. Pl. 1, Fig. 9;
b5460. *Kielciella fastigans* (BECKER, 1964). Pl. 1, Fig. 10a,b;
b5461. *Kielciella fastigans* (BECKER, 1964). Pl. 1, Fig. 11;
b5462. *Gravia schallreuteri* BECKER, 1970. Pl. 1, Fig. 12;
b5463. *Gravia schallreuteri* BECKER, 1970. Pl. 1, Fig. 13;
b5464. *Coryellina curta* (POLENOVA *in* ROZHDESTVENSKAJA, 1959). Pl. 2, Fig. 1;
b5465. *Coryellina curta* (POLENOVA *in* ROZHDESTVENSKAJA, 1959). Pl. 2, Fig. 2;
b5466. *Kielciella dorsi* ADAMCZAK, 1968? Pl. 2, Fig. 3a,b;
b5467. *Kielciella dorsi* ADAMCZAK, 1968? Pl. 2, Fig. 4;
b5468. *Urftella adamczaki* BECKER, 1970. Pl. 2, Fig. 5a,b;
b5469. *Coryellina cybaea* ROZHDESTVENSKAJA, 1959. Pl. 2, Fig. 6;
b5470. *Buregia ovata* (KUMMEROW, 1953). Pl. 2, Fig. 7;
b5471. *Buregia ovata* (KUMMEROW, 1953). Pl. 2, Fig. 8a,b;
b5472. *Botzentia? solitaris solitaris* ADAMCZAK, 1968. Pl. 2, Fig. 9;
b5473. *Roundyella patagiata* (BECKER, 1964). Pl. 2, Fig. 10;
b5474. *Roundyella patagiata* (BECKER, 1964). Pl. 2, Fig. 11;
b5475. *Refrathella* cf. *struvei* BECKER, 1967. Pl. 2, Fig. 12;
b5476. *Refrathella struvei* BECKER, 1967. Pl. 2, Fig. 13;
b5477. *Refrathella struvei* BECKER, 1967. Pl. 2, Fig. 14;
b5478. *Refrathella* cf. *incompta* BECKER, 1971. Pl. 2, Fig. 15a,b;
b5479. *Nodella faceta* ROZHDESTVENSKAJA, 1972. Pl. 3, Fig. 1;
b5480. *Nodella faceta* ROZHDESTVENSKAJA, 1972. Pl. 3, Fig. 2;
b5481. *Nodella hamata* BECKER, 1968. Pl. 3, Fig. 3;
b5482. *Aechmina* sp. Pl. 3, Fig. 4;
b5483. *Coeloenellina minima* (KUMMEROW, 1953). Pl. 3, Fig. 5a,b;
b5484. *Coeloenellina* cf. *bijensis* (ROZHDESTVENSKAJA, 1959). Pl. 3, Fig. 6;
b5485. *Coeloenellina* cf. *bijensis* (ROZHDESTVENSKAJA, 1959). Pl. 3, Fig. 7a,b, Fig. 4 *in* text;
b5486. *Coeloenellina optata* (POLENOVA, 1955). Fig. 5 *in textu*;
b5487. *Coeloenellina vellicata* n. sp. Holotype. Pl. 3, Fig. 8a,b;
b5488. *Coeloenellina vellicata* n. sp. Paratype. Pl. 3, Fig. 9a,b;
b5489. *Samarella* aff. *laevinodosa* BECKER, 1964. Pl. 3, Fig. 10a,b;
b5490. *Balantoides brauni* (BECKER, 1968). Pl. 3, Fig. 11;
b5491. *Balantoides brauni* (BECKER, 1968). Pl. 3, Fig. 12;
b5492. *Rectella trapezoides* ZASPELOVA, 1959? Pl. 3, Fig. 13a,b;
b5493. *Evlanella mitis* ADAMCZAK, 1968. Pl. 3, Fig. 14;
b5494. *Evlanella mitis* ADAMCZAK, 1968. Pl. 3, Fig. 15;
b5495. *Evlanella mitis* ADAMCZAK, 1968. Pl. 3, Fig. 16;
b5496. *Evlanella mitis* ADAMCZAK, 1968. Pl. 3, Fig. 17;
b5497. *Poloniella tertia* KRÖMMELBEIN, 1953. Pl. 4, Fig. 1;
b5498. *Poloniella tertia* KRÖMMELBEIN, 1953. Pl. 4, Fig. 2;
b5499. *Poloniella tertia* KRÖMMELBEIN, 1953. Pl. 4, Fig. 3a,
b; **b5500. *Poloniella claviformis* (KUMMEROW, 1953).** Pl. 4, Fig. 4a,b;
b5501. *Uchtovia abundans* (POKORNY, 1950). Pl. 4, Fig. 5a,b;
b5502. *Uchtovia abundans* (POKORNY, 1950). Pl. 4, Fig. 6a,b;
b5503. *Uchtovia abundans* (POKORNY, 1950). Pl. 4, Fig. 7;
b5504. *Evlanella germannica* BECKER, 1964. Pl. 4, Fig. 8;
b5505. *Evlanella germannica* BECKER, 1964. Pl. 4, Fig. 9;
b5506. *Evlanella germannica* BECKER, 1964. Pl. 4, Fig. 10;
b5507. *Evlanella fibulaeformis* (ROZHDESTVENSKAJA, 1959). Pl. 4, Fig. 11;
b5508. *Uchtovia refrathensis* (KRÖMMELBEIN, 1954). Pl. 5, Fig. 1a,b;

timorensis representative because the platform margins are not nodose as mentioned in the original diagnosis of KLAPPER, PHILIP & JACKSON, 1970.

Acknowledgements

Firstly I would like to thank the Walliser family for having made the photographic material of the conodonts of the Mech Irdane section available to me. Also I wish to thank Helga Groos-Uffenorde (Göttingen) who provided me with the necessary information for using this material. This paper contributes to IGCP 596 on Mid-Paleozoic climate and biodiversity. Jeffrey Over (SUNY-Geneseo) and Tom Uyeno (Geological Survey of Canada, Calgary) are very much thanked for the critical reading of the manuscript with valuable comments and linguistic corrections. The conodont plates were made by W. Miseur, the four figures by E. Dermience and the manuscript typewriting by A. Vandersypen (Department of Palaeontology).

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Typescript submitted: April 28, 2011
Revised typescript received: July 26, 2011

Explanation of plates

Most figured specimens are from the Mech Irdane (MI) section. They are deposited in the collections of the Museum of the Geoscience Center, Goettingen University (GZG). They bear a tripartite registration number e.g. 1601-487-Y104-7. The number 1601 is the collection number, 487 is the locality number of the Mech Irdane section and Y104-7 is the number of a figured specimen, 104 is the sample number and 7 refers to the specimen. Other figured specimens are from the Bou Tchrafine section (BT) and from the eastern part of the Jebel Ou Driss (ODE). They are deposited in the micropaleontological collections of the Department of Palaeontology of the Royal Belgian Institute of Natural Sciences (IRScNB n° b6305-b6381) Magnifications are x50 unless otherwise noted. The figured specimens are upper views of P_1 elements except where otherwise stated.

PLATE 1

Fig. 1 — *Polygnathus pseudofoliatus* WITTEKINDT, 1966, alpha morphotype, n. 1601-487-Y104-7.
Fig. 2 — *Polygnathus pseudofoliatus* WITTEKINDT, 1966, beta morphotype, n. 1601-487-Y107-3.
Figs 3-5 — *Polygnathus pseudoeiflius* n. sp., holotype and two paratypes, n°s 1601-487-Y108-10, 115-12 and 113-39; Fig. x60.
Fig. 6 — *Polygnathus eiflius* BISCHOFF & ZIEGLER, 1957, n° 1601-487-Y115-5.
Figs 7-10 — *Polygnathus* aff. *P. pseudofoliatus* WITTEKINDT, 1966, transitional forms to *Polygnathus hemiansatus* BULTYNCK, 1987, n°s 1601-487, Y122-3, Y122-15 and 16, Y122-6; Fig. 10 x60.
Fig. 11 — *Polygnathus hemiansatus* BULTYNCK, 1987, alpha morphotype, n° 1601-487-Y123-7; x60.
Figs 12-15 — *Polygnathus hemiansatus* BULTYNCK, 1987, gamma morphotype, n°s 1601-487-Y123-15, Y-123-2, Y-125-17, Y127-6; Figs 12, 14, 15 x60.
Fig. 16 — *Polygnathus hemiansatus* BULTYNCK, 1987, beta morphotype, n° 1601-487-Y131-42.
Fig. 17 — *Polygnathus hemiansatus* BULTYNCK, 1987, gamma morphotype, n° 1601-487-Y132-5; x60.
Fig. 18 — *Polygnathus* aff. *P. pseudofoliatus* WITTEKINDT, 1966, transitional form to *Polygnathus amphora* n. sp., n° 1601-487-Y118-28; x60.
Figs 19-20 — *Polygnathus amphora* n. sp., holotype and a juvenile form, n°s 1601-487-Y131-49, Y118-7.
Figs 21-22 — *Polygnathus ensensis* ZIEGLER & KLAPPER, 1976, n°s 1601-487-Y123-19 and Y123-14, oblique-lateral view.

PLATE 2

Figs 1-2 — *Polygnathus robusticostatus* BISCHOFF & ZIEGLER, 1957, n°s 1601-487-X109-2 and X108-5.
Figs 3-4 — *Polygnathus angusticostatus* WITTEKINDT, 1966, n°s 1601-487-X112-3 and X104-3.
Fig. 5a,b — *Polygnathus angustipennatus* BISCHOFF & ZIEGLER, 1957, n°s 1601-487-X104-29; fig. 5b is an oblique lateral view.
Fig. 6 — *Polygnathus trigonicus* BISCHOFF & ZIEGLER, 1957, n° 1601-487-X104-22.
Fig. 7 — *Polygnathus hemiansatus* BULTYNCK, 1987, beta morphotype, sample ODE 7-5, n° IRSNB b6305.
Fig. 8a-b — *Polygnathus timorensis* KLAPPER, PHILIP & JACKSON, 1970, sample BT20, n°s IRSNB b6366; 8b is an outer lateral view.
Fig. 9a-b — *Polygnathus timorensis* KLAPPER, PHILIP & JACKSON, 1970, sample BT20, n°s IRSNB b6367; 9b is an outer lateral view.
Fig. 10 — *Tortodus* n. sp. A, n° 1601-487-139-X, inner lateral view; x60.
Figs 11-12 — *Tortodus* ? *intermedius* (BULTYNCK, 1966), n°s 1601-487-X104-12 and X104-13; fig. 12 is an inner lateral view.
Figs 13-$14_{a\text{-}b}$ — *Tortodus variabilis* (BISCHOFF & ZIEGLER, 1957), n° 1601-487-X157-X and ODE-8-21; fig. 14b is an outer lateral view; the anterior part is broken; Fig. 14 a, b x60.
Fig. 15 — *Tortodus sardinia* MAWSON & TALENT, 1989, n° 1601-487-X128-19, inner lateral view.
Figs 16-17 — *Polygnathus timorensis* KLAPPER, PHILIP & JACKSON, 1970, n°s 1601-487-X139-1 and X139-6; Fig. 17 is an inner lateral view.

PLATE 3

Fig. 1 — *Polygnathus linguiformis linguiformis* HINDE, 1879, γ1a morphotype, n° 1601-487-L108-2.

Fig. 2 — *Polygnathus linguiformis linguiformis* HINDE, 1879, γ1b morphotype, n° 1601-487-L107-2, inner oblique lateral view.

Fig. 3 — *Polygnathus linguiformis linguiformis* HINDE, 1879, γ2 morphotype, n° 1601-487-L108-1.

Figs 4-6 — *Polygnathus linguiformis linguiformis* HINDE, 1879, γ3 morphotype, n°s 1601-487-L122-13, L122-8 and L122-7.

Figs 7-8 — *Polygnathus linguiformis klapperi* CLAUSEN, LEUTERITZ & ZIEGLER, 1979, n°s 1601-487-L123-54 and L118-1; Fig. 8 is an oblique inner lateral view.

Fig. 9 — *Polygnathus linguiformis* sp. A UYENO & BULTYNCK, 1993, n° ODE-8-10, n° IRScNB b6368; x60.

Figs 10-11 — *Polygnathus linguiformis weddigei* CLAUSEN, LEUTERITZ & ZIEGLER, 1979, n°s 1601-487-L141-21 and — L130-ob-4.

Figs 12-14 — *Polygnathus conradi* CHATTERTON, 1978, n°s 1601-487-X123-1, X127-1 and L141-31.

Figs 15-16 — *Polygnathus parawebbi* CHATTERTON, 1974, n°s 1601-487-L104-13 and L103-2; oblique inner lateral views, Fig. 15 x60.

PLATE 4

Magnification x45, except where otherwise stated.

Figs 1-4 — *Icriodus hollardi* n. sp., holotype and three paratypes, 1, 2 sample ODE-8-19 and 3, 4 sample BT-15, n°s IRScNB b6369, b6370, b6371 and b6372; Fig. 4 is an inner lateral view.

Figs 5-6 — *Icriodus hollardi* n. sp., two paratypes n°s 1601-487-J109-5 and J104-5.

Figs $7_{a\text{-}b}$-8 — *Icriodus amabilis* BULTYNCK & HOLLARD, 1980, sample ODE-8-9, n° IRScNB b6373, Fig. 7b is a lower view and 8 is an outer lateral view.

Figs 9-$10_{a\text{-}b}$ — *Icriodus struvei* WEDDIGE, 1977, sample ODE-8-9 and ODE-8-21, n° IRScNB b6374 and b6375; Fig. 10b is an inner lateral view.

Figs 11-12 — *Icriodus walliserianus* WEDDIGE, 1988, n°s 1601-487-J219-2 and J123-52.

Figs 13-15 — *Icriodus regularicrescens* BULTYNCK, 1970, samples ODE-8-23, ODE-8-19, ODE-X-X, n°s IRScNB b6376, b6377 and b6378; Fig. 15 is a transitional form to *Icriodus obliquimarginatus* BISCHOFF & ZIEGLER, 1957.

Fig. $16_{a\text{-}b}$ — *Icriodus obliquimarginatus* BISCHOFF & ZIEGLER, 1957, beta morphotype, sample ODE-7-11, n° IRScNB b6379 ; Fig. 16b is an inner lateral view of the same specimen; x62.

Figs 17-19 — *Icriodus obliquimarginatus* BISCHOFF & ZIEGLER, 1957, alpha morphotype n°s 1601-487-J125-9, J125-7 and J129-20.

Fig. $20_{a\text{-}b}$ — *Icriodus regularicrescens* BULTYNCK, 1970, transitional form to *Icriodus obliquimarginatus*, n° 1601-487-J104-2; Fig. 2b is an inner lateral view.

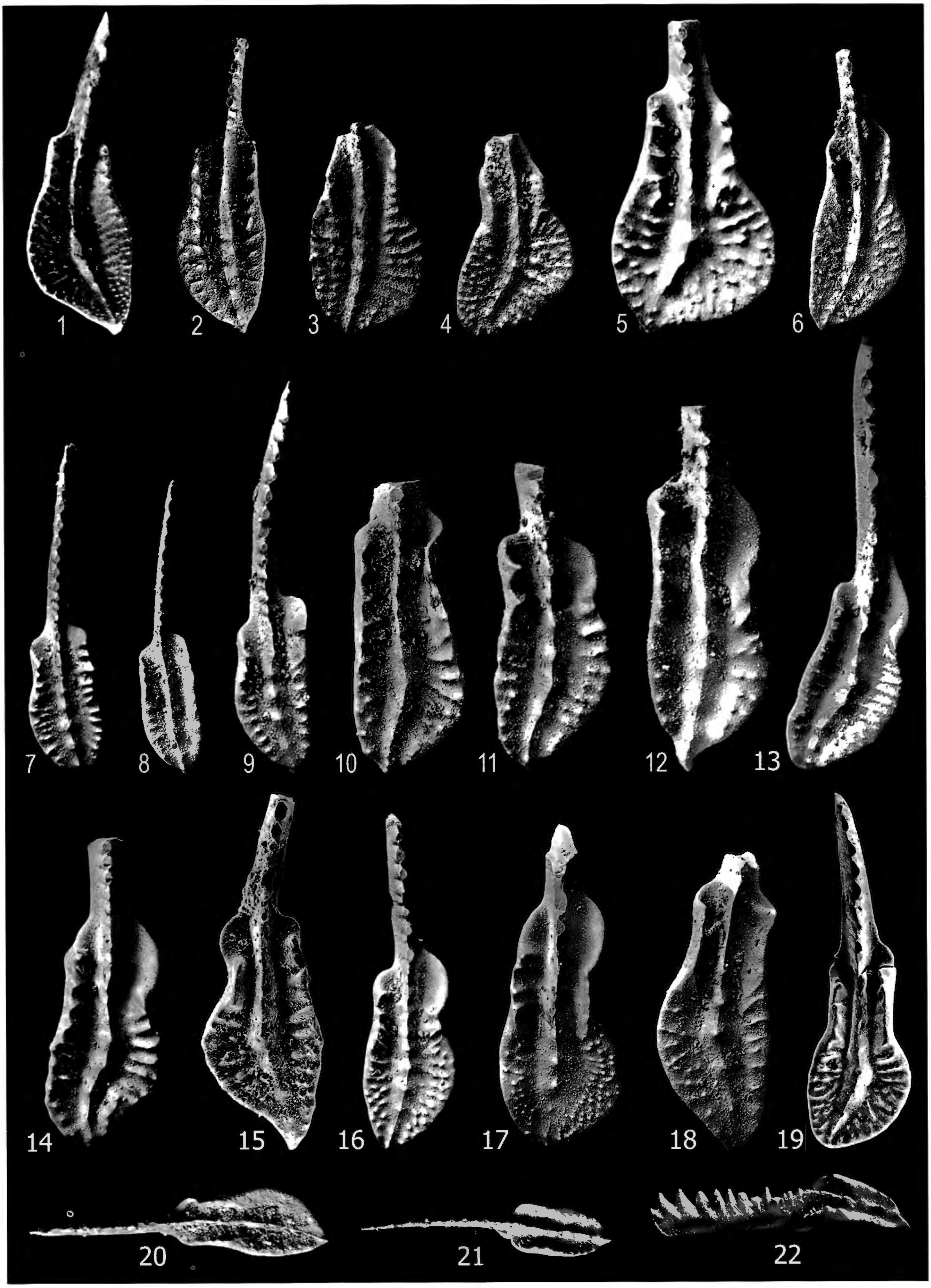

PLATE 1

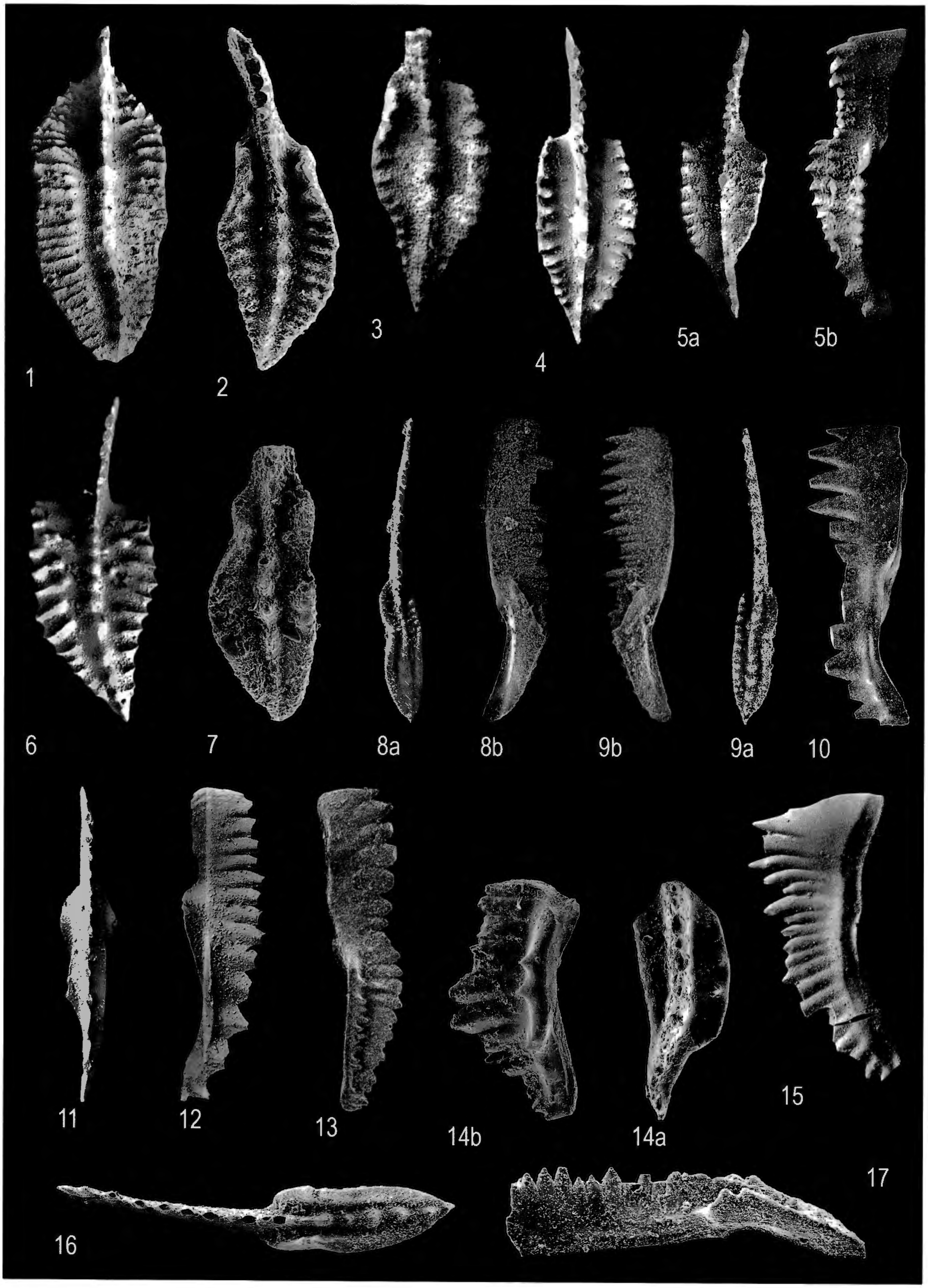

PLATE 2

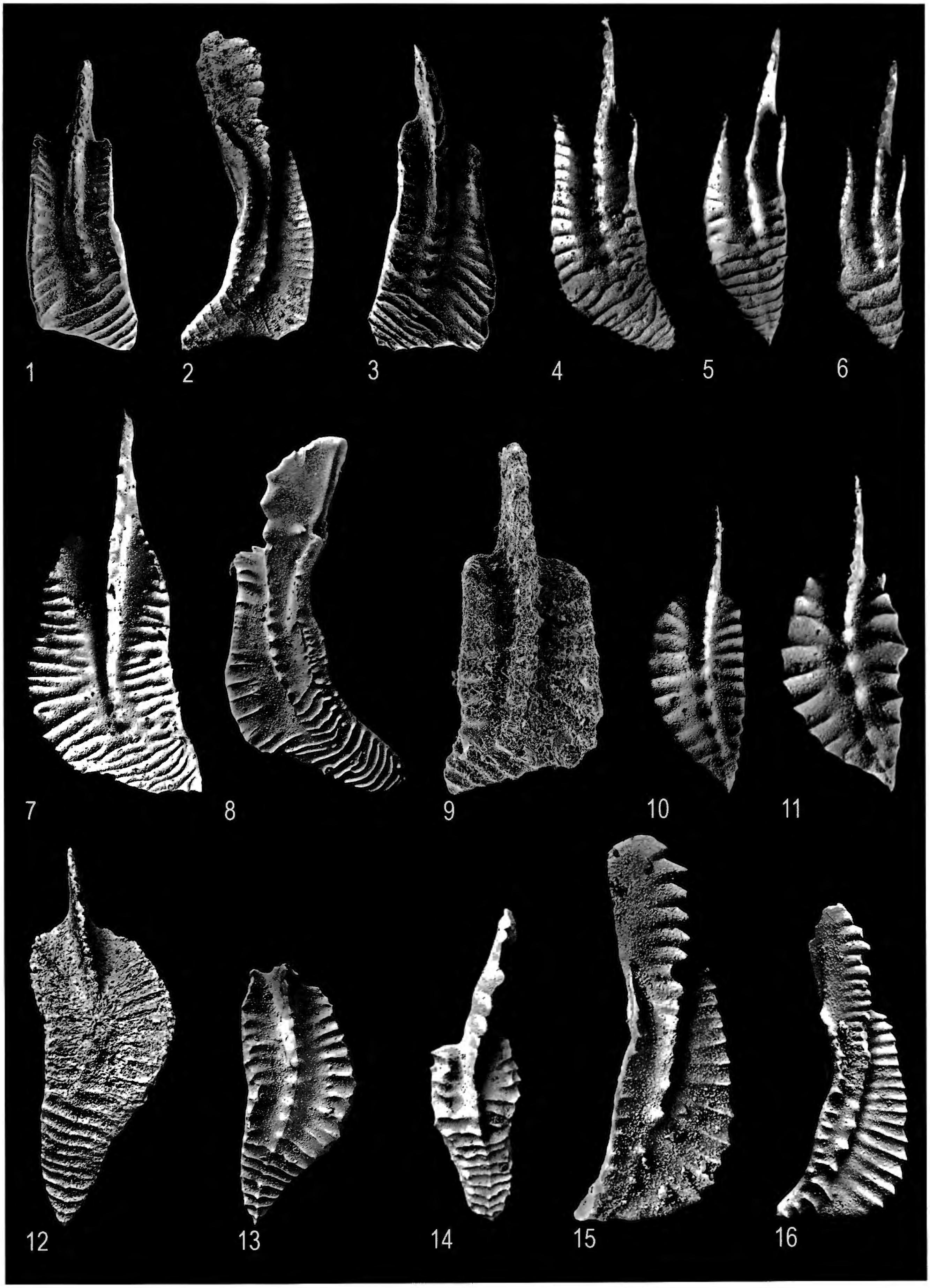

PLATE 3

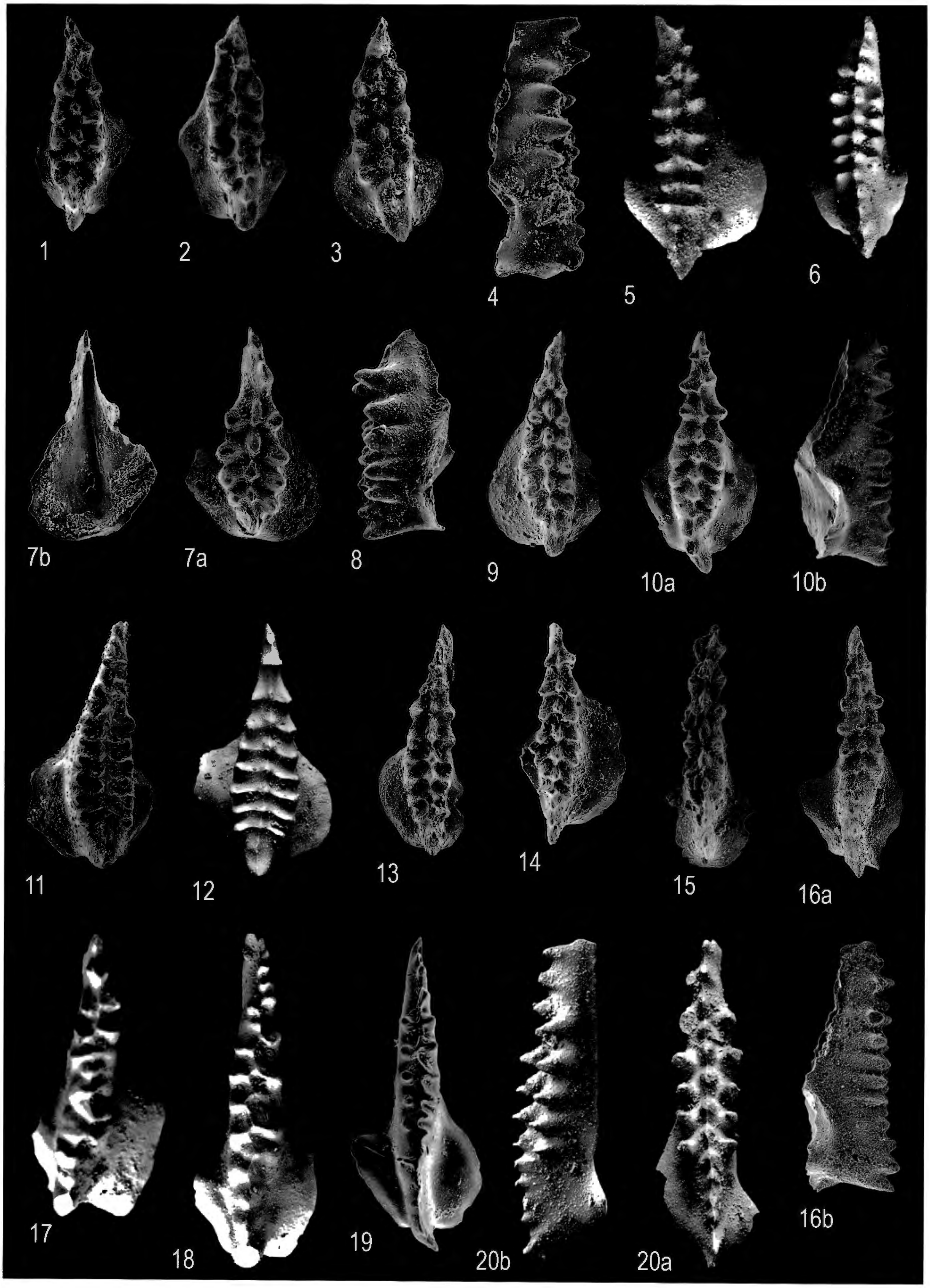

PLATE 4