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Pelagic and neritic conodont successions from the Givetian of pre-Sahara Morocco and the Ardennes

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Abstract

The present paper deals with conodont faunas ranging from the *kockelianus* Zone (late Eifelian) almost to the top of the Upper *varcus* Subzone (late Givetian). In the Ardennes, the conodont succession is primarily based on sections in the type area of the Givet Limestone, a 400 m thick sequence of mainly shallow water platform carbonates. Conodont faunas are dominated by species of *Icriodus* and *Eognathodus*. Species of *Ozarkodina* and *Polygnathus* are rare and in general their frequency is too low to ensure precise vertical ranges. Consequently, a direct and accurate correlation with the Eifelian-Givetian standard conodont zonation, established in the pelagic facies and based on species of *Polygnathus,* is difficult to establish. An alternative *Icriodus* zonation is proposed. In the Tafilalt (pre-Sahara of Morocco), the zonal succession is established in the Bou Tchrafine section near Erfoud in the middle and upper part of the Bou Tchrafine Group and the base of the Bouia Formation, a 17 m thick condensed cephalopod limestone sequence belonging to the pelagic realm. Species of *Polygnathus* are particularly abundant; species of *Icriodus* occur but their general distribution is more irregular. The standard conodont zones are recognized, although a refinement of the zonation is proposed. In the Ma'der three sections in the NW part of the Issimour arch are studied. The sequence, 240 m thick, extends from the Taboumakhlouf Formation into the Middle Member of the Bou Dib Formation. Sediments and fauna reflect a neritic shelf environment. Conodont faunas are generally dominated by species of *Polygnathus* although species of *Icriodus* occur regularly and may be abundant. The conodont standard zonation and the alternative *Icriodus* zonation are both partially recognized in the same beds. The lowest occurrence of *Polygnathus hemiansatus* n. sp. within the *ensensis* Zone recognized in four sections from pre-Sahara Morocco and also in the Cantabrian Mountains (Spain) and in the Guangxi Province (South China) is considered here as a good potential level for the Eifelian-Givetian boundary. Three new species of *Icriodus* are described: *I. platyobliquimarginatus, I. lilliputensis* and *I. obesus.*
Key-words: Biostratigraphy, Conodonts, Givetian, Ardennes, pre-Sahara Morocco.

Résumé

La présente contribution concerne des faunes à Conodontes observées de la Zone à *kockelianus* (fin de l'Eifelien) jusque près du sommet de la Sous-Zone à *varcus* Supérieure (fin du Givetien). Dans les Ardennes, la succession à Conodontes est principalement établie d'après l'étude de coupes situées dans la région-type du Calcaire de Givet, séquence épaisse de 400 m et surtout formée de carbonates déposés en milieu de plate-forme peu profonde. Les faunes à Conodontes sont dominées par des espèces d'*Icriodus* et d'*Eognathodus.* Les espèces d'*Ozarkodina* et de *Polygnathus* sont rares et leurs trop faibles fréquences ne permettent généralement pas d'établir avec exactitude les extensions stratigraphiques. Par conséquent, une corrélation directe et précise avec la zonation standard à *Polygnathus* etablie dans le facies pélagique est difficile à établir. Une zonation parallèle à *Icriodus* est proposée. Dans le Tafilalt (Maroc présaharien), la succession des zones est établie dans la coupe de Bou Tchrafine, près d'Erfoud, dans les parties moyenne et supérieure du Groupe de Bou Tchrafine et à la base de la Formation de Bouia; cette sequence condensée de calcaires à Céphalopodes est épaisse de 17 m et appartient au domaine pélagique. Les espèces de *Polygnathus* sont spécialement abondantes; les espèces d'*Icriodus* sont présentes mais leur distribution est généralement plus irrégulière. Les zones classiques à Conodontes sont reconnues bien qu'une subdivision plus détaillée soit proposée. Dans le Ma'der, trois coupes sont étudiées dans la partie NW d'Issimour. La séquence, épaisse de 240 m, est étendue de la Formation de Taboumakhlouf jusqu'au Membre Moyen de la Formation de Bou Dib. Les sédiments et la faune reflètent un environnement néritique de plate-forme. Les faunes à Conodontes sont généralement dominées par des espèces de *Polygnathus* bien que les espèces d'*Icriodus* soient régulièrement présentes et puissent être abondantes. La zonation standard à Conodontes et la zonation parallèle à *Icriodus* sont toutes deux partiellement reconnues dans les mêmes bancs. La première apparition de *Polygnathus hemiansatus* n. sp. dans la Zone à *ensensis* est établie dans quatre coupes du Maroc présaharien et est aussi reconnue dans les Monts Cantabriques, en Espagne, et dans la Province de Guangxi, en Chine méridionale; ce niveau biostratigraphique offre de bonnes possibilités de corrélation en ce qui concerne la limite Eifelien-Givetien. Trois nouvelles espèces d'*Icriodus* sont fondées: *I. platyobliquimarginatus, I. lilliputensis* et *I. obesus.*
Mots-clefs: Biostratigraphie, Conodontes, Givetien, Ardennes, Maroc présaharien.

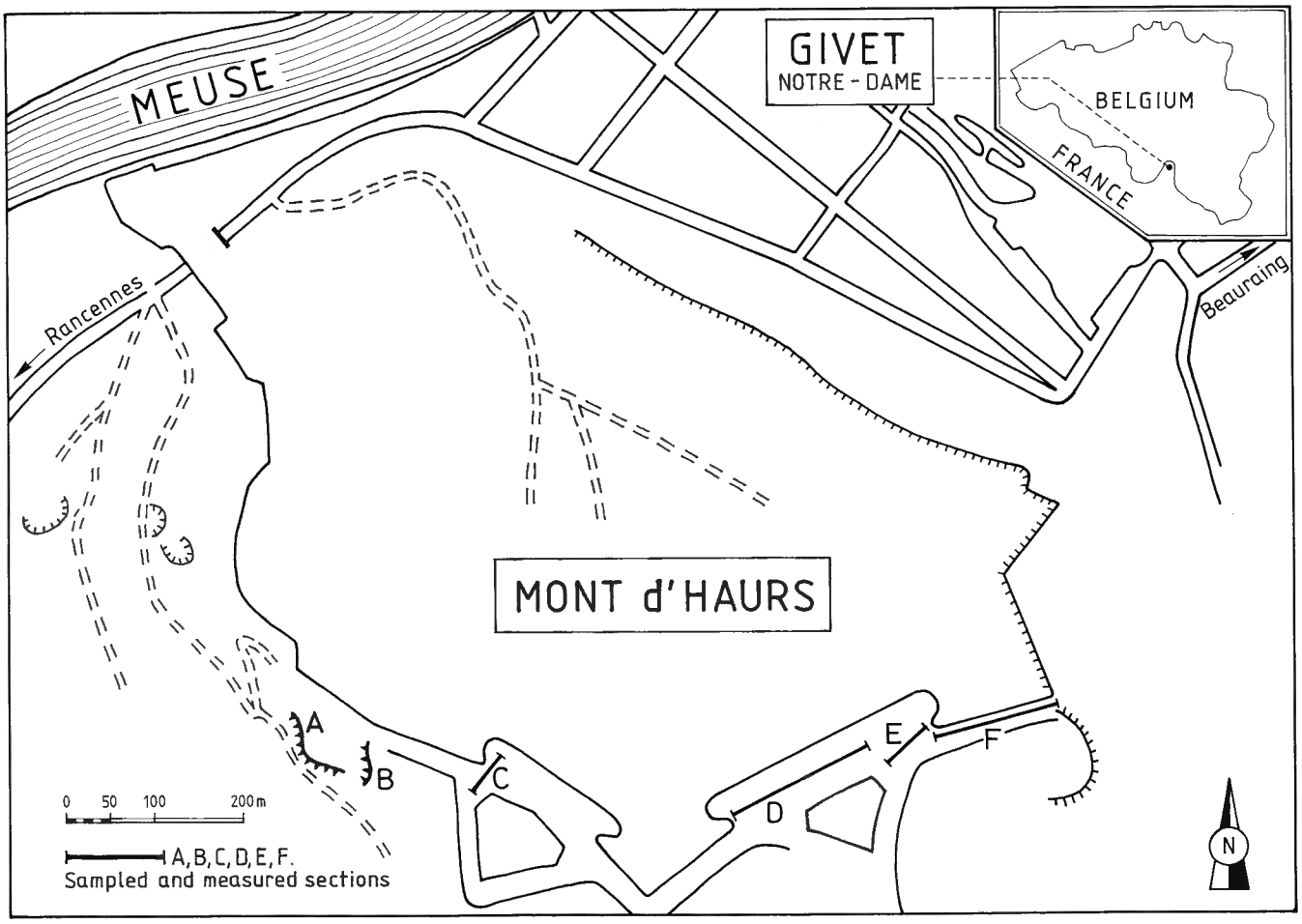
I. - Introduction

This paper provides new data on Eifelian-Givetian conodont successions, from the *kockelianus* Zone up to the Upper *varcus* Subzone, in new and previously described sections in the southeastern pre-Sahara of Morocco (BULTYNCK & HOLLARD, 1980; BULTYNCK & JACOBS, 1981; BULTYNCK, 1985) and from the type area of the Givet Limestone in the Belgian-French Ardennes. Eifelian and Givetian conodont faunas from the latter region have been studied in BULTYNCK (1972, 1974, 1976), BULTYNCK & GODEFROID (1974) and COEN, BULTYNCK & PEL (1974).

Comparison between the conodont successions from the two areas illustrates the difficulties encountered when correlating sections with different conodont biofacies. During the Givetian shallow water platform carbonate deposits predominated over a large part of the world. In these deposits mainly Icriodontidae occur, while the critical *Polygnathus* species of the standard zonation, in the present case the *ensensis* and *varcus* Zones, are absent or very rare. This is particularly true for the Givetian of the type area form which an alternative *Icriodus* zonation, proposed here, is the most accurate and useful tool. This *Icriodus* zonation is correlated with the standard zonation and with a refined *Polygnathus* succession recognized in the Eifelian-Givetian sections from Morocco with a deeper neritic or pelagic facies. This succession is conceived as a regional improvement of the standard zonation. Reasons for this and the modifications can be summarized as follows. BULTYNCK & HOLLARD (1980, p. 42) recognized in the Bou Tchrafine section (Tafilalt) a form *Polygnathus* aff. *P. ansatus* that enters 1.85 m above the top of the *kockelianus* Zone and below the first occurrence of *P. timorensis,* which defines the base of the *varcus* Zone. KLAPPER & JOHNSON (1980, p. 413) considered this form to be identical to *P. ansatus,* the first occurrence of which characterizes the base of the Middle *varcus* Subzone. According to this synonymy the *ensensis* Zone and the Lower *varcus* Subzone would be missing or represented in the 1.85 m unsampled interval. Sampling of this interval and restudy of BULTYNCK's & HOLLARD's (1980) collections confirm the differences between *P. ansatus* and *P.* aff. *P. ansatus,* described herein as *P. hemiansatus* n. sp. This species is identified in other Moroccan sections and outside Morocco and its earliest occurrence is used to subdivide the *ensensis* Zone into two subzones.

BULTYNCK & HOLLARD (1980, p. 47) also proposed replacement of the *varcus* Zone, with its threefold subdivision, by four zones. WEDDIGE (1984, p. 185) suggested comparable nomenclatorial modifications for the *varcus* Zone. HUDDLE (1981) drew attention to the difficulty in using the *varcus* Zone in western New York, due in part to the scarcity of the species. That *P. varcus* is rare in the western New York succession can also be concluded from the conodont distribution tables in ZIEGLER, KLAPPER & JOHNSON (1974, tabl. 1-4), where the species is recorded from only one sample in one section. Therefore, although the subdivisions of the *varcus* Zone are mentioned in

Fig. 1. – *Sketch map showing the Mont d'Haurs sections at Givet. Inset map shows location of Givet.*



figures 2, 4 and 6 for reasons of common usage, a more precise regional zonation for this biostratigraphical interval is given in figure 9.

II. - Sections and their conodont successions

II-1. Ardennes Sections Mont d'Haurs and Fromelennes
(France IGN Mapsheet Givet XXX-7)
(Figs. 1-2)

The conodont results derive mainly from the succession at Mont d'Haurs, an old fortification on the east side of the Meuse at Givet, where the top of the Hanonet Formation (late Eifelian) and the two lower formations of the Givet Group, the Trois-Fontaines and the Mont d'Haurs Formations, are exposed. Seventy-five 3 to 6 kg samples have been processed. Conodont samples from Mont d'Haurs mentioned *in* BULTYNCK (1972) and *in* COEN, BULTYNCK & PEL (1974) have been incorporated in the sample succession on figure 2. The succession at Mont d'Haurs is established on the basis of six sections (Fig. 1, A to F). The distribution of the samples according to these sections is given in the locality and sample index. Data for the top of the Mont d'Haurs Formation and the lower part of the Fromelennes Formation are based on sampling of the section at Fromelennes by BULTYNCK (1974).

I use the lithostratigraphic subdivisions established by SARTENAER & ERRERA, *in* ERRERA, MAMET & SARTENAER (1972) with the single exception that the base of the Mont d'Haurs Formation is drawn at the base of phase 10 and not at the base of phase 8. In the same paper (1972) ERRERA & MAMET recognized thirty-one sedimentary major phases (Fig. 2, column B) representing an alternation of open marine fore-reef deposits with reef deposits (coral and stromatoporoïd biostromes) and back-reef deposits, the last two of which largely dominate in the succession. All the conodont samples have been located with reference to these phases.

Conodont faunas are generally sparse, most commonly about 5 up to 20 specimens/kg, rarely more than 20/kg, and in only two samples more than 100/kg. The most productive samples are from phases 7, 8 and 9 just below the Mont d'Haurs Formation and from the basal part of the Fromelennes Formation; each case involves an open marine fore-reef environment with calcareous shales, carbonated nodules and argillaceous and silty limestones. The macrofauna includes brachiopods, tabulate and rugose corals, and trilobites. Samples from the back-reef environment, sample 17 to 24 and above sample 62, were barren.

The conodont faunas are dominated by *Icriodus* taxa and *Eognathodus bipennatus bipennatus* in the Trois-Fontaines Formation, and by *Icriodus* taxa in the Mont d'Haurs and the Fromelennes Formation. Apart from a few samples from the basal part of the Fromelennes Formation, *Polygnathus* species are rare. For this reason the boundaries of the conodont standard zones, in the present case the *ensensis* Zone and the *varcus* Zone with its subdivisions, cannot be identified with precision. Using Polygnathidae it can be demonstrated directly that the basal 5 m of the Givet Limestone belong to the *ensensis* Zone. The eponymous zonal species has not been found in the Mont d'Haurs sections, but occurs 47 m below the base of the Givet Limestone in the Hanonet Formation at Couvin, 25 km west of Givet (recorded as *Polygnathus xyla* in BULTYNCK, 1970, Pl. XV, Fig. 2). The presence of *Tortodus intermedius* and *Ozarkodina bidentata,* known to disappear below the top of the *ensensis* Zone demonstrates that the basal 5 m of the Givet Limestone at Givet are still within the *ensensis* Zone.

The first *Polygnathus* taxon indicative of the *varcus* Zone, *P. xylus xylus,* occurs 92 m above this level; *P. timorensis,* the first occurence of which normally defines the base of the *varcus* Zone, appears much later, in the middle part of the Mont d'Haurs Formation. Specimens from samples 59 to 62, 220 m above the base of the Givet Limestone, belong to a brief open-marine incursion (phase 13) within a thick biostrome/back-reef sequence. There is also some evidence for the base of the Middle *varcus* Subzone in the lower part of the Fromelennes Formation. This interpretation is based on the last occurrence of *P. pseudofoliatus* and the first occurrence of specimens close to *P. ansatus* (see Pl. 8, Fig. 9). The Upper *varcus* Subzone and the *hermanni-cristatus* Zone were not recognized higher in the Fromelennes Formation, and the upper part of this formation was assigned to the Upper *dengleri* Subzone by BULTYNCK & JACOBS (1982, p. 36).

Distribution of Icriodids in the Givet Limestone is much more regular and at some levels they are abundant. In the Trois-Fontaines Formation, the Mont d'Haurs Formation and the lower part of the Fromelennes Formation eleven *Icriodus* taxa occur, three of which are new: *I. platyobliquimarginatus, I. lilliputensis* and *I. obesus.* The most important stratigraphically are *I. regularicrescens, I. obliquimarginatus, I. lindensis* and *I. brevis.* These probably belong to one phylogenetic lineage and have a wide regional distribution in W. Europe, N. Africa and N. America (pars). Three new *Icriodus* zones, *regularicrescens, obliquimarginatus* and *brevis,* are established, the base of each zone being defined by the earliest occurrence of the zonal index. The three zones cover the *kockelianus* Zone, the *ensensis* Zone and part of the lower *varcus* Subzone. The earliest occurrence of *I. lindensis* divides the *obliquimarginatus* Zone into lower and upper subzones.

The earliest occurrence of *I. obliquimarginatus* was used by ZIEGLER (1971, p. 24) to characterize the *obliquimarginatus* Zone, abandoned since 1976. The species is present in the top of the Hanonet Formation

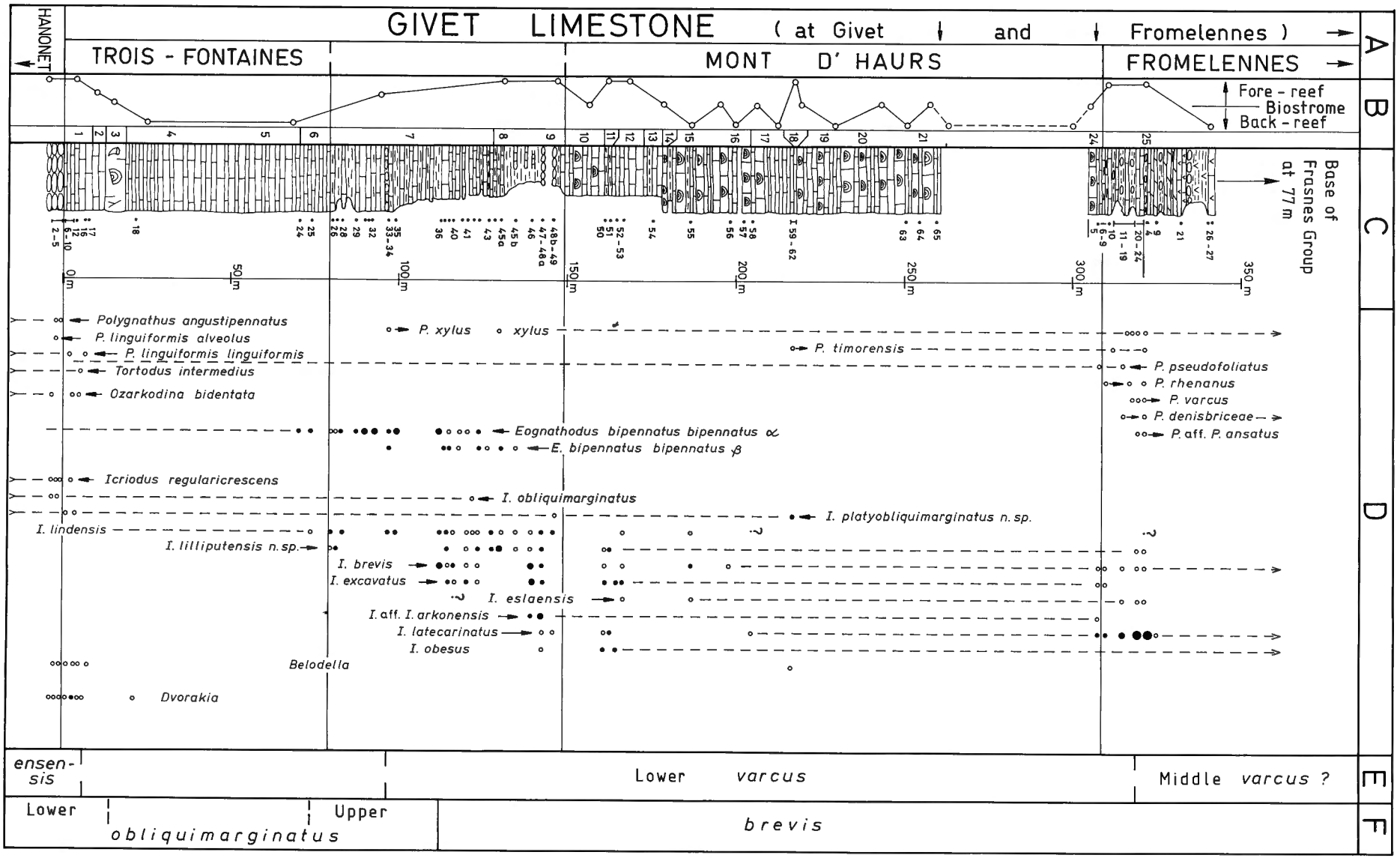
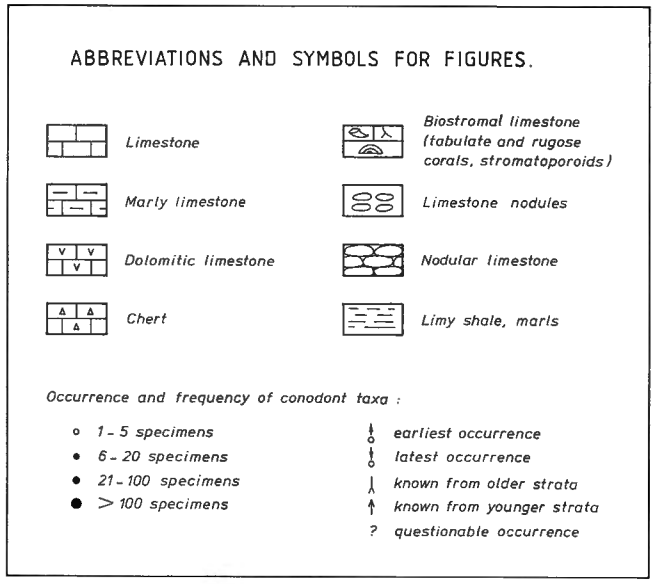
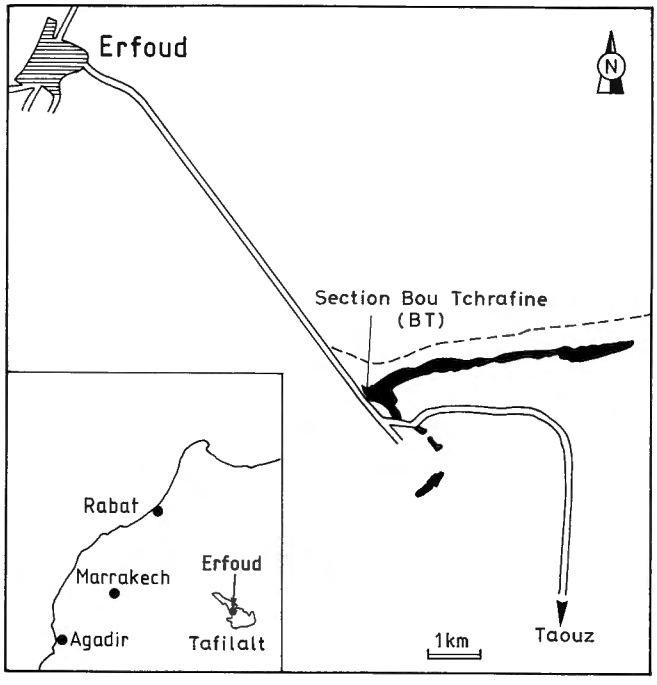


Fig. 2. – *Conodont distribution and frequency in the Mont d'Haurs sections and in the lower part of the Fromelennes section. Column A: lithostratigraphy, group and formations; B: sedimentary major phases after* ERRERA & MAMET in ERRERA, MAMET & SARTENAER *(1972); C: columnar section and conodont sample numbers; D: distribution and frequency of conodont taxa; E: conodont standard zonation; F: alternative* Icriodus *zonation.*



at Mont d'Haurs, 4 m below the base of the Givet Limestone, although this is certainly not the earliest record for the type area. In other sections, for example Wellin - Fond des Vaux 5 (BULTYNCK & GODEFROID, 1974, p. 30, between samples 19 and 22), 24 km east of Givet, and Marenne (COEN, BULTYNCK & PEL, 1974, p. 13, sample 1), 45 km northeast of Givet, *I. obliquimarginatus* occurs respectively 18 m and 13 m below beds with the brachiopod *Undispirifer givefex* STRUVE, 1981, characteristic of the base of the Givet Limestone in the Ardennes.

Fig. 3. – *Sketch map showing the Bou Tchrafine section. Erfoud is situated in the northern Tafilalt, shown in the small index map of part of Morocco.*

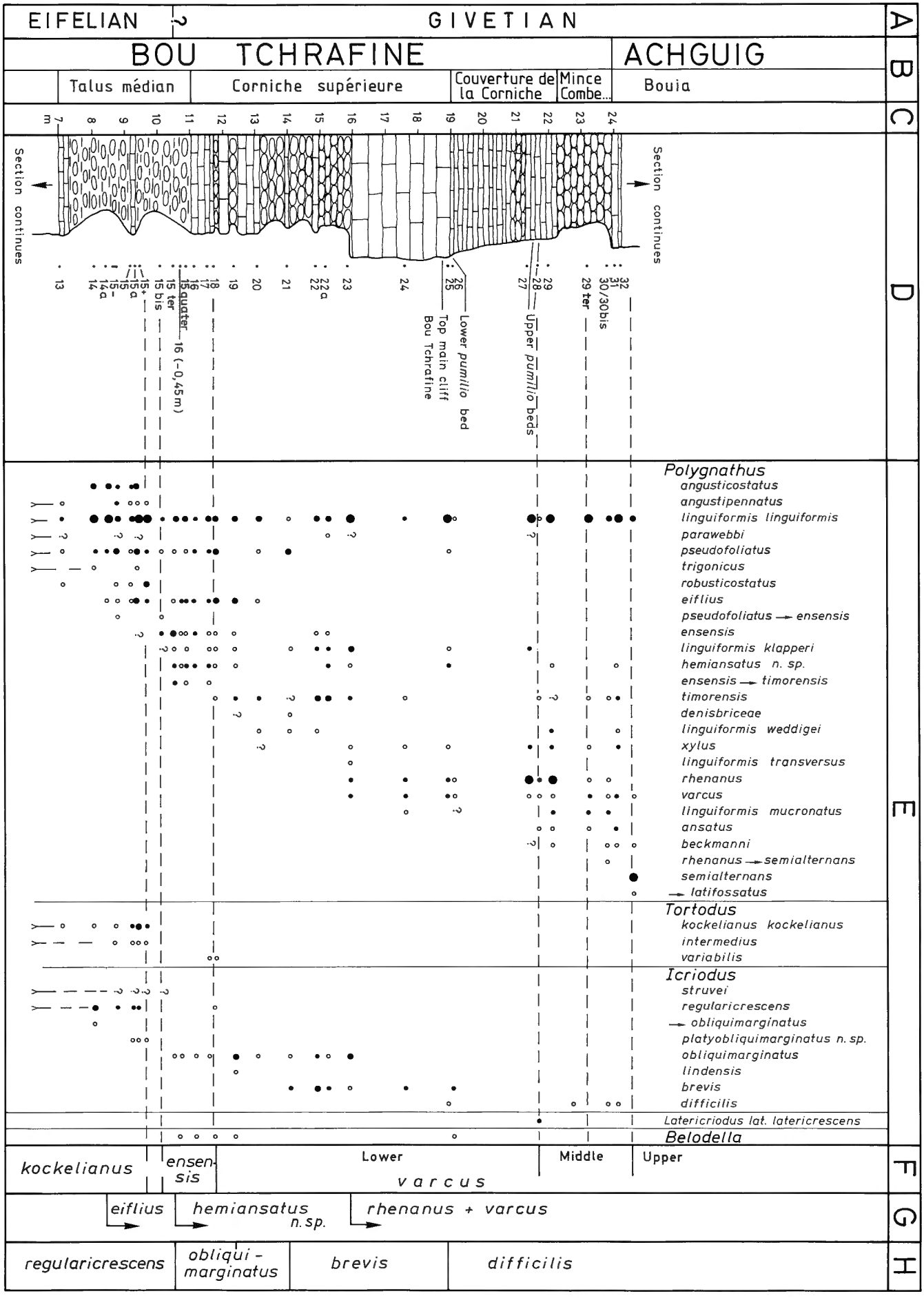


Icriodus platyobliquimarginatus, a species that may be confused with *I. obliquimarginatus,* occurs a little earlier and the entry of the latter species probably marks the conodont faunal change that corresponds most closely to the base of the Givet Limestone in the type area. The earliest occurence of *I. lindensis* may also be close to the base of this unit. In the Mont d'Haurs section the earliest record is 74 m above the base of the Givet Limestone, although it should be noted that there is a 50 m barren interval between samples 24 and 18. In the Marenne section (COEN, BULTYNCK & PEL, 1974, p. 13) the species occurs in sample 12 (specimens figured here Pl. 4, Figs. 20, 21), 14 m above the beds with *Undispirifer givefex*; consequently the range of the species is extended downwards by a dotted line in figure 2.

The earliest occurrence of *Eognathus bipennatus bipennatus* is not reliably known. In the Mont d'Haurs section it enters 70 m above the base of the Givet Limestone, in the Marenne section, 3 m below the level with *Undispirifer givefex.* This possible downwards extension is indicated by a dotted line in figure 2.

II-2. Tafilalt Section Bou Tchrafine (Morocco Mapsheet Erfoud NH-30-XX-2) (Figs. 3-4)

A typical Eifelian-Givetian succession in the pelagic facies is exposed in the Bou Tchrafine section near Erfoud in the southern Tafilalt. The top of the Eifelian and most of the Givetian are represented by 17 m of cephalopod limestone, belonging to the Bou Tchrafine Group and subdivided into four formations by HOLLARD (1981). Goniatites and conodonts from this part of the section were discussed by BULTYNCK & HOLLARD (1980). In the present paper the conodont results are completed, especially in the Eifelian-Givetian boundary interval, where eight supplementary samples were taken from about 3 m of strata, between samples 14 and 16 of the 1980 study. The goniatite succession will be refined by WALLISER (University of Göttingen). Conodont frequency in the Eifelian and Givetian samples from the Bou Tchrafine section is good, most samples containing 50 to 100 specimens/kg. Species of *Polygnathus,* particularly in the *P. linguiformis* group, are abundant and diversified; species of *Icriodus* occur also in most of the samples but their frequency is irregular and species diversity is low. The standard conodont zones, *kockelianus* Zone, *ensensis* Zone and *varcus* Zone with original subdivisions, can be recognized, although some refinement is proposed. This includes the subdivision of the *kockelianus* Zone and the *ensensis* Zone into lower and upper subzones and the replacement of the *varcus* Zone of ZIEGLER, KLAPPER & JOHNSON (1976) by four zones, in ascending order: *timorensis, rhenanus-varcus, ansatus,* and *semialternans-latifossatus* Zones. The most characte-


EIFELIAN
?
GIVETIAN
BOU TCHRAFINE
ACHGUIG
Talus médian
Corniche supérieure
Couverture de la Corniche
Mince Combe...
Bouia
A
B
C
D
E
F
G
H
m
Section continues
Section continues
13
14
14a
15-
15
15a
15+
15 bis
15 ter
15 quater
16 (-0,45m)
17
18
19
20
21
22
22a
23
24
25
26
27
28
29
29 ter
30/30bis
31
32
Top main cliff
Bou Tchrafine
Lower pumilio bed
Upper pumilio beds
Polygnathus
angusticostatus
angustipennatus
linguiformis linguiformis
parawebbi
pseudofoliatus
trigonicus
robusticostatus
eiflius
pseudofoliatus → ensensis
ensensis
linguiformis klapperi
hemiansatus n. sp.
ensensis → timorensis
timorensis
denisbriceae
linguiformis weddigei
xylus
linguiformis transversus
rhenanus
varcus
linguiformis mucronatus
ansatus
beckmanni
rhenanus → semialternans
semialternans
→ latifossatus
Tortodus
kockelianus kockelianus
intermedius
variabilis
Icriodus
struvei
regularicrescens
→ obliquimarginatus
platyobliquimarginatus n. sp.
obliquimarginatus
lindensis
brevis
difficilis
Latericriodus lat. latericrescens
Belodella
kockelianus
ensensis
Lower
varcus
Middle
Upper
eiflius
hemiansatus n. sp.
rhenanus + varcus
regularicrescens
obliqui-marginatus
brevis
difficilis

ristic features of the conodont succession are summarized as follows.

1. - The entry of *P. eiflius* (sample 14a) is used to define the base of the Upper *kockelianus* Subzone.
2. - There is a clear faunal break between samples 15+ and 15bis. Six species common in Eifelian strata below have their last occurrence in bed 15+ or 15a, 15 cm below: *P. angusticostatus, P. angustipennatus, P. trigonicus, P. robusticostatus, Tortodus kockelianus kockelianus* and *T. intermedius*. It should be stressed that there is no clear lithological break at this level. Typical specimens of *P. ensensis* occur from sample 15bis upwards; one questionable specimen was found in sample 15a.
3. - *P. hemiansatus* n. sp. appears within the *ensensis* Zone (sample 15ter). BULTYNCK & HOLLARD (1980) and BULTYNCK (1985) identified specimens now assigned to the new species as *P.* aff. *P. ansatus* or as "early morphotype of *P. ansatus* (see systematic part). *P. hemiansatus* is found in the same stratigraphic position in three Moroccan sections: Ma'der, Akka Bou Khedach, discussed here below; Ouahlane (BULTYNCK, 1985, Fig. 10, sample 27); and Jbel Ou Driss (HOLLARD, 1981, sample ODE 6). I identified the new species in material from Guangxi Province, South China, in sample 407 from the Sihongshan section described by ZIEGLER & WANG (1985); a specimen is figured on Plate 8, Fig. 5. Specimens from the Portilla Formation in the Cantabrian Mountains (Spain) identified by GARCIA-LOPEZ (1987, Pl. 11, Fig. 23; Pl. 12, Figs. 1-6, 9) as *P. ansantus* belong to *P. hemiansatus*. The lowest occurrence of *P. hemiansatus* is proposed here to define the base of the Upper *ensensis* Subzone.
4. - The base of the (Lower) *varcus* Subzone, according to the definition of ZIEGLER, KLAPPER & JOHNSON (1976), is recognized by the first occurrence of *P. timorensis* in sample 18. It corresponds with the base of the *timorensis* Zone of the present paper.
5. - *P. rhenanus* and *P. varcus* first occur in sample 23. Some authors consider *P. rhenanus* as a junior synonym of *P. timorensis* but they are separated in the present study (see systematic part). In different Moroccan sections *P. rhenanus* and *P. varcus* appear distinctly later than *P. timorensis*. Therefore that part of the Lower *varcus* Subzone with *P. timorensis* and before the entry of *P. rhenanus* and *P. varcus* is defined here as the *timorensis* Zone; the joint occurence of *P. rhenanus* and *P. varcus,* which precedes the first appearance of *P. ansatus,* defines the *rhenanus-varcus* Zone.
6. - *P. ansatus* is known first in sample 28; this level corresponds to the base of the Middle *varcus* Subzone of ZIEGLER, KLAPPER & JOHNSON (1976), named *ansatus* Zone in the present paper. In the Bou Tchrafine section occur three *"pumilio„* beds, which are coquina beds containing small terebratulids. Similar strata are well known from the Rheinisches Schiefergebirge and constitute the so-called *"pumilio"* Event of LOTTMANN, SANDBERG, SCHINDLER, WALLISER & ZIEGLER (1986). In the Bou Tchrafine section the lowest *"pumilio"* bed (sample 26) is within the *rhenanus-varcus* Zone (= upper part of Lower *varcus* Subzone); the two upper *"pumilio"* beds (between sample 27 and 28, and sample 28) are at the base of the *ansatus* Zone (= Middle *varcus* Zone).
7. - *Polygnathus semialternans* and specimens transitional between *P. semialternans* and *P. latifossatus* occur first in sample 32. This level corresponds closely to the base of the Upper *varcus* Subzone of ZIEGLER, KLAPPER & JOHNSON (1976) and is named *semialternans-latifossatus* Zone in the present paper.
8. - The *I. regularicrescens, I. obliquimarginatus* and *I. brevis* Zones, established in the Eifelian and Givetian sequence of the Ardennes, are recognized in the Bou Tchrafine section. This *Icriodus* zonation is completed here with the *I. difficilis* Zone, the base of which is defined by the earliest occurrence of the nominal species.
   In the Bou Tchrafine section the base of the *obliquimarginatus* Zone coïncides with the entry of *P. hemiansatus*. In the Givet Limestone, as noted earlier, the entry of *I. obliquimarginatus* is the most reliable first appearance that is closest to the base of this unit, and the provisional positioning of the Eifelian-Givetian boundary in the Bou Tchrafine section is based on the correlation with this biostratigraphic level.

II-3. Ma'der Sections Akka Bou Khedach, Taboumakhlouf Terrasse and Taboumakhlouf South
(Morocco Mapsheet Msissi NH-30-XX-1)
(Pl. 1-3 and Figs. 5, 6, 7)

◁ Fig. 4. – *Conodont distribution and frequency in the Bou Tchrafine section. Column A: Chronostratigraphy; provisional positioning of the Eifelian-Givetian boundary is based on the correlation with a level not far below the base of the Givet Limestone in the type area and characterized there by the earliest occurrence of* Icriodus obliquimarginatus*; B: lithostratigraphy after HOLLARD (1981); D: columnar section and conodont sample numbers, a photo of Bou Tchrafine with indication of key beds was published by BULTYNCK & JACOBS (1982, Pl. 1); E: distribution and frequency of conodont taxa; F: conodont standard zonation; G: earliest occurrence of* Polygnathus species *used in refined* Polygnathus *zonation; H: alternative* Icriodus *zonation.*

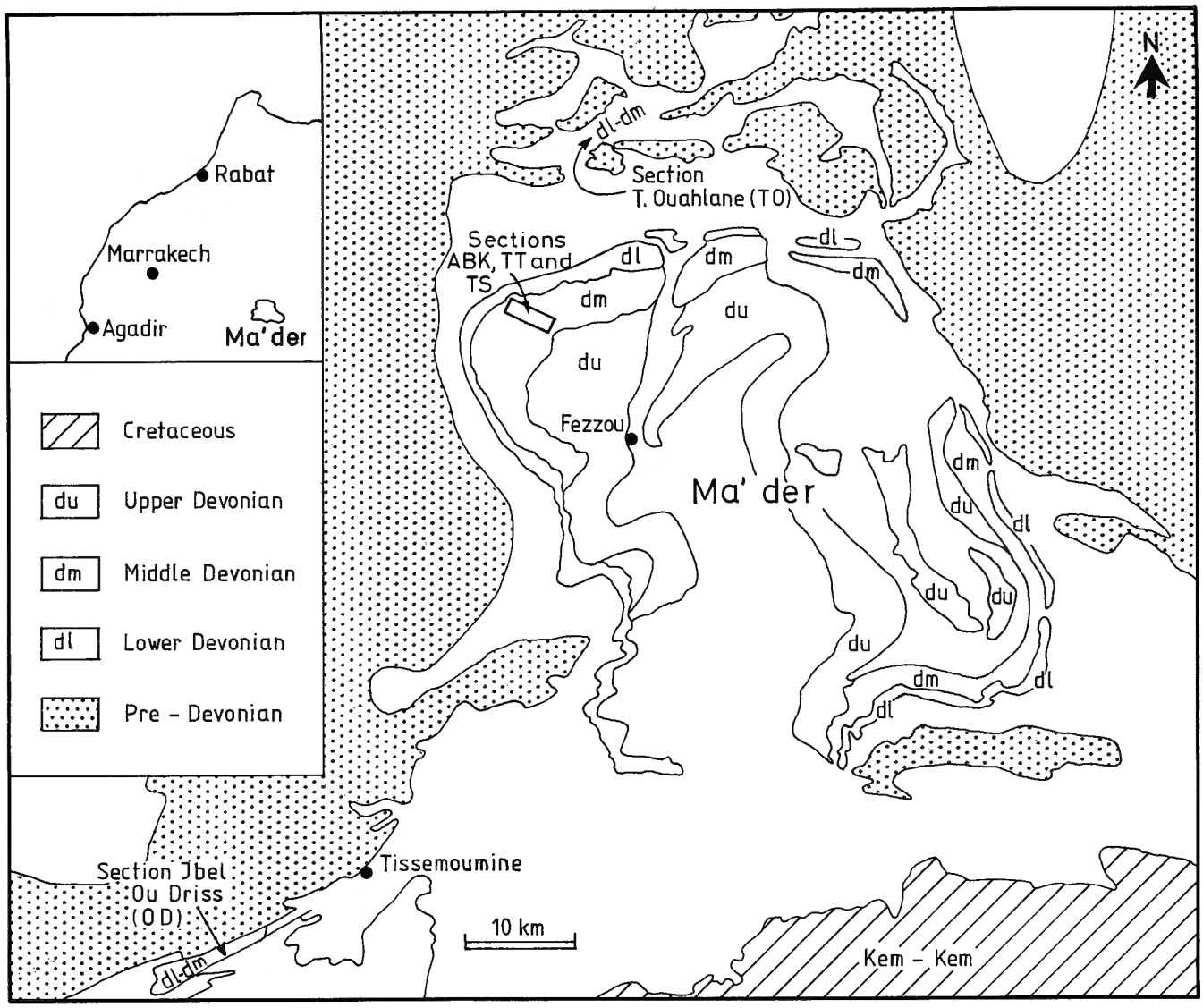
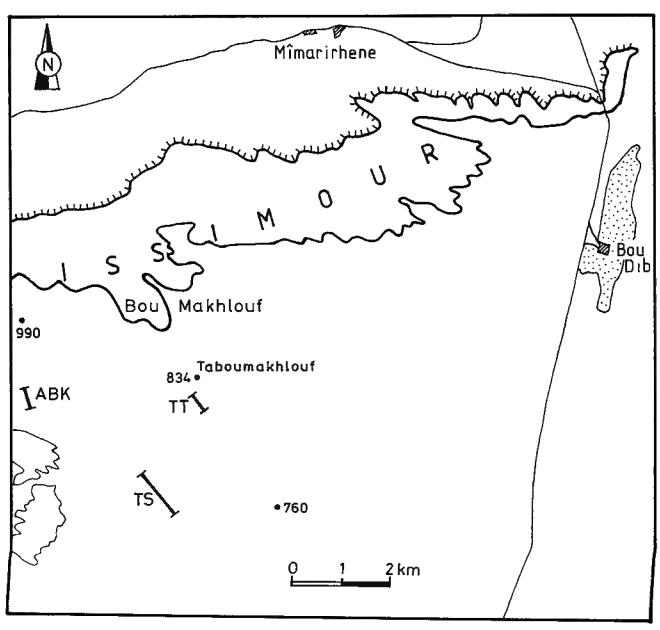


Fig. 5. – *Geological sketch map of the Ma'der showing the five sections referred to in the text (modified from* HOLLARD, *1974, Fig. 1); location of more detailed map (Fig. 6) shown by small rectangle with sections ABK, TT and TS. Inset map of part of Morocco shows location of the Ma'der.*



In the Ma'der area, about 100 km SW from Erfoud, three sections in the NW part of the Issimour arch, Akka Bou Khedach (ABK), Taboumakhlouf Terrasse (TT) and Taboumakhlouf South (TS), constitute a complete uppermost Eifelian-Givetian succession. The sequence, about 240 m thick, extends from the Taboumakhlouf Formation into the Middle Member of the Bou Dib Formation (HOLLARD, 1974 and 1981) The lithology, described by HOLLARD (1974, pp. 49-56), and the macrofauna, mainly brachiopods, corals at some levels and sparcely occurring goniatites, reflect a deeper shelf environment.

Fig. 6. – *Sketch map of the NW part of the Issimour arch showing the position of measured sections Akka Bou Khedach (ABK), Taboumakhlouf Terrasse (TT) and Taboumakhlouf South; detail of Ma'der map (Fig. 5).*

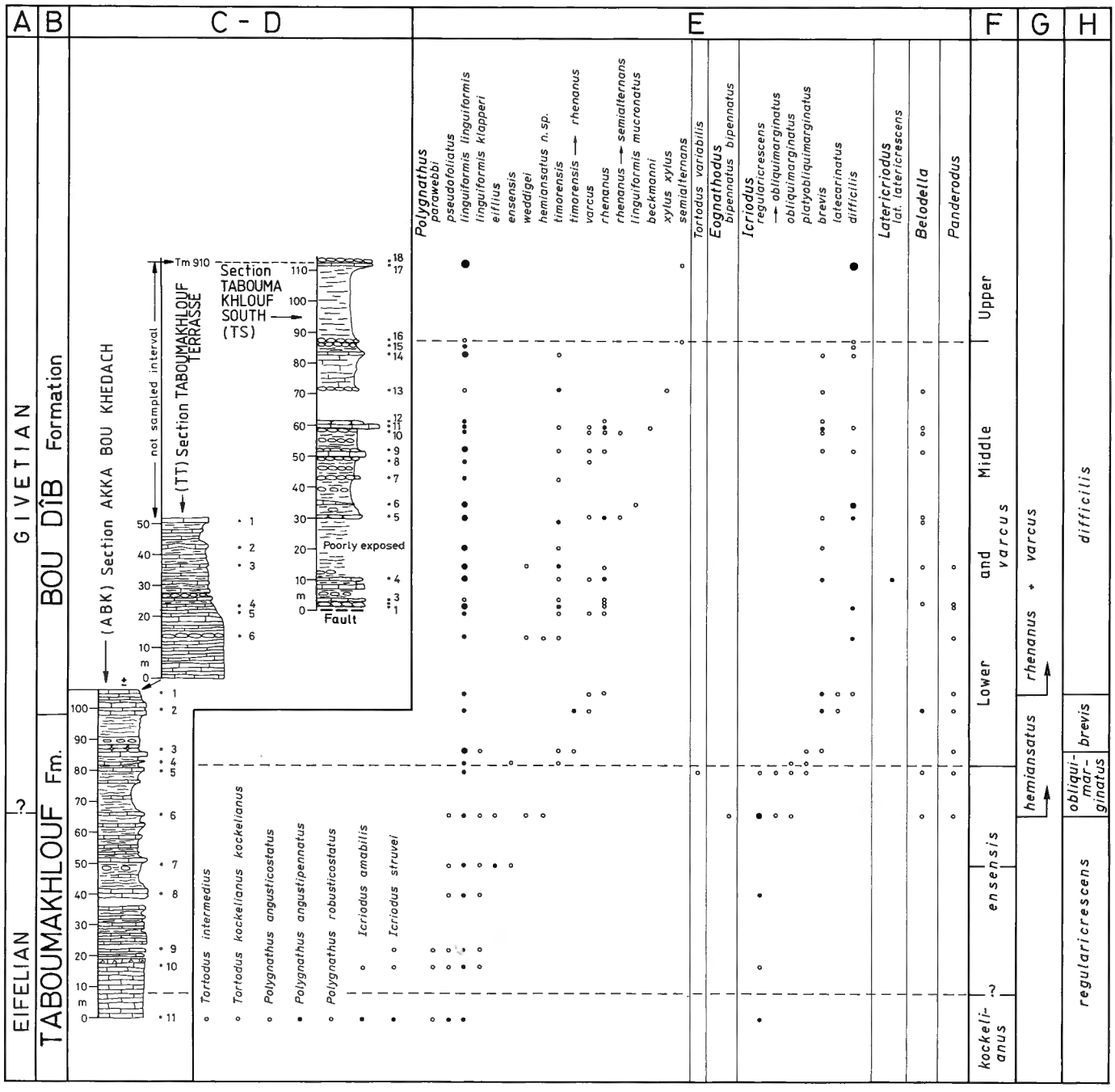


Fig. 7. – *Conodont distribution and frequency in sections Akka Bou Khedach, Taboumakhlouf Terrasse and Taboumakhlouf South. Columns A-H: see figure 4.*

Conodont frequency is a little lower than in the Bou Tchrafine section and varies between about 20 and 100 specimens/kg. *Polygnathus* species are dominant, although not so abundant as in the Bou Tchrafine section. *Icriodus* species occur regularly and are abundant at some levels.

The conodont standard zonation from the *kockelianus* Zone into the Upper *varcus* Subzone is partially recognized. It proved impossible to separate the Lower from the Middle *varcus* Subzone and the base of the Upper *varcus* Subzone is indicated approximatively by the earliest occurrence of *P. semialternans*. Of the three new critical entries of *Polygnathus* species in the Bou Tchrafine section, two occur at the same stratigraphic position: *P. hemiansatus* in sample ABK 6, and *P. rhenanus* together with *P. varcus* in sample ABK 1. The alternative *Icriodus* zonation is also recognized.

III. Systematic Palaeontology

Representatives of taxa mentioned in the range charts (Figs. 2, 4, 7, 9) are figured in plates 4-9 and in figure 8. *Eognathodus bipennatus bipennatus, Icriodus brevis, I. eslaensis, I. excavatus, I. lindensis, I. obliquimarginatus, I.* aff. *I. arkonensis, Polygnathus ansatus, P. ensensis, P. rhenanus, P. semialternans* and *P. timorensis* are discussed below. *Icriodus lilliputensis* n. sp., *I. obesus* n. sp., *I. platyobliquimarginatus* n. sp. and *Polygnathus hemiansatus* n. sp. are established. All remarks and descriptions refer to Pa elements.

Genus *Eognathodus* PHILIP, 1965
Eognathodus bipennatus bipennatus (BISCHOFF & ZIEGLER, 1957)
(Plate 9, Figures 1-10)

* 1957 *Spathognathodus bipennatus* n. sp. — BISSCHOFF & ZIEGLER, pp. 115-116, Pl. 21, Fig. 31.

Remarks:
The upper side of the platform of the holotype of *E. bipennatus bipennatus* is characterized by a relatively well developed medial groove or depression extending from just behind the high convex blade almost to the posterior end. On both sides the depression is flanked by a row of low nodes or transversal ridges. I distinguish two morphotypes of *E. bipennatus bipennatus.* In the alpha morphotype (Pl. 9, Figs. 1-5) the medial groove is relatively narrow, does not extend so far posteriorly as in the holotype and is flanked on both sides by a smooth of weakly nodose ridge. The beta morphotype (Pl. 9, Figs. 8-10) is very similar to the holotype. However, the beta morphotype includes specimens with a much broader medial depression than in the holotype. In the Mont d'Haurs section the alpha morphotype appears earlier than the beta morphotype. The angle between the anterior margins and the lower margin can be slightly sharp, right of slightly obtuse, contrary to the opinion of WEDDIGE (1977).

Genus *Icriodus* BRANSON & MEHL, 1938
Icriodus brevis STAUFFER, 1940
(Plate 6, Figures 1-14)

* 1940 *Icriodus brevis* n. sp. — STAUFFER, p. 424, pl. 60, figs. 30, 43, 44, 52.
1972 *Icriodus eslaensis* assemblage — BULTYNCK, p. 81, *partim,* figs. 14, B-C; non figs. 13, A, E, F = *I. lindensis.*
1975 *Icriodus brevis* STAUFFER, 1940 — KLAPPER *in* ZIEGLER (ed.), pp. 89-90, pl. 3, figs. 1-3.

Remarks:
The denticulation pattern on the spindle of *Icriodus brevis, I. eslaensis* and *I. lindensis* is identical: the medial-row and lateral-row denticles are discrete and of equal size with a tendency to alternation; in the medial row denticles can be intercalated. The extension of the medial-row denticles posterior of the spindle is relatively long: 3 to 5 denticles. The three species can be distinguished on the basis of the outline of the posterior extension in lateral view. In *I. brevis* the denticles of this posterior extension are not markedly higher than the denticles on the spindle, the general outline of the extension is slightly fan-shaped, the highest denticle being at mid-length. The cusp is inclined and generally wider than the other denticles of the extension. For differences with *I. eslaensis* and *I. lindensis*: see below under the discussion of these species.

Icriodus eslaensis VAN ADRICHEM BOOGAERT, 1967
(Figure 8, a-f)

* 1967 *Icriodus eslaensis* n. sp. — VAN ADRICHEM BOOGAERT, pp. 180-181, figs. 9, 10, 12; 11?

Remarks:
There is much confusion about the status of this taxon. According to SEDDON (1970), the types of this species belong to *I. obliquimarginatus.* KLAPPER *in ZIEGLER (1975, ed.) considers the taxon synonymous with I. brevis* and WEDDIGE (1977) includes one of the primary types of *I. eslaensis* in *I. lindensis.*
After a restudy of the figured types and additional material from the sample containing the holotype that is figured here I consider the taxon as valid. It can be separated from *I. brevis* and *I. lindensis* by the outline of the posterior extension of the medial-row denticles behind the spindle. The first denticles of the posterior extension, 2 to 4, are relatively small, the cusp behind is markedly higher and wider.
See also under *I. brevis* and *I. lindensis.*

Icriodus excavatus WEDDIGE, 1984
(Plate 6, Figures 21-25)

* 1984 *Icriodus excavatus* n. sp. — WEDDIGE, p. 208, pl. 1, figs. 9-22.

Remarks:
In his diagnosis of *I. excavatus,* WEDDIGE (1984) mentions that there is not always a medial depression in the posterior part of the spindle. The figured type material of *I. excavatus* can be subdivided into a more slender morphotype on the one hand to which the holotype and four paratypes (Pl. 1, Figs. 10-13) all from the sample DaI6 belong — and a broad strongly biconvex morphotype (Pl. 1, Figs. 15-22) from a series of samples from another locality on the other hand. Specimens from the Givet Limestone assigned to *I. excavatus* all belong to the first morphotype and the middle-row denticles always lie in a depression in the

posterior part of the spindle. In the Givet Limestone occur also specimens similar to the broad biconvex morphotype. However, these specimens never have a depression in the posterior part of the spindle. Therefore they are not included in *I. excavatus* and described below as a new species *I. obesus*. Previously, BULTYNCK (1972 and 1979) figured these forms as *Icriodus* n. sp. a assemblage and *I.* aff. *I. subterminus*. WEDDIGE (1977) included them in *I. subterminus*; the same author (1984) assigned them to *I. excavatus*. See also under *I. obesus*.

Icriodus lindensis WEDDIGE, 1977
(Plate 4, Figures 17-22)

1972 *Icriodus eslaensis* assemblage — BULTYNCK, p. 81, *partim*, figs. 14, A, E, F.
* 1977 *Icriodus lindensis* n. sp. — WEDDIGE, pp. 293-294, pl. 2, figs. 38-39.

Remarks:
The spindle of *I. lindensis* is slightly biconvex. The 3 to 4 denticles of the posterior extension of the middle row increase regularly in height. The cusp is a little higher and wider than the other denticles and slightly to strongly reclined. In representative specimens of *I. lindensis* the posterior extension of the middle row is slightly curved in upper view.
See also under *I. brevis* and *I. eslaensis*.

Icriodus lilliputensis n. sp.
(Plate 5, Figures 13-19)

1977 *Icriodus subterminus* YOUNGQUIST, 1947 — WEDDIGE, pp. 297-298, pl. 3, figs. 44, 45.

Derivatio nominis:
Lilliputensis, from Lilliput, referring to the small size of the species.

Types:
Holotype. I.R.Sc.N.B. N° b1893 (= Pl. 5, Fig. 14).
Paratypes. I.R.Sc.N.B. N° b1892, N° b1984, N° b1895, N° b1896, N° b1897, N° b1898 (= Pl. 5, Figs. 13, 15-19).

Locus typicus:
Givet (France), Mont d'Haurs, section D.

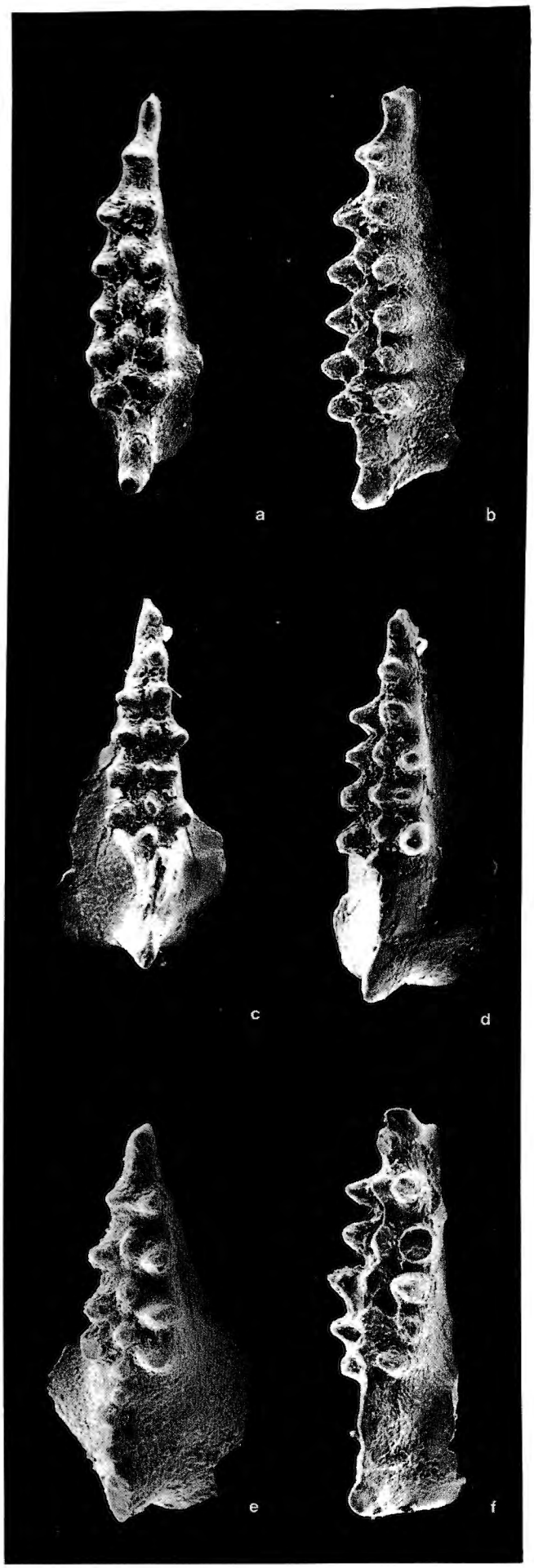


Fig. 8. – Icriodus eslaensis *VAN ADRICHEM BOOGAERT 1967 (× 120) a-d, f: upper and oblique-lateral views of RGM383192-2, -1 and -4; Rio Esla area, Cantabrian mountains (Spain), sample IV-C-74 in VAN ADRICHEM BOOGAERT (1967), stratum typicum of* I. eslaensis*; specimens preserved at Rijksmuseum van Geologie en Mineralogie, Leiden (The Netherlands). e: upper view of I.R.Sc.N.B. N° b1857; sample Mont d'Haurs 53.*

Stratum typicum:
Givet Group, Trois Fontaines Formation, phase 7, sample 27.

Diagnosis:
Spindle short with biconvex or triangular outline. Four to five pairs of rounded to slightly oval-shaped lateral-row denticles on spindle and five to six rounded medial-row denticles. Medial-row denticles may be connected by a longitudinal ridge and they are at the same height as the lateral-row denticles. High and straight anterior rim in lateral view and with prominent denticle. Posterior extension of medial row with two to four fused denticles and not markedly higher than the other denticles. Cusp slightly inclined. Basal cavity moderately expanded in the posterior half of the unit and with a weak or prominent spur.

Remarks:
I. lilliputensis is similar to *I. subterminus*. However, in the latter species the denticles of the middle row are lower than those of the lateral rows and the denticles of the posterior extension of the middle row are abruptly and much higher than the others.

Icriodus obesus n. sp.
(Plate 6, Figures 15-20)

1972 *Icriodus* n. sp. a assemblage — BULTYNCK, p. 82, figs. 16, A-E.
1979 *Icriodus* aff. *I. subterminus* — BULTYNCK *in* BRICE *et al.*, p. 334, pl. 27, figs. 28, 29, 32.

Derivatio nominis:
Obesus, Latin, fat, referring to the strongly biconvex outline of the spindle.

Types:
Holotype. I.R.Sc.N.B. N° b1913 (= Pl. 6, Fig. 15).
Paratypes. I.R.Sc.N.B. N° b1914, N° b1915, N° b1916, N° b1917, N° b1918 (= Pl. 6, Figs. 16-20).

Locus typicus:
Givet (France), Mond d'Haurs, section D.

Stratum typicum:
Givet Group, Mont d'Haurs Formation, phase 11, sample 50.

Diagnosis:
Spindle thick-set and strongly biconvex, upper surface flat. Four to six pairs of rounded to oval-shaped lateral-row denticles, usually slightly smaller. Lateral-row denticles well spaced. Short and broad posterior extension of medial row with two or three fused denticles and at the same level as the other denticles on the spindle. Nearly symmetrical and very broadly expanded basal cavity; expansion starting near the anterior termination; weak spur may be present.

Remarks:
I. obesus is similar to *I. amabilis* BULTYNCK & HOLLARD, 1980. However, specimens of the latter species have the posterior half of the middle row set higher than the lateral rows and the expanded part of the basal cavity is much more posteriorly located.
In *I. excavatus* the basal cavity is markedly asymmetric and the medial-row denticles lie in a depression in the posterior part of the spindle. The variation of *I. excavatus* also includes more slender morphotypes.
See also under *I. excavatus*.

Icriodus obliquimarginatus
BISCHOFF & ZIEGLER, 1957
(Plate 4, Figures 7-10, 12-16)

* 1957 *Icriodus obliquimarginatus* n. sp. — BISCHOFF & ZIEGLER, pp. 62-63, fig. 14.

Remarks:
Most specimens assigned here to *I. obliquimarginatus* perfectly demonstrate the diagnostic features mentioned in the emended diagnosis of WEDDIGE (1977). In the present study typical specimens of *I. obliquimarginatus* are restricted to the upper part of the *ensensis* Zone and the lower part of the Lower *varcus* Subzone. Below the range of *I. obliquimarginatus*, *Icriodus* specimens occur, which are very similar to *I. obliquimarginatus*. However, they differ from the latter by the high posterior cusp and the straight posterior extension of the medial row. Such specimens, figured by BULTYNCK (1970, Pl. 8, Figs. 2, 4, 7, 8) were included by WEDDIGE (1977) in *I. obliquimarginatus*. They are considered here as transitional forms between *I. regularicrescens* and *I. obliquimarginatus*. In most specimens recorded from the neritic shallow water facies (Givet Limestone) the denticles on the spindle are discrete, whereas specimens from the pelagic facies (Bou Tchrafine Group) develop irregular transversal ridges on the spindle.
See also under *I. platyobliquimarginatus*.

Icriodus platyobliquimarginatus n. sp.
(Plate 5, Figures 1-9)

1970 *Icriodus obliquimarginatus* BISCHOFF & ZIEGLER — BULTYNCK, pp. 109-110, *partim,* pl. 8, figs. 1, 5; non pl. 8, fig. 3 = *I. obliquimarginatus.*
1972 *Icriodus* aff. *I. obliquimarginatus* assemblage — BULTYNCK, p. 81, figs. 13, C, D.
1974 *Icriodus* aff. *I. obliquimarginatus* — COEN, BULTYNCK & PEL, pp. 13-16.

Derivato nominis:
Platys, from πλατυς, Greek, broad + *obliquimarginatus,* referring to the broad spindle and the similarity to *I. obliquimarginatus.*

Types:
Holotype. I.R.Sc.N.B. N° b1881 (= Pl. 5, Fig. 2).
Paratypes. I.R.Sc.N.B. N° b1880, N° b1882, N° b1883, N° b1884, N° b1885, N° b1886, N° b1887, N° b1888 (Pl. 5, Figs. 1, 3-9).

Locus typicus:
Menil (Belgium), section described in COEN, BULTYNCK & PEL (1974, pp. 14-16).

Stratum typicum:
Givet Group, trois-Fontaines Formation, sample 67 in COEN, BULTYNCK, PEL (1974, p. 16).

Diagnosis:
Rather robust form. Spindle broad, with triangular to slightly biconvex outline, widest posteriorly. Four to five pairs of transversely expanded and well-spaced lateral-row denticles on spindle and five to seven rounded to elongate medial-row denticles, slightly smaller than the lateral-row denticles. Medial-row denticles mostly connected by a longitudinal ridge that reaches the anterior termination. Posterior extension of the middle row with four to seven denticles and with arcuate profile, highest medially and with moderately to strongly reclined posterior border. Nearly symmetrical basal cavity, broadly expanded posteriorly.

Remarks:
I. platyobliquimarginatus is distinguished from *I. obliquimarginatus* by possessing a distinctly broader spindle and by the different outline of the basal cavity.

Icriodus aff. *I. arkonensis*
(Plate 6, Figures 26-30)

Remarks:
The specimens identified herein as *I.* aff. *arkonensis* are similar to *I. arkonensis* STAUFFER, 1938 by the biconvex to slightly triangular outline of the platform, the transversely expanded lateral-row denticles, the smaller medial-row denticles connected by a longitudinal ridge and the outline of the basal with a prominent spur. However, in the specimens at hand the median ridge is less prominent, they have fewer denticles on the spindle and the posterior extension of the middle row is distinctly longer.

Genus *Polygnathus* HINDE, 1879
Polygnathus ansatus ZIEGLER & KLAPPER, 1976
(Plate 8, Figures 10-14)

* 1976 *Polygnathus ansatus* n. sp. — ZIEGLER & KLAPPER *in* ZIEGLER, KLAPPER & JOHNSON, pp. 119-120, figs. 11-26.

Remarks:
The specimens identified herein as *P. ansatus* are characterized by the distinct outward bowing of the outer and inner anterior trough margins. The trough margins, especially the outer, are relatively long. In specimens from the Lower Member of the Fromelennes Formation identified as *P.* aff. *P. ansatus* (Pl. 8, Fig. 9) the outward bowing of the anterior trough is only weakly indicated and the anterior trough margins are shorter than in typical specimens of *P. ansatus*. See also under *P. hemiansatus*.

Polygnatus ensensis ZIEGLER & KLAPPER, 1976
(Plate 7, Figures 1-6)

1970 *Polygnatus xyla* STAUFFER, 1940 — BULTYNCK, p. 131, *partim,* pl. 15, figs. 2, 8, non fig. 5 = *P. pseudofoliatus.*
1974 *Polygnathus varcus* group — BULTYNCK & GODEFROID, pp. 13-15.
* 1976 *Polygnathus xylus ensensis* n. subsp. — ZIEGLER & KLAPPER *in* ZIEGLER, KLAPPER & JOHNSON, pp. 121-127, pl. 3, figs. 4-9.
1977 *Polygnathus xylus ensensis* ZIEGLER and KLAPPER, 1976 — WEDDIGE, pp. 321-322, *partim,* pl. 4, figs. 62, 64, 65?, non fig. 63 = juvenile specimen of *P. pseudofoliatus* or *P. eiflius.*
1980 *Polygnathus* aff. *P. xylus ensensis* ZIEGLER, W. and KLAPPER, G., 1976 — BULTYNCK & HOLLARD, p. 46, pl. 6, fig. 1.

Remarks:
Characteristic features of specimens identified herein as *P. ensensis* include the distinctly serrated anterior platform margins, the straight to steeply downward declined anterior trough margins, meeting the blade at the same position and the posteriorly down-arched platform. In specimens transitional between *P. ensensis* and *P. timorensis* (Pl. 7, Figs. 7, 8) only one of the anterior platform margins is serrated and the anterior trough margins decline less steeply downward.

Polygnathus hemiansatus n. sp.
(Plate 7, Figures 16-27; Plate 8, Figures 1-7)

1980 *Polygnathus* aff. *P. ansatus* ZIEGLER, W. and KLAPPER, G., 1976 — BULTYNCK & HOLLARD, p. 42, pl. 5, fig. 18; pl. 6, figs. 2-4.
1985 *Polygnathus ansatus* ZIEGLER and KLAPPER, 1976, early morphotype — BULTYNCK, p. 269, pl. 6, figs. 19, 20.
1987 *Polygnathus ansatus* ZIEGLER and KLAPPER, 1976 — GARCIA-LOPEZ, pp. 86-87, *partim,* pl. 11, fig. 23; pl. 12, figs. 1-6, 9; non pl. 12, figs. 7, 8, 10-13.

Derivatio nominis:
Hemi, from ἡμι, Greek, half + *ansatus,* referring to the similarity to *P. ansatus.*

Types:
Holotype. I.R.Sc.N.B. N° b1953 (= Pl. 7, Fig. 26).
Paratypes. I.R.Sc.N.B. N° b951 (= Pl. 5, Fig. 18 in BULTYNCK & HOLLARD, 1980), N° b954 - N° b955

(= Pl. 6, Figs. 2-3 in BULTYNCK & HOLLARD, 1980), N° b1943 - N° b1952, N° b1954 - N° b1958 (= Pl. 7, Figs. 16-25, 27, Pl. 8, Figs. 1-4).

Locus typicus:
Erfoud (Morocco), Bou Tchrafine section described herein.

Stratum typicum:
Bou Tchrafine Group, "Talus Médian", sample 15ter.

Diagnosis:
Platform with a strong constriction at the outer geniculation point, located at the anterior third of the platform, and with a pronounced convex expansion of the platform margin posterior of this point. Outer anterior trough margin strongly bowed outward. Inner platform margin nearly straigth without an outward bowing of the anterior trough margin and serrated just anterior of the geniculation point. Inner anterior trough margin declining steeply downward. Two geniculation points generally not opposite and junction of two anterior trough margins with blade at slightly different position. Platform ornamentation nodose to ridged. Blade about half the length of the unit or a little longer and with numerous denticles of about equal height.

Remarks:
Platform characteristics of the new species are best demonstrated in the paratype N° b1955 (Pl. 8, Fig. 1). However, the blade of this specimen is incomplete and therefore the specimen is not designated as Holotype. Lower views of *P. hemiansatus* are figured in BULTYNCK & HOLLARD (1980, Pl. 5, Fig. 18b and Pl. 6, Fig. 3b).
P. hemiansatus can be distinguished from *P. ansatus* by the straight inner platform margin and by the missing outward bowing of the inner anterior trough margin. I recognize a more slender (Pl. 7, Fig. 25) and a broader morphotype (Pl. 7, Fig. 16). The less ornamentated platform, the more sagitate platform outline and the deeper adcarinal troughs distinguish *P. timorensis* from the slender morphotype of *P. hemiansatus*.

Polygnathus rhenanus KLAPPER, PHILIP & JACKSON, 1970 (Plate 7, Figures 13-15)

* 1970 *Polygnathus rhenanus* sp. nov. — KLAPPER, PHILIP & JACKSON, pp. 654-655, pl. 2, figs. 13-15, 19-22.
1980 *Polygnathus rhenanus* KLAPPER, G., PHILIP, G.M. et JACKSON, J.H., 1970 — BULTYNCK & HOLLARD, p. 45, pl. 6, figs. 15-17.
1981 *Polygnathus rhenanus marijae* n. subsp. — HUDDLE, p. 1132, *partim*, pl. 17, figs. 10-12 (= holotype), non figs. 16-18, ?figs. 19-27.

Remarks:
P. rhenanus can be distinguished from *P. timorensis* by the more posterior position of the outer geniculation point, located between one-third to one-half of the total length of the outer platform margin. Moreover, *P. rhenanus* is characterized by the more pronounced outward bowing of the outer anterior trough margin and the extremely long blade that is about two-thirds the length of the unit. The presence or absence of ornamentation on the platform margins is not regarded as diagnosticly important. Specimens with a strongly reduced platform (Pl. 8, Fig. 23) are considered here as transitional with *P. semialternans*.

Polygnathus semialternans (WIRTH, 1967)

* 1967 *Spathognathodus semialternans* n. sp. — WIRTH, p. 235, pl. 23, figs. 6-10; fig. 14a, b.
1976 *Ozarkodina semialternans* (WIRTH) — ZIEGLER & KLAPPER *in* ZIEGLER, KLAPPER & JOHNSON, pp. 118-119, pl. 3, figs. 22-34.
1980 *Polygnathus semialternans* (WIRTH, M., 1967) — BULTYNCK & HOLLARD, p. 45, pl. 8, figs. 5-6.

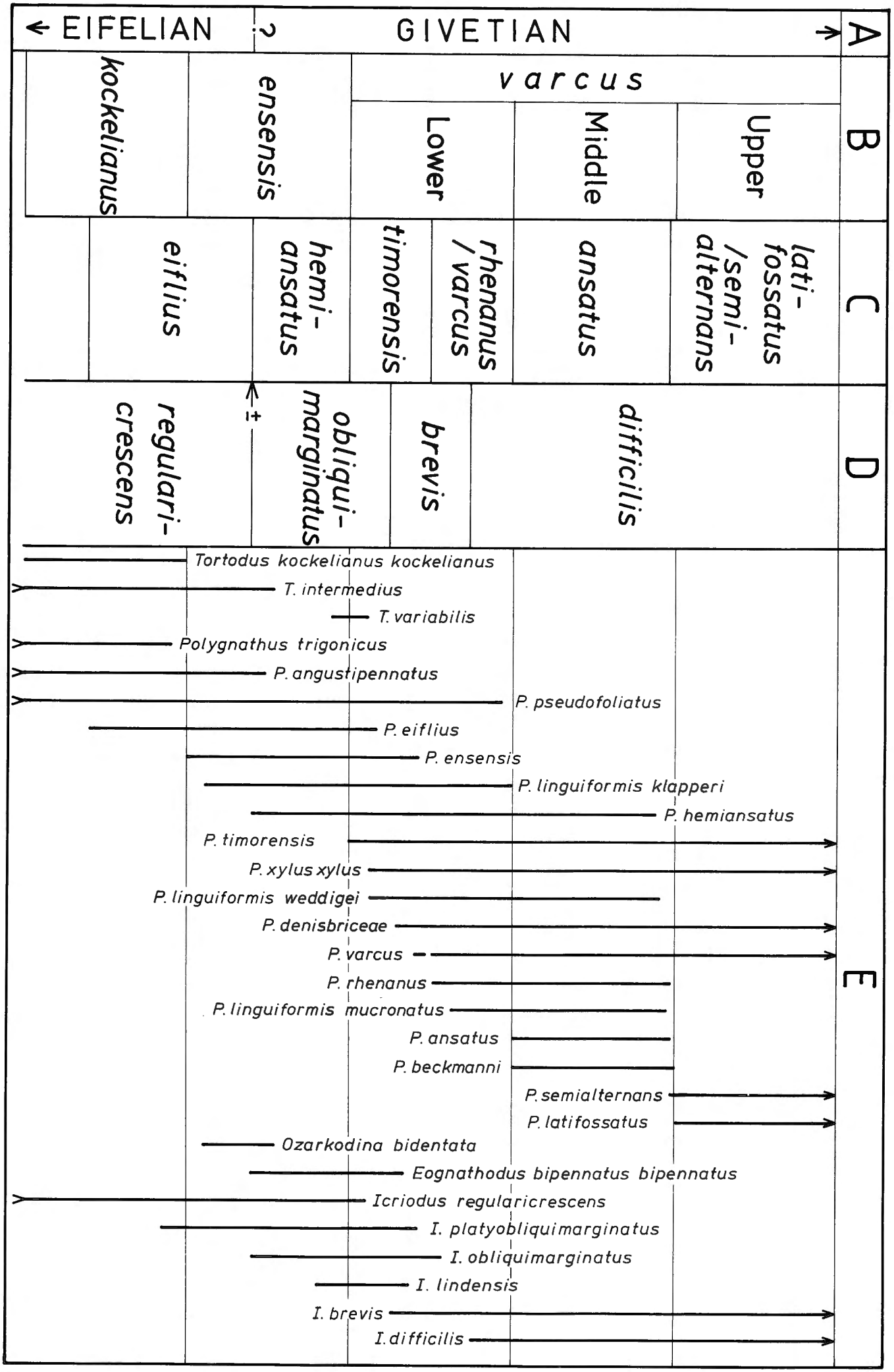
Remarks:
Representative Moroccan specimens of *P. semialternans* are illustrated in BULTYNCK & HOLLARD (1980). The occurrence of forms transitional between *P. rhenanus* (see under *P. rhenanus*) and *P. semialternans* suggests that the latter was derived from *P. rhenanus*. Consequently, the species is assigned here to the genus *Polygnathus*.

Polygnathus timorensis KLAPPER, PHILIP & JACKSON, 1970 (Plate 7, Figures 9-10)

* 1970 *Polygnathus timorensis* sp. nov. — KLAPPER, PHILIP & JACKSON, pp. 655-656, pl. 1, figs. 1-3, 7-10.
1974 *Polygnathus rhenanus* KLAPPER, G., PHILIP, G.M. et JACKSON, J.H., 1970 — BULTYNCK, p. 23, *partim*, pl. 5, fig. 1.
1976 *Polygnathus timorensis* KLAPPER, PHILIP & JACKSON — ZIEGLER & KLAPPER in ZIEGLER, KLAPPER & JOHNSON, p. 125, pl. 2, figs. 27-32, pl. 3, fig. 10.
1980 *Polygnathus timorensis* KLAPPER, G., PHILIP, G.M. et JACKSON, J.H., 1970 — BULTYNCK & HOLLARD, p. 45, pl. 6, figs. 8-13.
1985 *Polygnathus timorensis* KLAPPER, PHILIP & JACKSON, 1970 — BULTYNCK, pl. 6, figs. 17-18.

Remarks:
Differences with *P. hemiansatus* and with *P. rhenanus* are discussed under these species.

Fig. 9. – *Ranges of selected conodont taxa in the uppermost Eifelian and lower-middle Givetian with respect to the conodont standard zonation (column B) and the alternative* Polygnathus *and* Icriodus *zonations (columns C and D); column A: see figure 4.* ▷


← EIFELIAN
?
GIVETIAN →
A
varcus
kockelianus
ensensis
Lower
Middle
Upper
B
eiflius
hemi-ansatus
timorensis
rhenanus / varcus
ansatus
lati-fossatus / semi-alternans
C
regulari-crescens
obliqui-marginatus
brevis
difficilis
D
Tortodus kockelianus kockelianus
T. intermedius
T. variabilis
Polygnathus trigonicus
P. angustipennatus
P. pseudofoliatus
P. eiflius
P. ensensis
P. linguiformis klapperi
P. hemiansatus
P. timorensis
P. xylus xylus
P. linguiformis weddigei
P. denisbriceae
P. varcus
P. rhenanus
P. linguiformis mucronatus
P. ansatus
P. beckmanni
P. semialternans
P. latifossatus
Ozarkodina bidentata
Eognathodus bipennatus bipennatus
Icriodus regularicrescens
I. platyobliquimarginatus
I. obliquimarginatus
I. lindensis
I. brevis
I. difficilis
E

IV. Conclusions

The most important conclusions of the present study can be derived from the range chart in figure 9. It shows the correlations of the newly refined local *Polygnathus* zonation (column C) established in the pelagic sequence from the Tafilalt area and of the alternative *Icriodus* zonation (column D), mainly based on the shallow water platform carbonates of the Givet Limestone in the Ardennes, with the standard conodont zonation from the *kockelianus* Zone up to the Upper *varcus* Subzone (column B). All zones and subzones are defined on the basis of first occurrences of one or two species. The reasons for proposing these alternative zonations are discussed in detail in the introduction and under the separate headings of the individual sections. In brief, they comprise different conodont biofacies encountered in the Givet Limestone; the differing taxonomic treatments of *Polygnathus ansatus* and finally the concept and definition of the *varcus* Zone and its subdivisions by ZIEGLER, KLAPPER & JOHNSON (1976).

The earliest occurrences of *Polygnathus eiflius* and *P. hemiansatus* are not only of local interest but here they are proposed to subdivide formally the *kockelianus* Zone and the *ensensis* Zone.

The range chart also summarizes the vertical distribution of 29 selected conodont taxa in the two studied areas. The range chart is compared with similar charts established for the same period by WEDDIGE (1977), CLAUSEN, LEUTERITZ & ZIEGLER (1979) and JOHNSON, KLAPPER & TROJAN (1980) for the northern Antelop Range (Nevada). The results of this comparison are presented in table 1.

On the range chart (Fig. 9) the position of the Eifelian-Givetian boundary (column 1) is shown with a question-mark, because definition by the Subcommission on Devonian Stratigraphy is pending. However, at the 1986 and 1987 Subcommission meetings a majority of the members favoured a level at the base of or within the *ensensis* Zone. The provisional positioning of the boundary in the range chart corresponds to the earliest occurrence of *P. hemiansatus* within the *ensensis* Zone. In the Bou Tchrafine section the entry of *P. hemiansatus* coïncides with that of *I. obliquimarginatus*. In the Givet Limestone of the type area the entry of the latter species is the most reliable first appearance that is closest to the base of this unit, historically the base for the Givetian stage. *P. hemiansatus* has also been recognized in sections in the Cantabrian Mountains (Spain) and in the Guangxi Province (South China). Consequently its lowest occurrence is considered here as a good potential level for the Eifelian-Givetian boundary.

Table 1

Reference	Number of taxa with same vertical range	Number of taxa with different earliest occurrence	Number of taxa with different latest occurrence
WEDDIGE (1977, tabl. 2, pp. 322-333)	11(a)	6(b)	8(c)
CLAUSEN *et al.* (1979, tabl. 7, p. 31)	8(d)	4(e)	3(f)
JOHNSON *et al.* (1980, tabl. 23, p. 98)	7(g)	3(h)	4(i)

a: *Eognathodus bipennatus bipennatus, Icriodus brevis, I. lindensis, Polygnathus ansatus, P. angustipennatus, P. latifossatus, P. linguiformis weddigei, P. pseudofoliatus, P. timorensis, P. xylus xylus, Tortodus variabilis;* b: *I. difficilis, Ozarkodina bidentata, P. beckmanni, P. eiflius, P. semialternans, T. intermedius;* c: *I. obliquimarginatus, I. regularicrescens, P. ensensis, P. linguiformis klapperi, P. linguiformis mucronatus, P. trigonicus, P. varcus, T. kockelianus kockelianus.*

d: *I. brevis, P. ansatus, P. latifossatus, P. linguiformis weddigei, P. pseudofoliatus, P. timorensis, P. varcus, P. xylus xylus;* e: *I. difficilis, P. beckmanni, P. linguiformis mucronatus, P. semialternans;* f: *I. obliquimarginatus, P. ensensis, P. linguiformis klapperi.*

g: *I. brevis, P. ansatus, P. beckmanni, P. ensensis, P. pseudofoliatus, P. timorensis, T. kockelianus kockelianus;* h: *I. difficilis, P. trigonicus, P. xylus xylus;* i: *I. obliquimarginatus, P. angustipennatus, P. eiflius, P. intermedius.*

V. Appendix: locality and sample index Mont d'Haurs section

France, IGN Mapsheet Givet (XXX-7), Mont d'Haurs fortification on the SE side of the Meuse at Givet. All the measured sections are on the south side of the fortification (Fig. 1). Meterage between samples indicated between brackets.

Section A: samples 1 (0.40 m above base of outcrop), 2 (0.90 m), 3 (1.60 m), 3bis (0.40 m), 4 (0.70 m), 5 (0.25 m), 6 (0.90 m), 6bis (0.50 m), 7 (0.45 m), 8 (0.25 m), 9 (0.45 m), 10 (0.65 m, top of outcrop).

Section B: samples 11 (base of outcrop), 12 (0.60 m), 12bis (0.25 m), 13 (0.80 m), 13bis (0.15 m), 14 (0.15 m), 15 (0.75 m), 16 (1.60 m), 17 (1.00 m).

Section C: sample 18 (17.80 m above base of outcrop); samples 19-23, barren.

Section D: samples 24 (base of outcrop), 25 (4.20 m), 26 (4.80 m), 26bis (0.60 m), 27 (0.60 m), 28 (3.45 m), 29 (2.95 m), 30 (2.55 m), 31 (0.40 m), 32 (0.40 m), 33 (5.80 m), 34 (0.15 m), 35 (1.30 m), 36 (13.50 m, poorly exposed), 36bis (0.30 m), 37 (0.45 m), 38 (0.65 m), 39 (1.90 m), 40 (0.45 m), 40bis (1.80 m), 41 (2.30 m, interruption in exposure just below sample), 41bis (1.75 m), 42 (2.10 m), 43 (2.25 m), 44 (1.80 m) 45 (2.35 m), 45bis (3.00 m), 46 (3.65 m), 47 (4.30 m), 47bis (0.80 m), 48 (0.70 m, interruption in section just above sample), 48bis (3.40 m), 49 (0.80 m), 50 (15.00 m), 51 (1.85 m), 52 (2.45 m), 53 (1.65 m).

Section E: samples 54 (9.00 m), 55 (11.00 m), 56 (11.50 m).

Section F: samples 57 (4.00 m, base of outcrop), 58 (0.25 m), 59 (1.10 m), 60 (0.30 m), 61 (0.30 m), 62 (0.40 m), 63 (32.00 m), 64 (4.50 m), 65 (5.00 m, 1 m below top of exposure).

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Dr. VAN DEN BOOGAARD (Rijksmuseum van Geologie en Mineralogie, Leiden, The Netherlands) kindly allowed me to study the types and additional material of *Icriodus eslaensis*; he also provided me photographies of *I. eslaensis* specimens from the stratum typicum (Fig. 8, a-f). Dr. WANG CHENG-YUAN (Nanjing Institute of Geology and Palaeontology, Academia Sinica) allowed me to figure a specimen of *Polygnathus hemiansatus* (Pl. 8, Fig. 5) recognized in his collection from the Sihongshan section, Guangxi Province (China). Specimens of *P. hemiansatus* and *P. ansatus* (Pl. 8, Figs. 6, 7 and 10, 11) from the Tully Limestone (New York, U.S.) are from samples collected during a joint field trip with Drs. P.H. HECKEL and G. KLAPPER (University of Iowa) in 1972.

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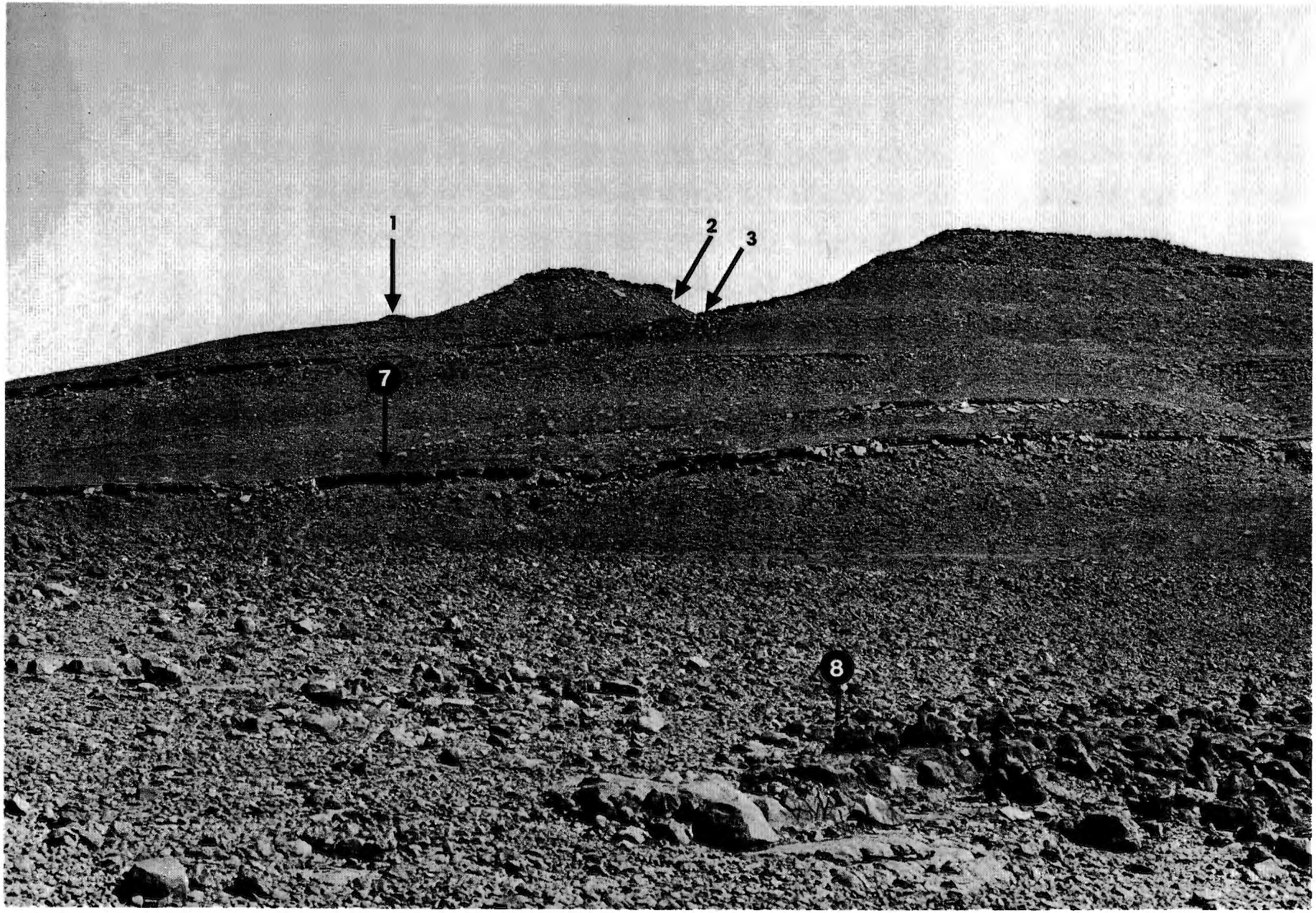
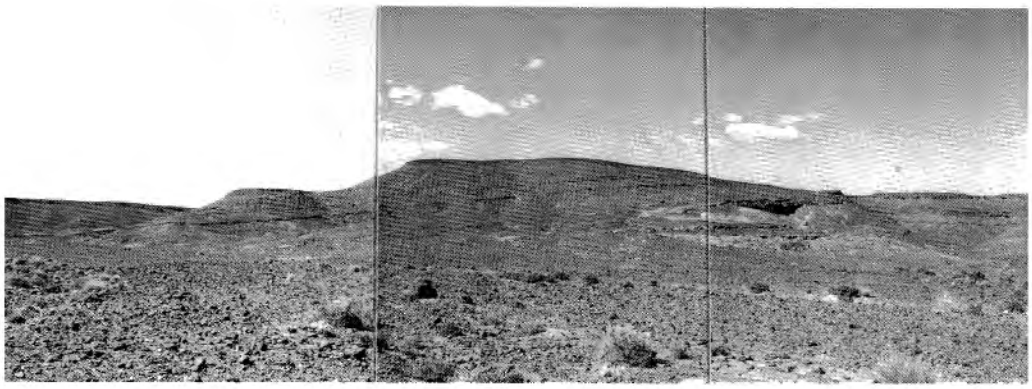


PLATE 1

Section Akka Bou Khedach, upper part with position of samples 1-3, 7 and 8.



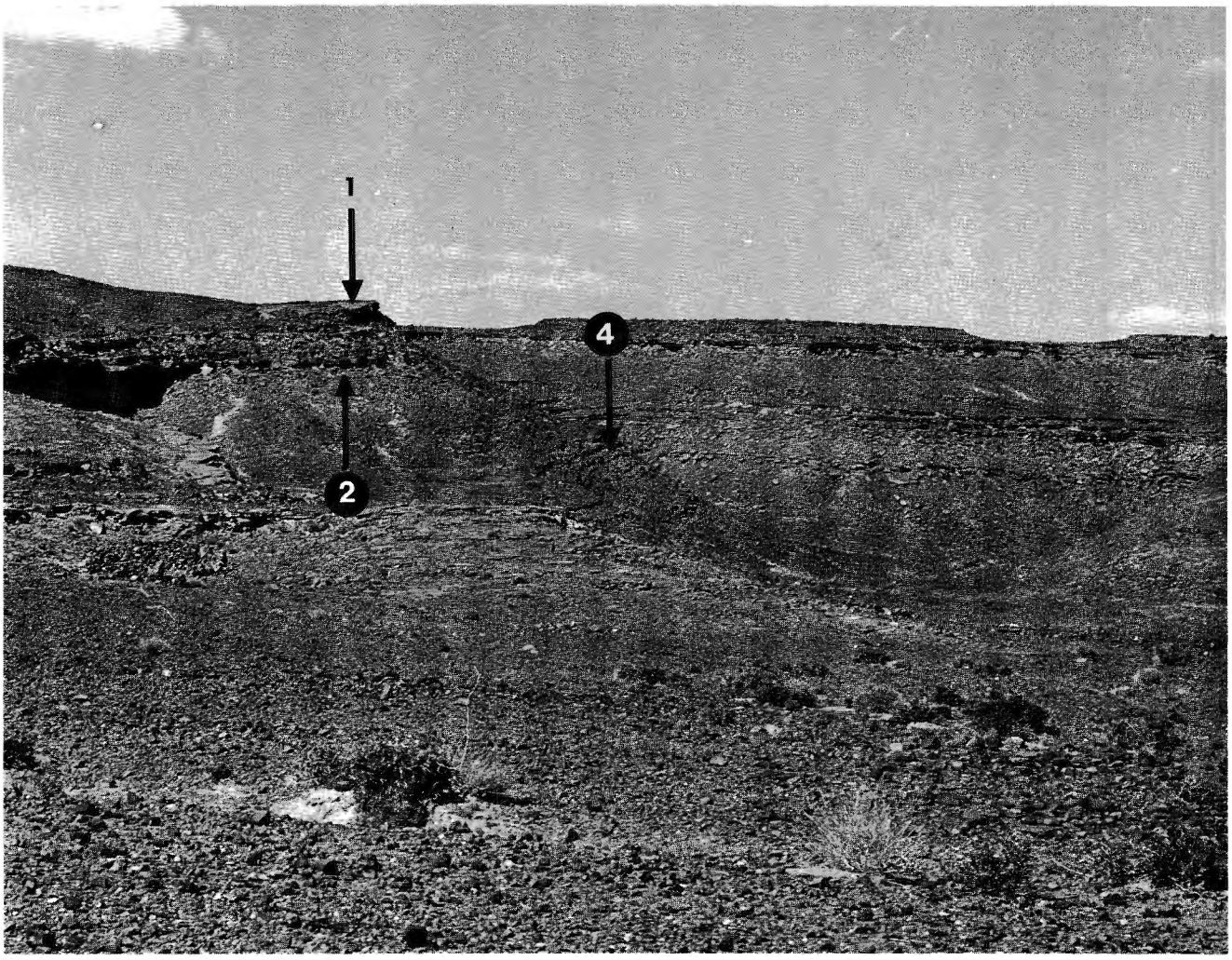


PLATE 2

Upper: section Taboumakhlouf Terasse, general view.
Lower: detail of the section with position of samples 1, 2 and 4.

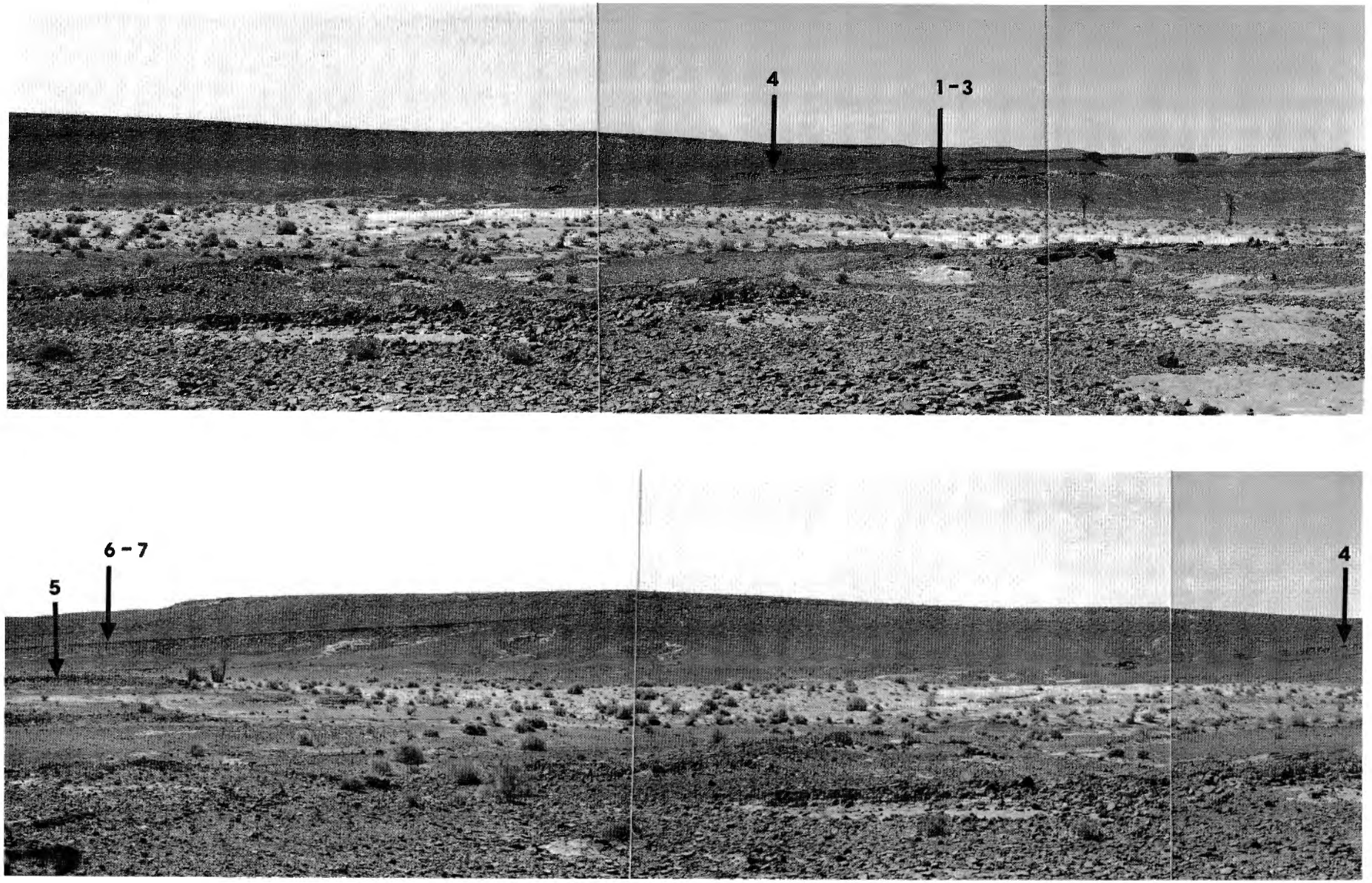


PLATE 3

NW part of section Taboumakhlouf South with position of samples 1 to 7; sample 1 is at the base and sample 3 at the top of the small cliff; sample 6 is 2.40 m below and sample 7 5.55 m above prominent bed.

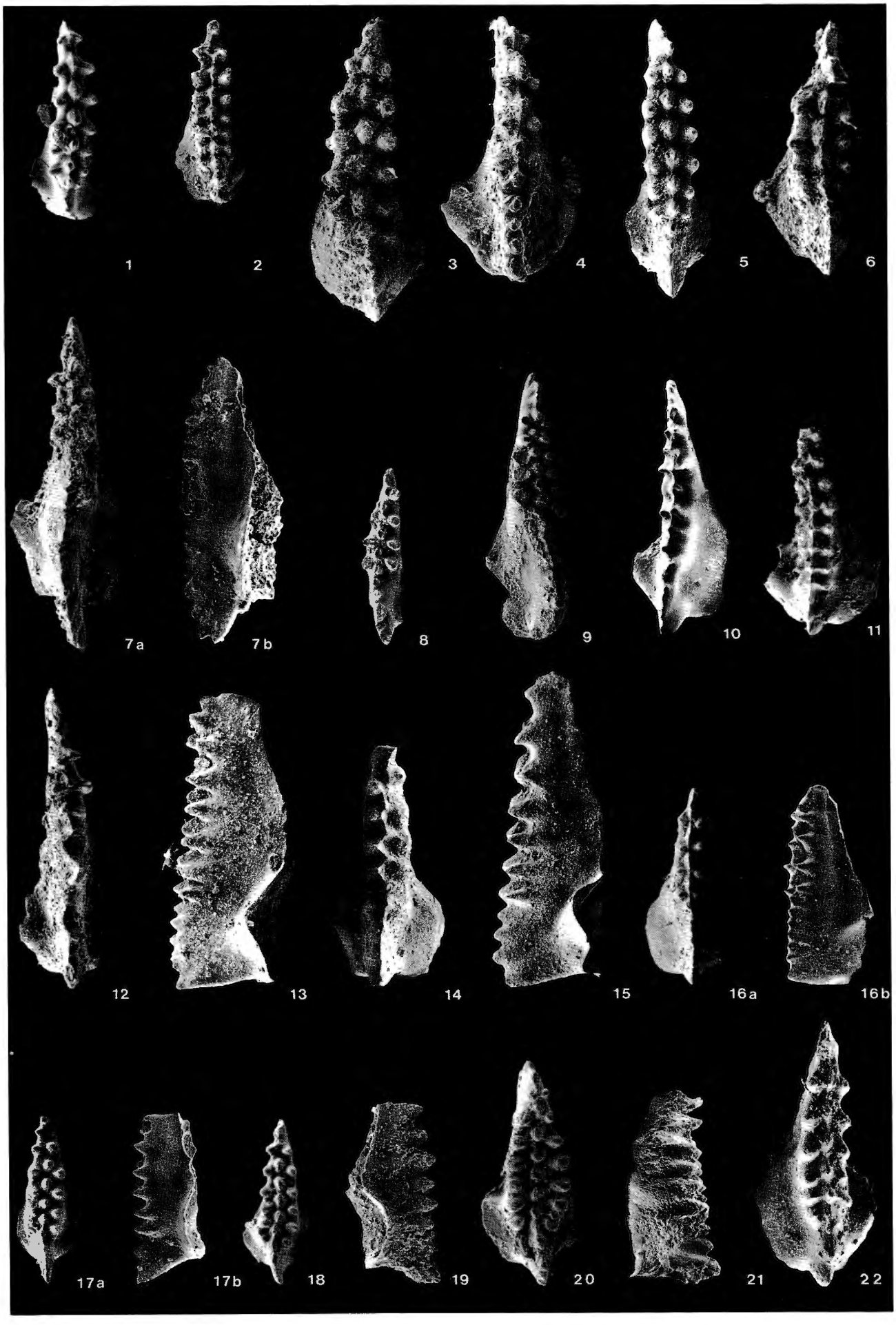

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PLATE 4

Magnification 45×, except where otherwise stated. MH: sample number Mont d'Haurs section; From: sample number Fromelennes section; BT: sample number Bou Tchrafine section; ABK: sample number Akka Bou Khedach section; H: sample number Haine Quarry (BULTYNCK & GODEFROID, 1974).

Figs. 1-3, 11. – Icriodus regularicrescens *BULTYNCK, 1970. Upper views of I.R.Sc.N.B. N° b1858 (65×), MH-10; N° b1859, ABK-6; N° b1860 (65×), BT-14; N° b1868, ABK-6.*

Figs. 4-6. – Icriodus regularicrescens *BULTYNCK, 1970* → Icriodus obliquimarginatus *BISCHOFF & ZIEGLER, 1957. Upper views of I.R.Sc.N.B. N° b1861 (100×), H-40; N° b1862, BT-14; N° b1863, BT-14.*

Figs. 7-10, 12-16. – Icriodus obliquimarginatus *BISCHOFF & ZIEGLER, 1957. Upper and lateral views of I.R.Sc.N.B. N° b1864, MH-3. Upper views of I.R.Sc.N.B. N° b1865 (65×), MH-42; N° b1866, Marenne B3; N° b1867, BT-19; N° b1869, BT-17. Lateral view of I.R.Sc.N.B. N° b1870, BT-19. Upper view of I.R.Sc.N.B. N° b1871, BT-23. Lateral view of I.R.Sc.N.B. N° b1872, BT-23. Upper and oblique-lateral views of I.R.Sc.N.B. N° b1873, BT-20.*

Figs. 17-22. – Icriodus lindensis *WEDDIGE, 1977. Upper and lateral views of I.R.Sc.N.B. N° b1874 (65×), MH-27. Upper view of I.R.Sc.N.B. N° b1875 (65×), MH-27. Lateral view of I.R.Sc.N.B. N° b1876 (65×), MH-40bis. Upper and lateral views of I.R.Sc.N.B. N° b1877 (65×), N° b1878 (65×), Marenne B12. Upper view of I.R.Sc.N.B. N° b1879, BT-19.*

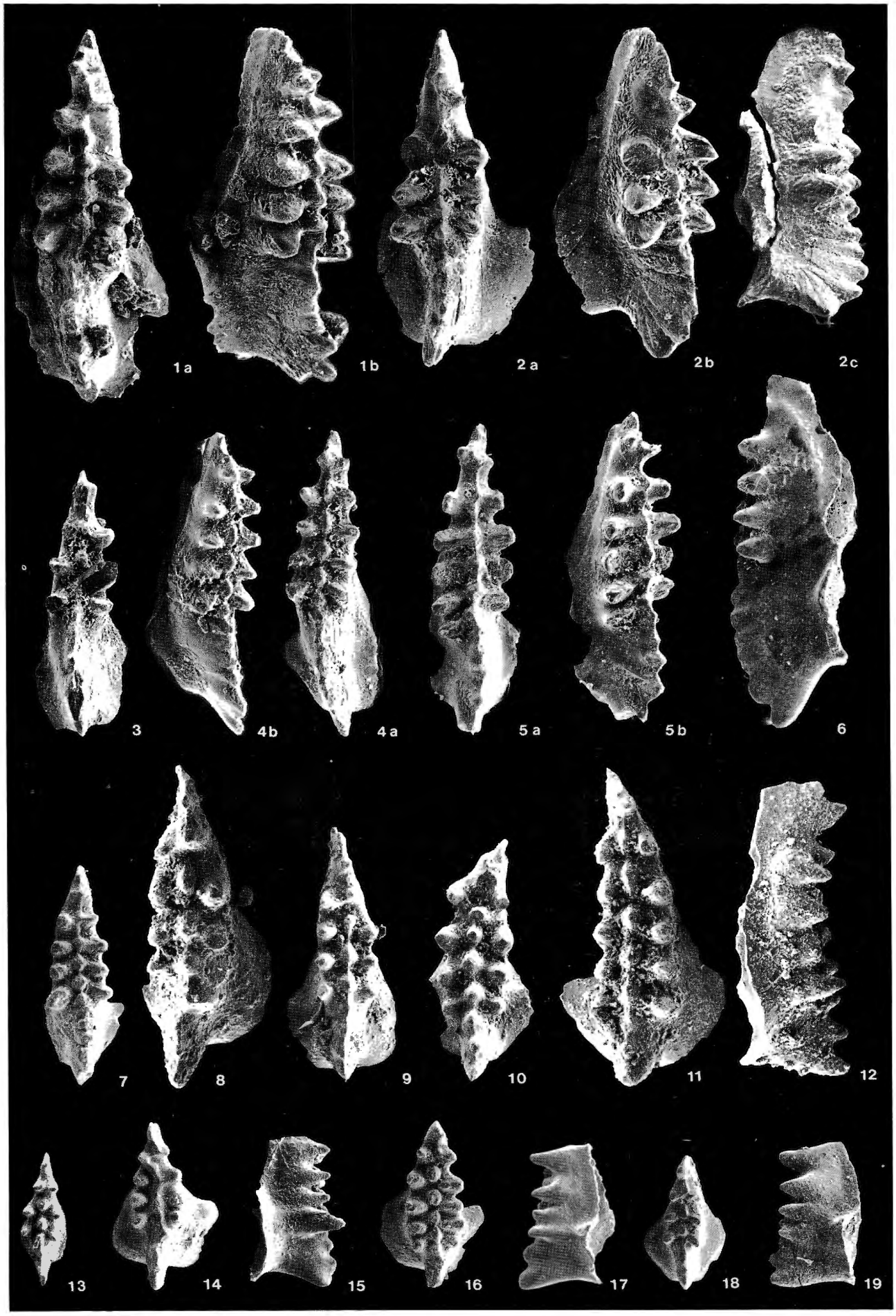
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PLATE 5

Magnification 65×, except where otherwise stated.

Figs. 1-9. – Icriodus platyobliquimarginatus *n. sp. Upper and oblique-lateral views of paratype I.R.Sc.N.B. N° b1880 (100×), Menil 010. Upper, oblique-lateral and lateral views of holotype I.R.Sc.N.B. N° b1881 (100×), Menil 67. Upper view of paratype I.R.Sc.N.B. N° b1882 (100×), Menil 67. Upper and oblique-lateral views of paratypes I.R.Sc.N.B. N° b1883 (100×), N° b1884 (100×), Menil 67. Lateral view of paratype I.R.Sc.N.B. N° b1885 (100=), Menil 67. Upper views of paratypes I.R.Sc.N.B. N° b1886, Marenne B7; N° b1887, BT-15; N° b1888 (45×), BT-15a.*

Figs. 10-12. – ?Icriodus struvei *WEDDIGE, 1977. Upper and lateral views of I.R.Sc.N.B. N° b1889 (45×), BT-15a; N° b1890, N° b1891, BT-15.*

Figs. 13-19. – Icriodus lilliputensis *n. sp. Upper view of paratype I.R.Sc.N.B. N° b1892, MH-27. Upper view of holotype I.R.Sc.N.B. N° b1893, MH-27. Lateral and upper views of paratypes I.R.Sc.N.B. N° b1894, MH-27; N° b1895, From W-4; N° b1896, N° b1897, MH-42; N° b1898, MH-43.*

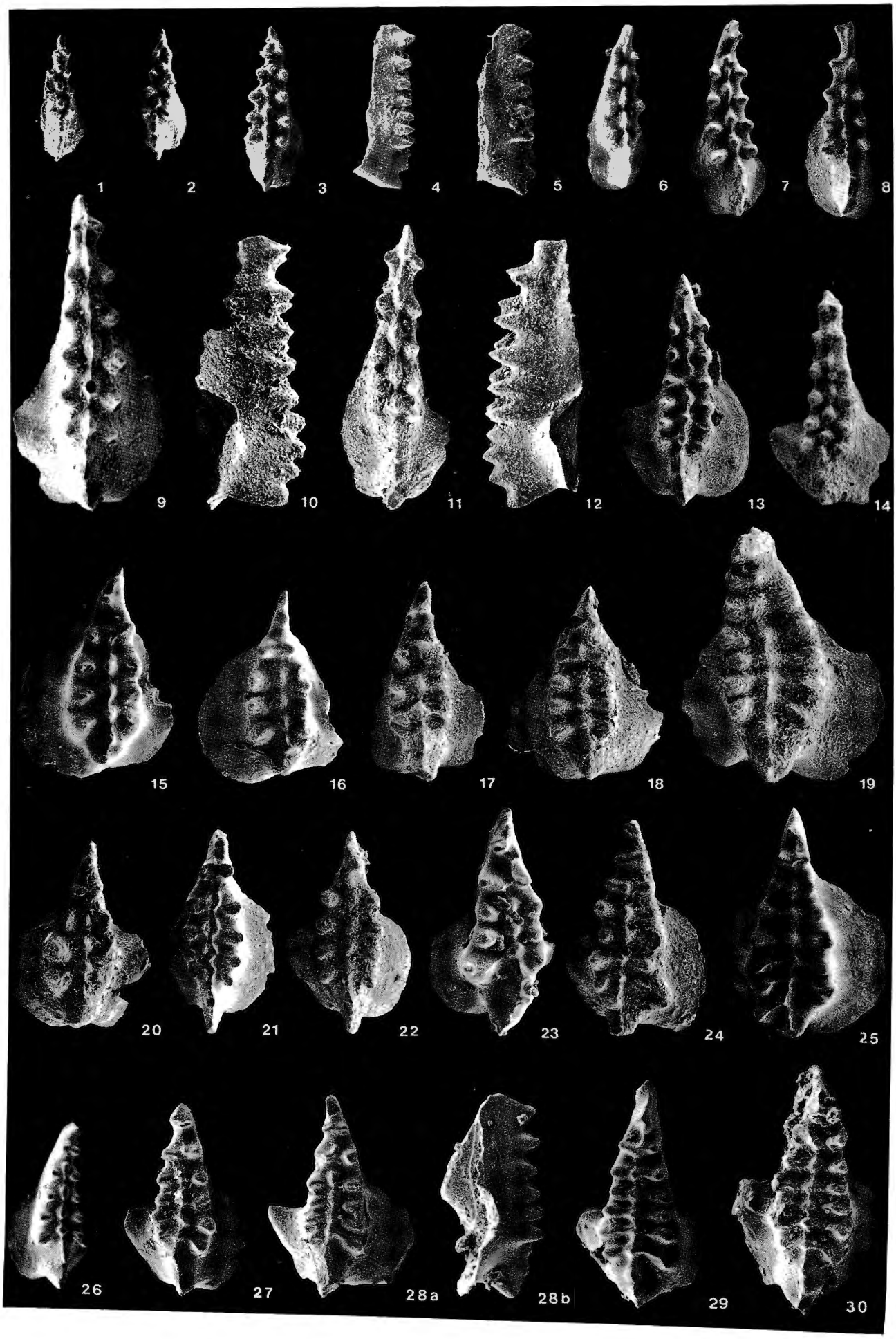
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PLATE 6

Magnification 65×, except where otherwise stated.

Figs. 1-14. – Icriodus brevis *STAUFFER, 1940. Upper views of I.R.Sc.N.B. N° b1899, MH-39; N° b1900, MH-46; N° b1901, MH-55. Lateral views of I.R.Sc.N.B. N° b1902, MH-36; N° b1903, MH-46. Upper views of I.R.Sc.N.B. N° b1904, MH-55; N° b1905, From W-4; N° b1906, MH-53; N° b1907, BT-24. Lateral and upper views of I.R.Sc.N.B. N° b1908, N° b1909, BT-22; N° b1910, BT-24; N° b1911, n° b1912, From W-4.*

Figs. 15-20. – Icriodus obesus *n. sp. Upper view of holotype I.R.Sc.N.B. N° b1913, MH-50. Upper views of paratypes I.R.Sc.N.B. N° b1914, MH-50; N° b1915, N° b1916, N° b1917 (45×), MH-51; N° b1918, MH-52.*

Figs. 21-25. – Icriodus excavatus, *WEDDIGE, 1984. Upper views of I.R.Sc.N.B. N° b1919, N° b1920, MH-39; N° b1921, MH-37; N° b1922, N° b1923, MH-53.*

Figs. 26-30. – Icriodus *aff.* I. arkonensis *STAUFFER, 1938. Upper views of I.R.Sc.N.B. N° b1924, N° b1925, MH-46. Upper and lateral view of I.R.Sc.N.B. N° b1926, MH-46. Upper views of I.R.Sc.N.B. N° ,b1927, N° b1928, MH-46.*

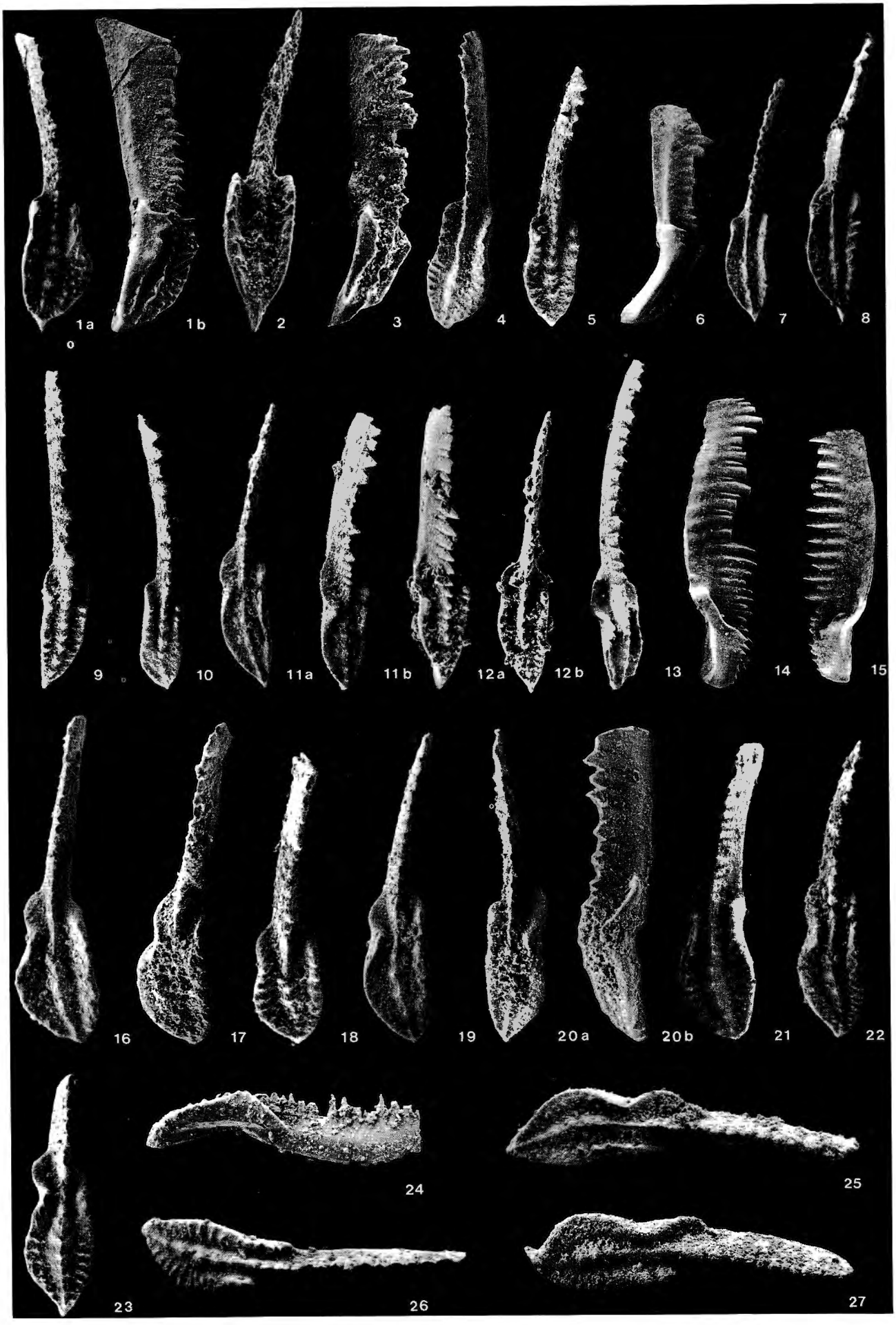
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PLATE 7

Magnification 45×, except where otherwise stated.

Figs. 1-6. – Polygnathus ensensis *ZIEGLER & KLAPPER, 1976. Upper and oblique-lateral view of I.R.Sc.N.B. N° b1929, BT-15bis. Upper and oblique-lateral views of I.R.Sc.N.B. N° b1930 (100×), BT-15bis; N° b1931 (65×), BT-15bis; N° b1932, N° b1933, BT-15ter; N° b1934, BT-17.*

Figs. 7-8. – Polygnathus ensensis *ZIEGLER & KLAPPER, 1976* → Polygnathus timorensis *KLAPPER, PHILIP & JACKSON, 1970. Upper views of I.R.Sc.N.B. N° b1935, N° b1936, BT-15ter.*

Figs. 9-12. – Polygnathus timorensis *KLAPPER, PHILIP & JACKSON, 1970. Upper views of I.R.Sc.N.B. N° b1937, BT-30; N° b1938, BT-28; Upper and oblique-lateral views of I.R.Sc.N.B. N° b1939, BT-18; N° b617, From W-4.*

Figs. 13-15. – Polygnathus rhenanus *KLAPPER, PHILIP & JACKSON, 1970. Oblique-upper view of I.R.Sc.N.B. N° b1940, BT-27. Lateral views of I.R.Sc.N.B. N° b1941 (30×), N° b1942 (30×), BT-27.*

Figs. 16-27. – Polygnathus hemiansatus *n. sp. Upper views of paratypes I.R.Sc.N.B. N° b1943, N° b1944, N° b1945, N° b1946, BT-15ter. Upper and oblique-lateral view of paratype I.R.Sc.N.B. N° b1947, BT-18. Upper views of paratypes I.R.Sc.N.B. N° b1948, BT-16; N° b1949, ABK-6; N° b1950, blade broken, BT-28. Lateral and upper views of paratypes I.R.Sc.N.B. N° b1951, ABK-6; N° b1952, BT-18. Upper view of holotype I.R.Sc.N.B. N° b1953, BT-15quater. Upper view of paratype I.R.Sc.N.B. N° b1954, section Ou Driss Centre, ODE-6 in HOLLARD (1981, tabl. 3).*


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PLATE 8

Magnification 45×, except where otherwise stated.

Figs. 1-7. – Polygnathus hemiansatus *n. sp. Upper view of paratype I.R.Sc.N.B. N° b1955, BT-15quater. Upper and oblique-lateral views of paratype I.R.Sc.N.B. N° b1956, BT-15quater. Upper views of paratypes I.R.Sc.N.B. N° b1957, BT-22a; N° b1958, BT-16. Upper view of specimen collection* WANG CHENG-YUAN *(Nanjing) from Sihongshan section, sample CD-407 in* ZIEGLER & WANG CHENG-YUAN *(1985, p. 20). Upper views of I.R.Sc.N.B. N° b1959, N° b1960, New York (U.S.), Bellona in* ZIEGLER, KLAPPER & JOHNSON *(1976, p. 128), Tully Limestone, Carpenter Falls.*

Figs. 8, 15-18. – Polygnathus eiflius *BISCHOFF & ZIEGLER, 1957. Upper views of I.R.Sc.N.B. N° b1961 (65×), N° b1968, BT-15; N° b1969, N° b1970, BT-20; N° b1971, BT-15ter.*

Fig. 9. – Polygnathus *aff.* P. ansatus *ZIEGLER & KLAPPER, 1976. Oblique-upper and upper views of I.R.Sc.N.B. N° b1962, From E-20.*

Figs. 10-14. – Polygnathus ansatus *ZIEGLER & KLAPPER, 1976. Upper views of I.R.Sc.N.B. N° b1963, N° b1964, same sample as for figs. 6-7; N° b1965, N° b1966, N° b1967, BT-28.*

Figs. 19, 20. – Polygnathus pseudofoliatus *WITTEKINDT, 1965. Upper views of I.R.Sc.N.B. N° b1972, BT-15ter; N° b1973, From E-19.*

Fig. 21. – Polygnathus denisbriceae *BULTYNCK, 1979. Upper view of I.R.Sc.N.B. N° b1974, BT-19.*

Figs. 22, 27. – Polygnathus xylus xylus *STAUFFER, 1940. Lateral, upper and oblique-lateral views of I.R.Sc.N.B. N° b1975, N° b1980, BT-25.*

Fig. 23. – Polygnathus rhenanus *KLAPPER, PHILIP & JACKSON, 1970* → Polygnathus semialternans *(WIRTH, 1967). Lateral view of I.R.Sc.N.B. N° b1976, BT-30bis.*

Fig. 24. – Polygnathus robusticostatus *BISCHOFF & ZIEGLER, 1957. Upper view of I.R.Sc.N.B. N° b1977, BT-15a.*

Figs. 25-26. – Polygnathus linguiformis weddigei *CLAUSEN, LEUTERITZ & ZIEGLER, 1979. Upper views of I.R.Sc.N.B. N° b1978 (65×), N° b1979 (65×), blade broken, BT-22a.*

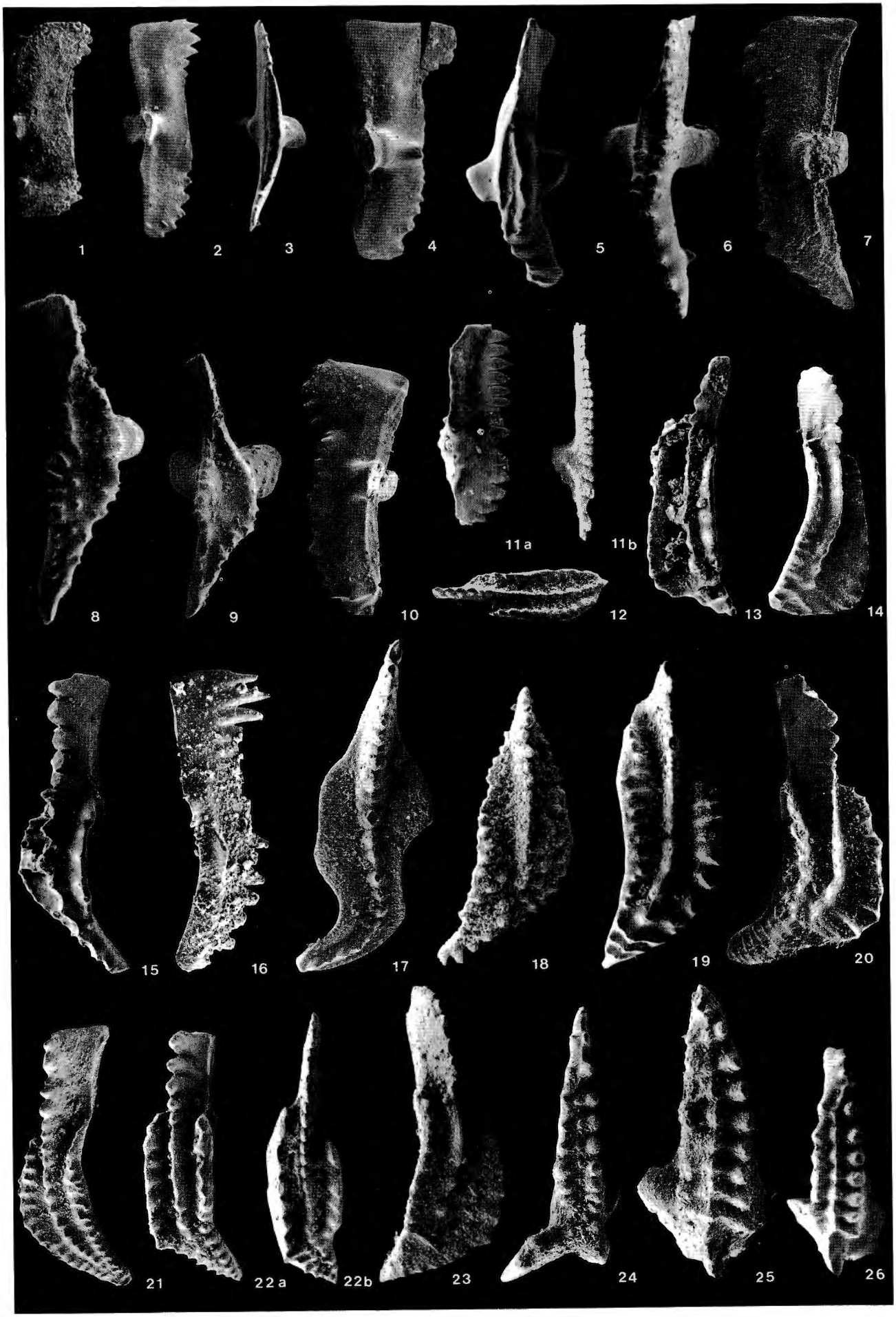
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PLATE 9

Magnification 45×, except where otherwise stated.

Figs. 1-7. – Eognathodus bipennatus bipennatus *(BISCHOFF & ZIEGLER, 1957) alpha morphotype. Lateral and upper views of I.R.Sc.N.B. N° b1981, MH-30; N° b1982, MH-33; N° b1983, MH-32; N° b1984, MH-35; N° b1985, ABK-6. Upper and lateral views of I.R.Sc.N.B. N° b1986, N° b1987, specimens transitional between alpha and beta morphotypes, MH-36.*

Figs. 8-10. – Eognathodus bipennatus bipennatus *(BISCHOFF & ZIEGLER, 1957) beta morphotype. Upper and lateral views of I.R.Sc.N.B. N° b1988, MH-37; N° b1989, (30×), MH-38; N° b1990, (30×), MH-37.*

Figs. 11a-b. – Ozarkodina bidentata *(BISCHOFF & ZIEGLER, 1957). Oblique-upper and lateral views of I.R.Sc.N.B. N° b1991, (65×), MH-3bis; N° b1992, (65×), MH-10.*

Fig. 12. – Polygnathus xylus xylus *STAUFFER, 1940. Upper view of I.R.Sc.N.B. N° b1993, MH-33.*

Fig. 13. – Polygnathus linguiformis alveolus *WEDDIGE, 1977. Upper view of I.R.Sc.N.B. N° b1994, MH-3bis.*

Fig. 14. – Polygnathus parawebbi *CHATTERTON, 1974. Oblique-upper view of I.R.Sc.N.B. N° b1995, BT-22a.*

Fig. 15. – Polygnathus angustipennatus *BISCHOFF & ZIEGLER, 1957. Oblique-upper view of I.R.Sc.N.B. N° b1996, MH-3bis.*

Fig. 16. – Tortodus intermedius *(BULTYNCK, 1966). Lateral view of I.R.Sc.N.B. N° b1997, BT-15.*

Fig. 17. – Tortodus kockelianus kockelianus *(BISCHOFF & ZIEGLER, 1957). Upper view of I.R.Sc.N.B. N° b1998, BT-15a.*

Fig. 18. – Polygnathus beckmanni *BISCHOFF & ZIEGLER, 1957. Upper view of I.R.Sc.N.B. N° b1999, BT-29.*

Fig. 19. – Polygnathus linguiformis transversus *WITTEKINDT, 1965. Upper view of I.R.Sc.N.B. N° b2000, BT-23.*

Fig. 20. – Polygnathus linguiformis klapperi *CLAUSEN, LEUTERITZ & ZIEGLER, 1979. Upper view of I.R.Sc.N.B. N° b2001, (30×), ABK-6.*

Fig. 21. – Polygnathus linguiformis *aff.* klapperi. *Upper view of I.R.Sc.N.B. N° b2002, (30×), BT-23.*

Fig. 22a-b. – Polygnathus linguiformis mucronatus *WITTEKINDT, 1965. Oblique-upper and upper views of I.R.Sc.N.B. N° b2003, N° b2004, BT-29ter.*

Fig. 23. – ?Polygnathus linguiformis klapperi *CLAUSEN, LEUTERITZ & ZIEGLER, 1979. Upper view of I.R.Sc.N.B. N° b2005, BT-15bis.*

Fig. 24. – Latericriodus latericrescens latericrescens *(BRANSON & MEHL, 1938). Upper view of I.R.Sc.N.B. N° b2006, BT-28.*

Figs. 25-26. – Icriodus difficilis *ZIEGLER & KLAPPER, 1976. Upper views of I.R.Sc.N.B. N° b2007, N° b2008, BT-25.*