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Assessment of an old stratotype: the Frasnian/Famennian boundary at Senzeilles, Southern Belgium

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Abstract

At Senzeilles, southern Belgium, the base of the Famennian as originally proposed by GOSSELET (1877-1880) corresponds best to that of the first bed of the Early *Palmatolepis triangularis* Zone. Conodonts from the latter are equated with those of the basal Famennian bed of the Frasnian-Famennian boundary stratotype at Coumiac, southern France (KLAPPER *et al.*, 1993). Eight taxa of the genus *Palmatolepis* are described; two new forms are distinguished in *Pa. triangularis*, and two others in *Pa. protorhomboidea*.
Pa. linguiformis, a species confined to its eponymous biozone at the top of the Frasnian, is found for the first time in the Matagne Member at the Neuville section, in the vicinity of Senzeilles.
Among the palynomorphs at Senzeilles, the most characteristic change is the appearance of *Visbysphaera*? *occultata* slightly below the ''historical'' Frasnian/Famennian boundary, introduced by SARTENAER (1983), located less than 1 m below GOSSELET's boundary, and based on the renewal of the macrofauna.

Key-words: Frasnian-Famennian boundary, Senzeilles, Belgium, acritarchs, chitinozoans, conodonts.

Résumé

A Senzeilles, dans le sud de la Belgique, le niveau de base du Famennien originellement proposé par GOSSELET (1877-1880) correspond au mieux avec le premier banc contenant la Zone Inférieure à *Palmatolepis triangularis*. Les conodontes de celui-ci sont comparables à ceux du premier banc famennien du stratotype de la limite Frasnien/Famennien à Coumiac, dans le sud de la France (KLAPPER *et al.*, 1993). Huit taxons du genre *Palmatolepis* sont décrits; deux nouvelles formes sont distinguées dans *Pa. triangularis* et deux autres dans *Pa. protorhomboidea*. *Pa. linguiformis*, espèce restreinte à la biozone éponyme du sommet du Frasnien, est trouvée pour la première fois dans le Membre de Matagne, à la section de Neuville proche de Senzeilles. Parmi les palynomorphes de Senzeilles, le changement le plus caractéristique concerne l' apparition de *Visbysphaera*? *occultata* peu sous la ''limite historique'' du Frasnian/Famennian. Celle-ci, introduite par SARTENAER (1983) et localisée moins d'1 m sous la limite de GOSSELET, est basée sur le renouvellement de la macrofaune.

Mots-clefs: limite Frasnien-Famennien, Senzeilles, Belgique, acritarches, chitinozoaires, conodontes.

Introduction

At the Washington meeting of the Subcommission on Devonian Stratigraphy (SDS) in 1989, two possible stratotypes for the Frasnian/Famennian boundary at the base of the *Palmatolepis triangularis* conodont Zone were judged worthy of further consideration. One is at Coumiac in the Montagne Noire, S France, the other at Steinbruch Schmidt, near Bad Wildungen in the E Rhenish Schiefergebirge, Germany. The preferred level occurs above a major extinction event, known as the Kellwasser Event (WALLISER, 1985, p. 405) and represented in many sections by the development of black hypoxic deposits. In 1992 the SDS recommended that the Global Stratotype Section and Point (GSSP) should be at Coumiac, a proposal approved by the International Commission on Stratigraphy (KLAPPER, FEIST, BECKER & HOUSE, 1993). The main purpose of the present paper is to compare the position of this GSSP with the original Frasnian/Famennian boundary at Senzeilles, in the type area of the two stages in S Belgium and to document acritarchs, chitinozoans and conodonts from boundary beds in the latter section. Conodont faunas from Senzeilles are also compared with those at Steinbruch Schmidt, where the Kellwasser Event is particularly well demonstrated and includes the reference section for the *Palmatolepis linguiformis* and Early- and Middle *Pa. triangularis* zones (ZIEGLER & SANDBERG, 1990), which are important for recognising the Frasnian/Famennian boundary.

GOSSELET (1877) drew special attention to the lithological and macrofaunal succession in the now-infilled Senzeilles railway cutting. Amongst the 13 lithological-faunal units (A to R) recognised by him, three are critical for the understanding of the Frasnian/Famennian boundary (GOSSELET, 1880, p. 108). Unit F (''schistes noirs très-feuilletés, 1 m, *Cardium palmatum*'') is assigned to the Matagne Shales; unit G (''schistes noirs, 4 m'') is considered transitional between F and H; and the latter (''schistes contenant de grosses plaques solides, 6 m, *Cyrtia Murchisoniana*...'') is ranged at the base of the Famenne Shales. GOSSELET stressed that it is very difficult to establish a clear cut boundary between the Matagne Shales and the Famenne Shales because of the transitional nature of unit G. GOSSELET (1880, p. 108) introduced a new unit for the lower part of the Famenne Shales, the ''Schistes de Senzeilles à *Rhynchonella omaliusi*.- Schistes argileux verdâtres, avec plaquettes dures tantôt siliceuses, tantôt calcaires'', the base of which coincides with the Frasnian/Famennian boundary. From

GOSSELET's (1888, pp. 557-551, fig. 136) drawing there is no doubt that the position of this boundary is at the base of unit H at Senzeilles. SARTENAER (1960, pp. 435-437, pl. 1), restudying the same section, concluded that on the basis of the renewal of the macrofauna, mainly brachiopods, the Frasnian (Schistes de Matagne)/Famennian boundary is a little below unit H of GOSSELET and within unit G. He also summarised the range of rhynchonellid zones established earlier by him which are critical for correlating the buried railway section with the 1988-89 cuttings here described. Subsequently, several authors referred to the latter Frasnian/Famennian boundary level as the "limite historique" or "historical boundary" (e.g. SARTENAER, 1983; VANGUESTAINE *et al.*, 1983; BULTYNCK, 1988; CASIER, 1989 and 1992). In a document submitted to the SDS, SARTENAER (1983, p. 3, fig. 1) gave details of the lithology and macrofauna of the boundary beds in the old railway cutting at Senzeilles, stating that the historical boundary is about 0.75 m below unit H of GOSSELET; these data were shown by BULTYNCK (1988 p. 23, fig. A 2/4). In 1976, the railway cutting was buried and a new reference section ("coupe-témoin"), about 17 m south of the original one, was excavated by the Geological Survey of Belgium. BULTYNCK & MARTIN (in MARTIN, 1985, fig. 3) illustrated the Famennian part of the "coupe-témoin".

The lowermost Senzeilles Shales and the transition to the Matagne Shales were not exposed in the 1976 cutting. In late 1988-early 1989 the IRScNB undertook the digging of two complementary cuttings. CASIER (1992) described the two trenches and discussed the palaeoenvironmental changes across the Frasnian/Famennian boundary, mainly on the basis of ostracods.

The position of the former railway section, the "coupe -témoin" and the two complementary cuttings, east and west, are shown (Fig. 1). In Spring 1993 the lower part of the "coupe - témoin" (up to 86 m, MARTIN, 1985, p. 5, fig. 3) and the two complementary cuttings were filled in, but documents, including photographs, and samples from the two last are at the IRScNB.

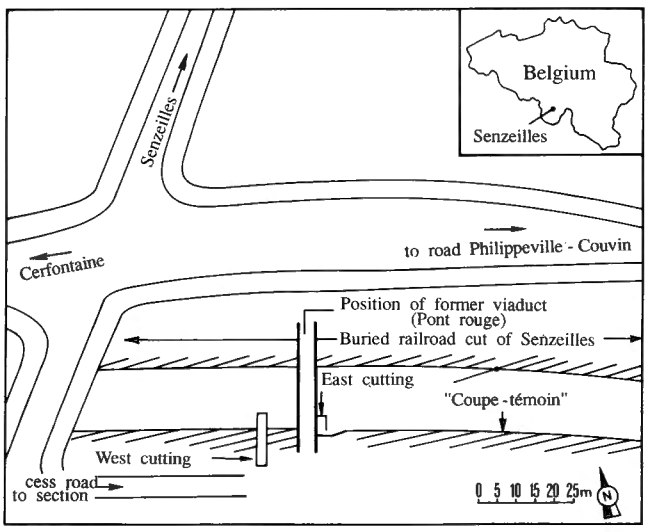

Fig. 1 — Sketch map showing the location of the original railway cutting at Senzeilles (1854-1976), the "coupe-témoin" (1976-1993) and the east and west cuttings (1989-1993); —●—: position of the original Frasnian/Famennian boundary and general strike of the beds.

Lithostratigraphy and macrofauna from the east and west cuttings and correlation with the old railway section

Lithostratigraphic units used here are shown (Fig. 2). The uppermost part of the Frasnes Group belongs to the Valisettes Formation (BOULVAIN *et al.*, 1993, p. 27) and consists mainly of fine, dark grey-greenish shales with nodules and a few limestone beds. According to the decision of the National Commission on Devonian Stratigraphy (minutes of meeting of May 26th, 1993), the formation is subdivided into a Wérin Member (lower part) and a Matagne Member (upper part), the latter characterised by fine, fissile, dark greyish to blackish shales with nodules and containing small, thin-shelled bivalves and brachiopods. The Senzeilles Formation, lower part of the Famenne Group, consists characteristically of greenish shales with nodules, and beds of nodular limestone and limestone. Between the typical Senzeilles Shales (= informal member 2) and the Matagne Shales are a few metres of more compact shale, blackish to bluish with rare macrofossils. The latter beds are more or less equivalent to unit G of GOSSELET (1877); to "passage de schistes noirâtres à des schistes bleuâtres puis verdâtres" of SARTENAER (1973a, p. 4); and to "schistes de transition" of CASIER (1992, pp. 110-113, fig. 2). The contact of the latter unit with the underlying Matagne Member is more clear cut than with the overlying Senzeilles Shales, and the transitional beds are included here as informal member 1 in the Senzeilles Formation.

It should be stressed that, because of the crumbly nature of shales exposed in the east and west cuttings, given thicknesses are approximate.

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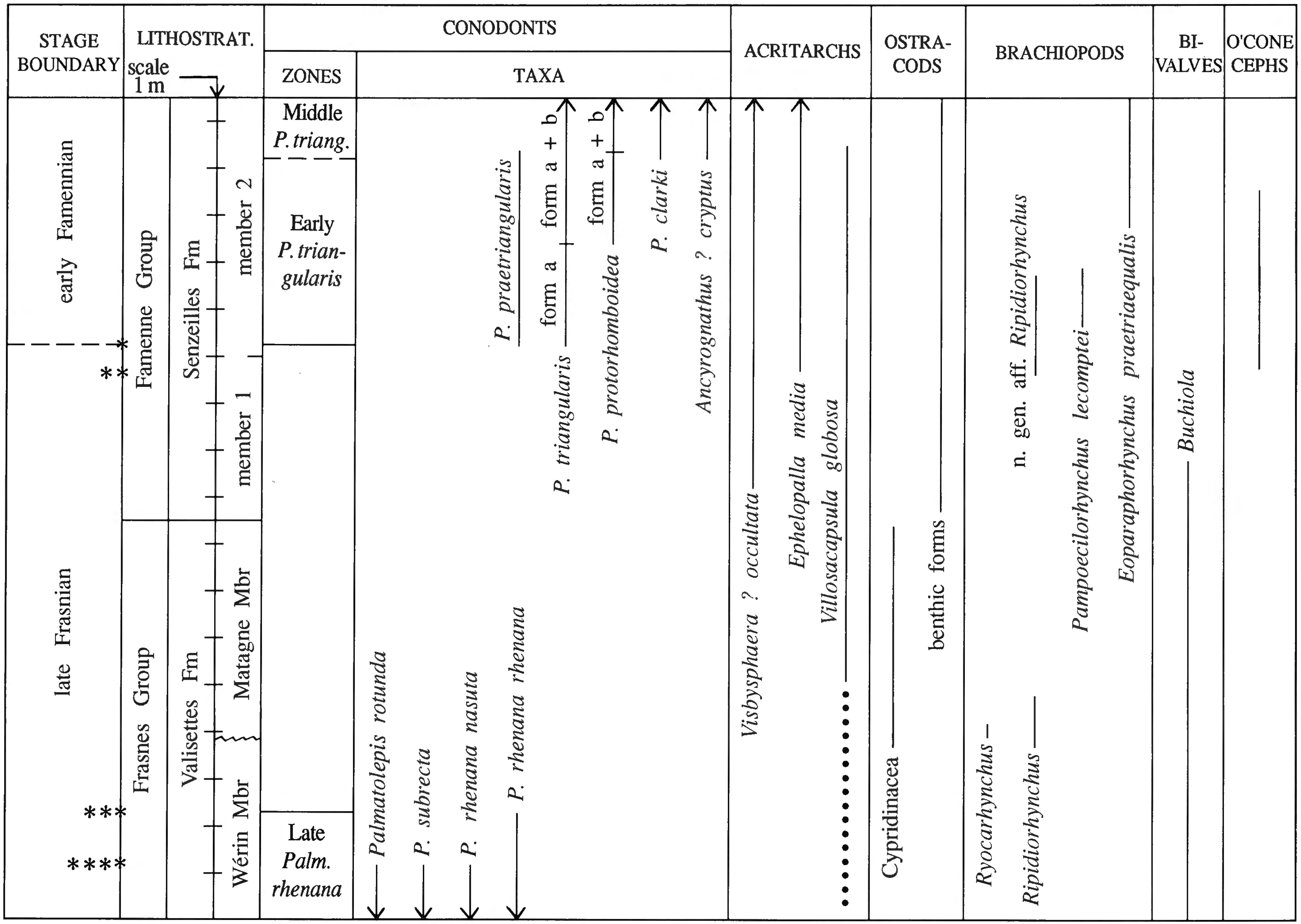
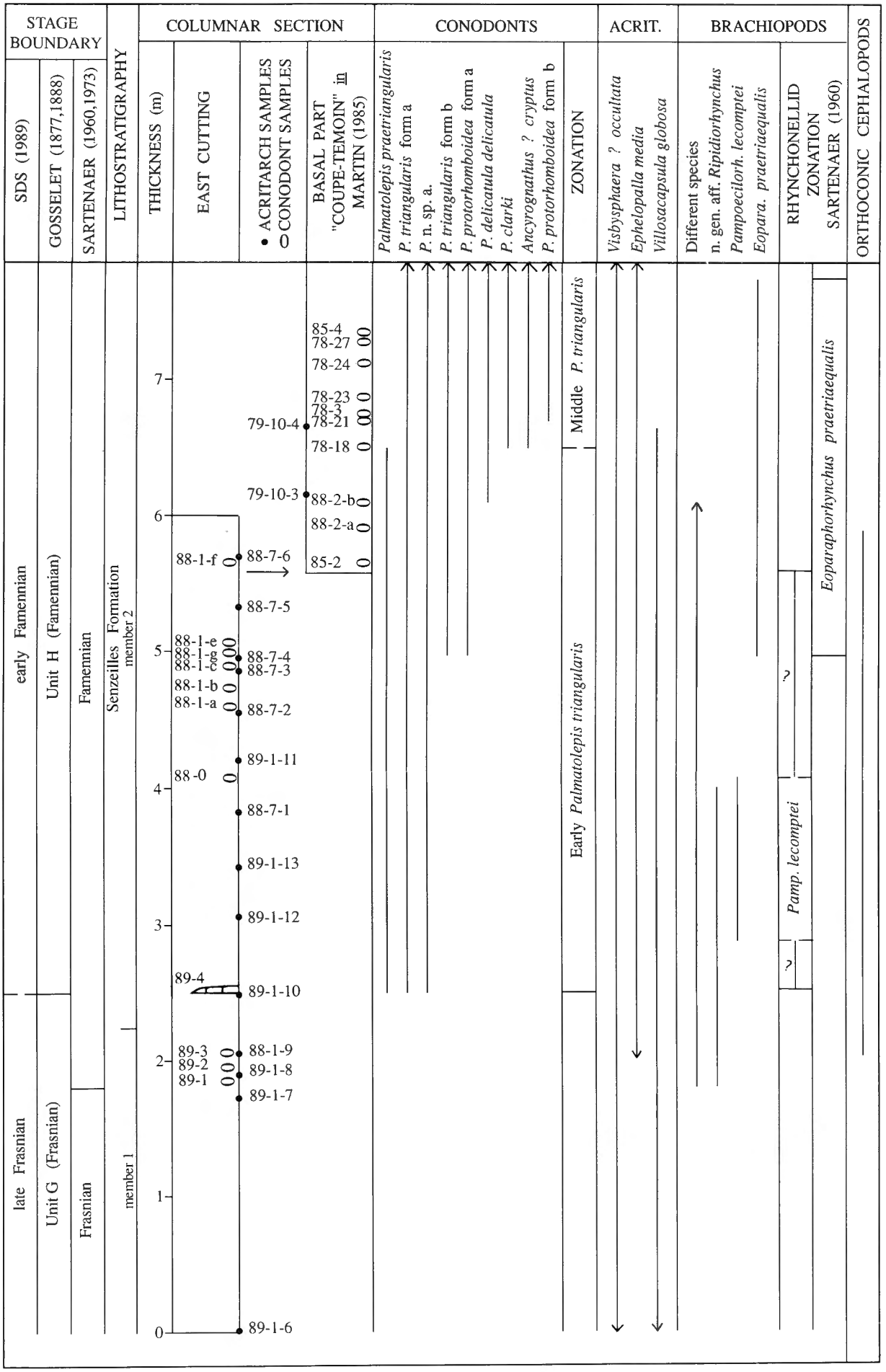
Fig. 2 — Ranges of selected taxa in the uppermost Frasnian and lowermost Famennian at Senzeilles. Data for the Matagne Mbr and the Senzeilles Fm are from the west and east cuttings and the basal part of the "coupe-témoin"; data for the Wérin Mbr are from MOURAVIEFF (1974, p.8), modified; *: position of the GOSSELET (1877-1880) boundary; **: position of the boundary according to SARTENAER (1960); *** and ****: position of samples 7 and 5 of MOURAVIEFF (1974); ↑ and ↓: taxa are known from younger and older strata in the same area.


STAGE BOUNDARY
LITHOSTRAT.
scale 1 m
CONODONTS
ZONES
TAXA
ACRITARCHS
OSTRA-CODS
BRACHIOPODS
BI-VALVES
O'CONE CEPHS
early Famennian
late Frasnian
Famenne Group
Frasnes Group
Senzeilles Fm
Valisettes Fm
member 2
member 1
Matagne Mbr
Wérin Mbr
Middle P. triang.
Early P. triangularis
Late Palm. rhenana
P. praetriangularis
P. triangularis
form a
form a + b
P. protorhomboidea
form a + b
P. clarki
Ancyrognathus ? cryptus
Palmatolepis rotunda
P. subrecta
P. rhenana nasuta
P. rhenana rhenana
Visbysphaera ? occultata
Ephelopalla media
Villosacapsula globosa
Cypridinacea
benthic forms
Ryocarhynchus
Ripidiorhynchus
n. gen. aff. Ripidiorhynchus
Pampoecilorhynchus lecomptei
Eoparaphorhynchus praetriaequalis
Buchiola


STAGE BOUNDARY
SDS (1989)
GOSSELET (1877,1888)
SARTENAER (1960,1973)
LITHOSTRATIGRAPHY
COLUMNAR SECTION
THICKNESS (m)
EAST CUTTING
• ACRITARCH SAMPLES
0 CONODONT SAMPLES
BASAL PART "COUPE-TEMOIN" in MARTIN (1985)
CONODONTS
ACRIT.
BRACHIOPODS
ZONATION
RHYNCHONELLID ZONATION SARTENAER (1960)
ORTHOCONIC CEPHALOPODS
late Frasnian
early Famennian
Unit G (Frasnian)
Unit H (Famennian)
Frasnian
Famennian
Senzeilles Formation
member 1
member 2
Palmatolepis praetriangularis
P. triangularis form a
P. n. sp. a.
P. triangularis form b
P. protorhomboidea form a
P. delicatula delicatula
P. clarki
Ancyrognathus ? cryptus
P. protorhomboidea form b
Middle P. triangularis
Early Palmatolepis triangularis
Visbysphaera ? occultata
Ephelopalla media
Villosacapsula globosa
Different species
n. gen. aff. Ripidiorhynchus
Pampoecilorh. lecomptei
Eopara. praetriaequalis
Pamp. lecomptei
Eoparaphorhynchus praetriaequalis
?
0
1
2
3
4
5
6
7
89-1-6
89-1-7
89-1-8
89-1-9
89-1-10
89-1-12
89-1-13
89-7-1
89-1-11
88-7-2
88-7-3
88-7-4
88-7-5
88-7-6
88-0
88-1-a
88-1-b
88-1-c
88-1-d
88-1-e
88-1-f
89-1
89-2
89-3
89-4
79-10-4
79-10-3
78-18
78-21
78-3
78-23
78-24
78-27
85-4
88-2-a
88-2-b
85-2

WEST CUTTING (Figs. 1 and 2)

For a complete description of the cutting, see CASIER (1992). Black Matagne Shales, 4.80 m thick, were exposed at the northern extremity of the trench, and the underlying Wérin Member was not reached. The overlying member 1 of the Senzeilles Formation was recognised, 3.50 m thick with a thin, clayey layer at the base. Shales exposed in the southern part of the trench were deeply weathered and the base of member 2 of the Senzeilles Formation could not be confidently recognised.

EAST CUTTING (Figs. 1 and 3).

Rocks exposed in the east cutting ranged from the upper part of member 1 into the lower part of member 2 of the Senzeilles Formation, crossing the Frasnian/Famennian boundary. The former unit, 2.20 m thick, contained dark bluish to blackish shales with some calcareous nodules; macrofossils were almost absent in the lower 1.75 m. Renewal of the macrofauna was observed in the sample interval 89-1 to 89-3 with the appearance of: *Athyris reticulata* (GOSSELET), *Aulacella arcuata* (PHILLIPS), *Productella subaculeata* (MURCHISON), *Schizophoria striatula* (von SCHLOTHEIM), *Cyrtospirifer verneuili* (MURCHISON) group, n. gen. aff. *Ripidiorhynchus* SARTENAER, Cranaenidae and orthoconic cephalopods.

The base of this interval was correlated with the ''historical'' Frasnian/Famennian boundary in the old railway section by SARTENAER (1960, pl. 1), 47.65 m W of the former viaduct (''Pont rouge''). The base of member 2 was marked by the first greenish shales and coincides with the base of the ''Schistes de Senzeilles'' (CASIER, 1992, p. 112, fig. 2). About 0.25 m higher was found a 5 cm thick brachiopod coquina containing the above listed taxa together with a probable *Cyrtiopsis murchisoniana* (DE KONINCK) (non de VERNEUIL) specimen. This level is correlated with the base of unit H of GOSSELET (1877), corresponding to the Frasnian/Famennian boundary as defined by him; it is 70 cm above the ''historical boundary'', as was the case in the old railway section. In the 3.50 m of overlying greenish shales were several layers of limestone nodules with a rich brachiopod fauna containing, in addition to the listed taxa: *Cyrtiopsis murchisoniana* group, *Pampoecilorhynchus lecomptei* (SARTENAER), *Eoparaphorhynchus praetriaequalis* (SARTENAER) and *''Orthotetes'' consimilis* (DE KONINCK). The two lowermost Famennian rhynchonellid zones (*P. lecomptei* and the *E. praetriaequalis* zones), established in the old railway section by SARTENAER (1954 and 1957) were recognized. In the latter section *P. lecomptei* and *E. praetriaequalis* appear respectively 0.70 m and 3.35 m above the ''historical boundary'', but in the east cutting they are 1 m and 3.20 m above it. Correlations between the different reference levels in the old railway section and the east cutting are considered here to be sufficiently reliable, and the difference of 0.30 m in the first occurrence of *P. lecomptei* may be explained by the relative rarity of the species.

The uppermost part of the east cutting was correlated with the lowermost part of the ''coupe-témoin'', conodont sample 88-1-f corresponding to conodont sample 85-2 (= sample 2* in MARTIN, 1985, p. 5, fig. 3 and sample 2 *in* BULTYNCK, 1988, p. 22, fig. A 2/3).

Conodont sequence (Figs. 2, 3 and Table 1)

Samples from the Matagne Member in the west cutting (bed S 86 *in* CASIER, 1992, p. 112, fig. 2 and calcareous nodules 0.10 m below) and from member 1 of the Senzeilles Formation in the east cutting did not produce conodonts. All samples, except one, from member 2 of the latter formation in the east cutting and the basal part of the ''coupe - témoin'', contained good conodont faunas, most commonly about 100 specimens/kg. In all these samples *Palmatolepis* and *Icriodus* taxa are dominant, generally more than 80% of the fauna, with *Polygnathus* forming between 10 and 20% (Table 1).

Using *Palmatolepis* taxa the conodont sequence from sample 89-4 up to sample 85-4 is divided into three biostratigraphical intervals, the two lowest of which belong to the Early *Pa. triangularis* Zone and the third to the Middle *Pa. triangularis* Zone.

In the first biostratigraphical interval, from sample 9-4 (= base of unit H of GOSSELET, 1877) to 88-1-c and 2.50 m thick, *Pa. triangularis* form a is the dominant *Palmatolepis* taxon with some *Pa. praetriangularis* and far fewer *Palmatolepis* n. sp. a. The base of the second interval , from sample 88-1-g to 88-2b and 1.50 m thick, coincides with the first occurrence of the b form of *Pa. triangularis* and the a form of *Pa. protorhomboidea*. The highest range of *Pa. praetriangularis* is at the top of the interval, and *Pa. delicatula delicatula* occurs first at the

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Fig. 3 — Ranges of selected taxa in the east cutting and the basal part of the ''coupe-témoin'' at Senzeilles; the thickness of the *Pampoecilorhynchus lecomptei* Zone is based on the range of the species recorded in the east cutting, completed (indicated by ''?'') with the data from the old railway section (SARTENAER, 1960, p.434); ↑ and ↓: taxa are known from younger and older strata in the same area.

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Table 1 — Distribution and number of conodont taxa and elements in samples from the east cutting and the basal part of the ''coupe-témoin'' at Senzeilles; * : sample 89-1 is 1.80m above the base of the sequence exposed in the east cutting; **: percentages of Pa elements belonging to the genera *Palmatolepis*, *Ancyrognathus*?, *Polygnathus*, *Mehlina* and *Icriodus*.

AGE	FORMATION	INFORMAL MEMBER	CONODONT ZONATION	PB SAMPLE NUMBER SENZEILLES : EAST CUTTING AND BASAL PART "COUPE-TEMOIN" *in* MARTIN (1985)	APPROXIMATE THICKNESS (m) BETWEEN SAMPLES	SAMPLE WEIGHT (kg)	CONODONTS – Pa ELEMENTS: *Palmatolepis* **	*praetriangularis*	*triangularis* form a	n. sp. a	*triangularis* form b	*protorhomboidea* form a	*delicatula delicatula*	*clarki*	*protorhomboidea* form b	*Ancyrognathus* ? **	*cryptus*	*Polygnathus* **	*aequalis*	*brevilaminus*	*aff. sinuosus*	*aff. planirostratus*	*Mehlina* **	sp.a.	*Icriodus* **	*alternatus alternatus*	*alternatus helmsi*	*iowaensis iowaensis*	OTHERS: Pb, M and S elements	Coniform elements
early Famennian	Senzeilles	2	Middle *Pa. triangularis*	85-4	0.05	1	49	-	3	1	2	3	1	-	1	-	-	15	1	5	-	-	2	1	34	11	1	1	17	-
				78-27	0.15	2.9	75	-	6	-	2	-	-	3	-	-	-	-	-	-	-	-	-	-	25	5	-	-	-	-
				78-24	0.25	0.5	64	-	3	1	-	-	-	-	-	-	-	18	-	-	-	-	-	-	18	-	-	-	-	-
				78-23	0.12	3.3	61	-	7	-	5	-	-	1	1	-	-	-	-	-	-	-	-	-	39	9	4	-	-	-
				85-3	0.05	1	63	-	8	-	5	5	1	-	2	-	-	8	1	-	-	-	3	1	26	15	1	-	40	-
				78-21	0.20	0.8	100	-	5	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				78-18	0.40	0.9	72	-	11	3	2	6	1	1	-	1	1	5	-	1	-	-	-	-	22	24	3	-	-	-
			Early *Pa. triangularis*	88-2-b	0.20	2	58	3	24	3	6	24	1	-	-	-	-	16	5	6	-	1	1	2	25	19	8	4	39	-
				88-2-a	0.25	2	56	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	44	3	-	1	3	1
				85-2	0.00	2	60	-	38	-	5	-	-	-	-	-	-	7	3	-	-	-	-	-	33	16	-	-	30	-
				88-1-f	0.60	1	53	2	3	-	1	1	-	-	-	-	-	18	-	-	-	-	-	-	29	2	2	-	2	-
				88-1-e	0.07	1	64	-	3	-	-	2	-	-	-	-	-	12	-	-	-	-	12	-	12	-	-	-	-	-
				88-1-g	0.10	3	49	4	25	4	10	27	-	-	-	-	-	17	11	13	-	-	-	-	34	33	10	1	40	3
				88-1-c	0.17	2.8	33	3	34	3	-	-	-	-	-	-	-	4	3	4	-	-	-	-	63	55	9	-	39	3
				88-1-b	0.10	2	30	3	16	-	-	-	-	-	-	-	-	14	5	3	-	1	-	-	56	43	3	-	14	1
				88-1-a	0.55	0.3	58	2	5	2	-	-	-	-	-	-	-	4	-	-	-	1	-	-	38	4	4	1	5	-
				88-0	1.55	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				89-4	0.50	12	36	23	134	1	-	-	-	-	-	-	-	11	13	17	1	-	1	3	52	204	12	21	375	10
late Fr.		1		89-3	0.10	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				89-2	0.10	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				89-1	*	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

same level. The third interval, from sample 78-18 upwards, is marked at the base by the first occurrence of *Palmatolepis clarki*; *Ancyrognathus*? *cryptus* appears at the same level and the b form of *Palmatolepis protorhomboidea* just above.

Comparison with the conodont succession established by KLAPPER (1990, pp. 34-37, fig. 18) and KLAPPER *et al.*, (1993, pp. 435-437) in the GSSP for the Frasnian/Famennian boundary at Coumiac and using the author's collection from the same section, indicates that interval 1 is certainly not younger than the two lowest Famennian beds 32 a (17 cm) and 32 b (18 cm), based on the common presence of *Pa. praetriangularis*, *Pa. triangularis* and *Palmatolepis* n. sp. a, and on the first occurrence of *Pa. protorhomboidea* and *Pa. delicatula delicatula* in interval 2 at Senzeilles and bed 32 c at Coumiac. Judging from the different levels of first occurrence of *Pa. triangularis* forms a and b, distinguished here, the conodont fauna of interval 1 at Senzeilles is best compared with that in the lower 3 cm of bed 32 a (= sample 32 a 1) at Coumiac. A reference sample from this level contained about 60 specimens of the a form and 1 specimen intermediate between the a and b forms, the latter of which first occurs in the upper 14 cm of bed 32 a (see Pl. 6, Figs. 1-3, 6).

Comparison with the standard conodont zonation in the late Frasnian (Late *Palmatolepis rhenana* Zone - *Pa. linguiformis* Zone) and the Early Famennian (Early and Middle *Pa. triangularis* zones) established by ZIEGLER & SANDBERG (1990, pp. 20-23) with reference section at Steinbruch Schmidt, indicates that the base of interval 1 is close to the base of the Early *Pa. triangularis* Zone and that the base of interval 3 cannot be older than the Middle *Pa. triangularis* Zone. All species listed for the former zone (*op. cit.*, p. 22) were found in intervals 1 and 2 at Senzeilles. The same authors also specified that *Pa. delicatula delicatula* first occurs at or just above the base of this zone and *Pa. protorhomboidea* high within it, but the two species appear in the middle part of the Early *Pa. triangularis* Zone at Devil's Gate, Nevada (SANDBERG *et al.*, 1988, pp. 286-287, tabl. 3). At Senzeilles the order of first occurrence of the two species is reversed, *Pa. protorhomboidea* being common to abundant from the base of interval 2 onwards and *Pa. delicatula delicatula* rare near the top of the interval. *Pa. delicatula platys* ZIEGLER & SANDBERG, 1990, the lowest range of which defines the base of the Middle *Pa. triangularis* Zone, has not been found in either the new cuttings or the whole "coupe - témoin " at Senzeilles.

Ancyrognathus? cryptus, which first occurs commonly at the base of the Middle *Pa. triangularis* Zone, and *Palmatolepis clarki*, which enters somewhat higher (ZIEGLER & SANDBERG 1990, p. 22), appear at the base of interval 3, so the latter can be no lower than the Middle *Pa. triangularis* Zone. We assume that most of interval 2 belongs to the higher part of the same zone, and interval 1 to the lower part of the Early *Pa. triangularis* Zone. In correlating with the lithological succession at Steinbruch Schmidt, interval 1 at Senzeilles is most likely represented in the lower part of bed A (0.14 to 0.21 m thick), without *Pa. delicatula delicatula* (SANDBERG *et al.*, 1988, pp. 278-279, tabl. 1); interval 2 is correlated with the upper part of bed A and with bed B (0.07 to 0.14 m thick); and the base of interval 3 coincides with the base of bed C. The occurrence of the a and b forms of *Pa. triangularis* has been checked in reference samples from beds A, B and C. Samples from A and B were almost completely dominated by form a, with one specimen of form b in sample A and several intermediate between a and b in sample B. In sample C both forms were common (Pl. 6 Figs. 4-5,7).

Although the base of biostratigraphic interval 1 is close to the base of the Early *Pa. triangularis* Zone and the base of the Famennian, there are no conodont data from the 8.50 m thick sequence immediately below. In order to offset this lack of data, the biostratigraphical interval 1 is positioned with reference to the youngest Frasnian conodont faunas from the old railway section at Senzeilles (MOURAVIEFF, 1974, p. 8, samples 6 and 7) and new conodont data from the Matagne Member in the nearby southern railway section at Neuville (BOULVAIN *et al.*, 1993, p. 18, fig. 4 for location) are provided.

Samples 6 and 7 of MOURAVIEFF (1974) were collected from the uppermost Wérin Member, on the NW side of the former viaduct ("Pont Rouge") and separated by a fault from the overlying Matagne Member. The thickness of this part of the Wérin Member (Fig. 2) was calculated from data in SARTENAER (1983, p. 3, fig. 1). Re-examination of MOURAVIEFF's conodont collections indicates that *Palmatolepis rotunda* ZIEGLER & SANDBERG, 1990, *Pa. rhenana nasuta* MÜLLER, 1956 and *Pa. subrecta* MILLER & YOUNGQUIST, 1947 have their last occurrence in sample 6, and that *Pa. rhenana rhenana* BISCHOFF, 1956 is present in samples 6 and 7. The two samples are assigned to the Late *Pa. rhenana* Zone on the basis of the presence of *Pa. rhenana rhenana* and the absence of *Palmatolepis linguiformis*, *Pa. praetriangularis* and *Ancyrognathus ubiquitus*.

The 5 to 8 m of Matagne Shales and transitional beds (= Matagne Member and member 1 of the Senzeilles Formation in the present paper) at Senzeilles have never yielded conodonts. According to SARTENAER (1983, p. 2) the limited thickness of Matagne Shales at Senzeilles compared with the Frasnes area, which belongs to the southern border of the Dinant Synclinorium where the exposed part is about 42 m thick (SARTENAER, 1974, p. 4), is related to the presence of an important fault at their base.

The Senzeilles area belongs to the Philippeville Massif, now 10 km N of Frasnes, and the thickness of Matagne Shales there is mostly reduced. COEN (1977, p. 27) described an undisturbed Frasnian to lower Famennian succession S of Philippeville with about 10 m of dark "Matagne" shales overlain by greenish Senzeilles Shales with nodular limestone beds containing *Palmatolepis triangularis*. Dark shales "d'aspect Matagne" about 6.5 m to 9 m thick were described from the southern railway section at Neuville (3.5 km W of the section at Senzeilles and belonging to the same structural unit) by

SARTENAER (1973b, unit 8) and by COEN & COEN-AUBERT (1974, pp. 4-5). BOUCKAERT, *et al.*, (1970, pp. 3-4) described conodont faunas with *Ancyrognathus asymmetricus* (ULRICH & BASSLER, 1926), *Ancyrodella curvata* BRANSON & MEHL, 1934 and *Palmatolepis subrecta* from the same beds. The Neuville Section was resampled for conodonts in collaboration with HAYDUKIEWICH (University of Wrocław). Sample 45, from the Matagne Shales exposed about 10 m SW of km 103, contained *Palmatolepis linguiformis*, *Pa. subrecta*, *Ancyrodella curvata* and *Ancyrognathus ubiquitus* (Pl. 9 Figs. 10-12), a fauna that belongs to the latest Frasnian *Pa. linguiformis* Zone. CASIER (1982, p. 4) described from the same interval an ostracod fauna with *Entoprimitia splendens* (WALDSCHMIDT, 1885) and *E. kayseri* (WALDSCHMIDT, 1885). Thus, conodonts and ostracods indicate that at one locality, at least, in the Philippeville Massif, the Matagne Member is of latest Frasnian age and can be correlated with the Upper Kellwasser Event (SCHINDLER, 1990, pp. 20-21).

Acritarch sequence and chitinozoan assemblage

The acritarchs and chitinozoans were concentrated by means of routine treatment using samples of about 30 g of shale, and are neither coloured nor oxidised. Composition of acritarch and chitinozoan assemblages (Tables 2, 3) is presented for each sample. Thicknesses shown between the latter are approximate as reference levels are very limited in the altered shales, especially in the western cutting, at the top of which stratigraphic control is difficult owing to man-made changes. The acritarchs, which number from some tens to some thousands per gramme of rock, are variably preserved and from slightly transparent yellow-brown to opaque. Details of ornamentation are irregularly preserved and often incomplete. Acritarchs are relatively most abundant and best preserved in the eastern cutting, from member 2 of the Senzeilles Formation upwards; only 1-10% of specimens were determinable in assemblages from older levels.

The chitinozoans, ranging at most from a few to some tens per gramme of rock, are blackish-brown and poorly preserved. Often flattened, with more or less parallel cracks and very incomplete ornamentation, they are relatively least rare in the Matagne Member of the Valisettes Formation.

Acritarchs

All acritarchs in the following list come from sections at Senzeilles. An asterisk (*) indicates the five species reviewed in discussion of the Frasnian/Famennian boundary on the southern margin of the Dinant Basin (MARTIN, 1993, p. 518-521) because of their relatively limited range within the Upper Devonian and as the point at which they appear can be estimated with reference to the conodont zonation. A hyphen (-) indicates three taxa omitted from the tables of assemblage composition, as they are known at least from the Silurian. Except for the latter, all forms have been illustrated, described or discussed by MARTIN (1981, 1982, 1985); none have yet provided evidence useful for defining the Frasnian/Famennian boundary as it was agreed by the SDS in 1988 (OLIVER & CHLUPÁČ, 1991). Names and references within quotation marks indicate combinations not accepted by FENSOME *et al.*, (1990) but used here.

'*Ammonidium exoticum* (DEUNFF) LISTER, 1970'
Ammonidium grosjeani (STOCKMANS & WILLIERE) MARTIN, 1981
Craterisphaeridium sprucegrovense (STAPLIN) TURNER, 1986
Daillydium pentaster (STAPLIN) emend. PLAYFORD in PLAYFORD & DRING, 1981
Duvernaysphaera radiata BRITO, 1967
'*Eisenackidium martensianum* STOCKMANS & WILLIERE, 1969'
**Ephelopalla media* (STOCKMANS & WILLIERE) MARTIN, 1985
Evittia cf. *E. sommeri* BRITO, 1967
'*Exochoderma cleopatra* (DEUNFF) MARTIN, 1985'
Maranhites cf. *M. gallicus* TAUGOURDEAU-LANTZ, 1968
Maranhites stockmansii MARTIN, 1981 emend. MARTIN, 1985
- *Micrhystridum stellatum* DEFLANDRE, 1945
Multiplicisphaeridium ramispinosum STAPLIN, 1961
Palacanthus ledanoisii (DEUNFF) PLAYFORD, 1977
Pterospermella tenellula PLAYFORD, 1981
Schizocystia? aff. *S.*? *bicornuta* JARDINE *et al.*, 1974
Stellinium comptum WICANDER & LOEBLICH, 1977
'*Stellinium micropolygonale* (STOCKMANS & WILLIERE) PLAYFORD, 1977'
Stellinium cf. *S. rabians* (CRAMER) EISENACK *et al.*, 1976
'*Unellium cornutum* WICANDER & LOEBLICH, 1977'
Unellium elongatum WICANDER, 1974
Unellium piriforme RAUSCHER, 1969
- *Veryhachium downiei* STOCKMANS & WILLIERE, 1962
- *Veryhachium europaeum* STOCKMANS & WILLIERE, 1960
Veryhachium polyaster STAPLIN, 1961
*'*Villosacapsula ceratioides* (STOCKMANS & WILLIERE) LOEBLICH & TAPPAN, 1976'
**Villosacapsula globosa* VANGUESTAINE *et al.*, 1983
**Visbysphaera*? *fecunda* VANGUESTAINE *et al.*, 1983
**Visbysphaera*? *occultata* MARTIN, 1985
Winwaloeusia ranulaeforma MARTIN, 1985

PALYNOFLORA? I

In the lower half of the western cutting, corresponding to the upper part of the Matagne Member of the Valisettes

→

Table 2 — Range chart of acritarchs and chitinozoans at Senzeilles west cutting. (Number of specimens: rr = 1; r = 2—19; c = 20—100; cc = more than 100).

late Frasnian																	?													AGE
Valisettes																	Senzeilles													FORMATION
Matagne																	1											2		MEMBER
		just below PB-89-2							10 cm below lowest white layer (2-3 cm)							new brachiopods appear													INDEX HORIZON
89-1-1	89-1-2	89-1-3	89-1-4	88-7-20	89-1-5	88-7-19	88-7-18	88-7-17	88-7-16	88-7-15	88-7-13	88-7-12	88-7-11	88-7-10	88-7-9	88-7-8	88-7-7													FM SAMPLE NUMBER SENZEILLES: WEST CUTTING
measured								calculated																						APPROXIMATE THICKNESS (m) BETWEEN SAMPLES
0.75	0.15	1.05	0.85	0.40	0.10	0.45	0.70	0.10	0.60	1.50	0.55	0.75	0.60	0.50	0.30	0.30														
palynoflora ? I								palynoflora II																						ACRITARCH ZONATION
-	π	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-													*Visbysphaera ? fecunda*
r	c	r	r	π	-	-	-	-	π	-	-	-	-	π	-	π	π													*Villosacapsula ceratioides*
-	π	r	-	-	π	r	-	π	-	r	r	r	r	r	c	r	r													*V. globosa*
-	-	-	-	-	-	-	-	-	r	r	r	c	c	c	r	c	c													*Visbysphaera ? occultata*
-	-	-	-	-	-	-	-	-	-	-	π	-	π	r	r	r	π													*Ephelopalla media*
-	-	-	-	-	-	-	π	π	cc	c	c	c	cc	c	r	r	c													*Exochoderma cleopatra*
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	π													*Schizocystia ?* aff. *S. ? bicornuta*
-	-	-	-	r	-	-	-	r	r	-	-	-	-	-	-	-	r													*Ammonidium grosjeani*
-	-	π	-	π	-	π	-	-	π	r	-	-	r	r	π	r	r													*Daillydium pentaster*
-	-	-	-	-	-	-	-	π	r	r	r	r	r	π	-	-	-													*Duvernaysphaera radiata*
-	-	-	-	-	-	-	-	-	-	-	r	r	c	r	-	-	r													*Eisenackidium martensianum*
-	-	-	-	-	-	-	-	-	-	-	π	-	-	-	-	-	-													*Maranhites* cf. *M. gallicus*
-	-	-	-	-	-	-	-	-	-	-	r	r	-	r	-	-	-													*M. stockmansii*
π	-	π	r	-	-	-	π	-	-	r	r	r	r	r	c	r	r													*Multiplicisphaeridium ramispinosum*
-	-	-	-	-	-	π	-	-	-	-	-	-	-	-	-	-	-													*Pterospermella tenellula*
-	-	π	-	π	-	-	-	-	-	-	π	-	r	π	r	π	π													*Stellinium comptum*
-	r	-	π	r	-	-	π	-	π	π	r	-	r	r	π	r	r													*S. micropolygonale*
-	π	-	-	-	-	-	-	-	r	-	-	-	-	-	r	r	-													*Unellium cornutum*
-	-	π	π	-	-	-	-	-	π	-	-	-	-	-	-	-	π													*U. elongatum*
-	-	π	-	-	-	-	-	-	-	-	-	-	-	-	-	π	r													*U. piriforme*
-	-	-	π	-	-	-	-	-	r	-	-	-	-	r	-	r	π													*Veryhachium polyaster*
π	-	r	r	r	-	-	-	-	-	-	π	r	r	r	-	-	-													*Winwaloeusia ranulaeforma*
Angochitininids																														CHITINOZOAN ASSEMBLAGE
c	c	c	c	c	c	r	r	r	c	r	r	c	r	r	r	r	r													Angochitininae gen. et sp. nov.
c	c	c	r	c	c	r	-	r	r	-	-	r	r	r	r	-	-													*Sphaerochitina* cf. *S. sphaerocephala*
r	r	r	-	π	-	-	-	-	-	-	-	r	-	r	r	-	-													*Angochitina* sp. 1
r	c	c	r	c	r	-	-	-	-	-	-	-	-	-	-	-	-													*Angochitina* sp. 2
r	-	-	-	π	-	-	-	-	-	-	r	r	r	r	r	-	-													*Gotlandochitina* sp.

ACRITARCHS

CHITINOZOANS

late Frasnian	early Famennian	AGE
Senzeilles		FORMATION
1	2	INFORMAL MEMBER
	Early *Pa. triangularis*	CONODONT ZONATION
	just below PB-89-4 / just above PB-88-1f	INDEX HORIZON
89-1-6 / 89-1-7 / 89-1-8 / 89-1-9 / 89-1-10 / 89-1-12 / 89-1-13 / 88-7-1 / 89-1-11 / 88-7-2 / 88-7-3 / 88-7-4 / 88-7-5 / 88-7-6		FM SAMPLE NUMBER SENZEILLES: EAST CUTTING
calculated: 1.70 / 0.15 / 0.15 / 0.50 — measured: 0.55 / 0.40 / 0.35 / 0.40 / 0.30 / 0.35 / 0.10 / 0.40 / 0.35		APPROXIMATE THICKNESS (m) BETWEEN SAMPLES
palynoflora II		ACRITARCH ZONATION
r r - r c c c c c c c c c cc r	*Villosacapsula globosa*	ACRITARCHS
c c c c cc cc c r cc r r r r r	*Visbysphaera ? occultata*	
- - - rr rr - - r - rr r r cc c	*Ephelopalla media*	
r r r r c c r cc cc r r c cc r	*Exochoderma cleopatra*	
- - - - - - - - - - - - rr -	*Ammonidium exoticum*	
rr - - - rr rr rr - rr - - r r rr	*A. grosjeani*	
- - - - - - - r rr - r rr - r	*Craterisphaeridium sprucegrovense*	
- rr r rr rr rr r r r - - r rr r	*Daillydium pentaster*	
r - - - - - - - - - - - - -	*Duvernaysphaera radiata*	
- r r r r r rr r r - r r rr r	*Eisenackidium martensianum*	
- - - - - - - - - - - rr - -	*Evittia* cf. *E. sommeri*	
- - - - - r - - - - - - - -	*Maranhites* cf. *M. gallicus*	
rr r - - - rr - r rr rr r r r -	*M. stockmansii*	
r r r r r c c cc c c r cc c c	*Multiplicisphaeridium ramispinosum*	
- - - - - - - - - r rr - - rr rr	*Palacanthus ledanoisii*	
- rr - - - - - - - r - - - -	*Pterospermella tenellula*	
rr r - rr r r r r - - - - - r	*Stellinium comptum*	
- - rr r r c r c c c r c c r	*S. micropolygonale*	
- - - - - - r - - - - - - -	*S.* cf. *S. rabians*	
- rr - - r r r r r r r r r r	*Unellium cornutum*	
- - - rr - r r r r r rr rr r r	*U. elongatum*	
- - - - r rr r r r - r r r r	*U. piriforme*	
- rr - rr - c - r r r rr rr r r	*Veryhachium polyaster*	
- r r - - rr r rr - - - r rr r	*Winwaloeusia ranulaeforma*	
Angochitininids		CHITINOZOAN ASSEMBLAGE
r r r rr - - - - - - r r - r	Angochitininae gen. et sp. nov.	CHITINOZOANS
- r - - - - - - - - - - - -	*Gotlandochitina* sp.	

Formation and to the lower part of member 1 of the Senzeilles Formation. *Villosacapsula globosa* (Pl. 1, Figs. 1, 4, 5, 8, 11, 13, 14) and *V. ceratioides* (Pl. 1, Figs. 10, 12, 15) were rarely determined, except in a single sample (FM-89-1-2) near the base of the section. The latter contains relatively numerous *V. ceratioides* and is also the only sample to yield very rare *Visbysphaera? fecunda*, a species easy to recognise even in a fragmentary state. The two lowest levels in member 1 of the Senzeilles Formation contain, notably, *Exochoderma cleopatra*. This taxon, considered here as a synonym of *Diexallophasis remota* (DEUNFF) PLAYFORD, 1977 sensu VANGUESTAINE *et al.*, (1983), is without detailed stratigraphic value either in or outside Belgium, as noted by VANGUESTAINE *et al.*, (1983, p. 148) and by LOBOZIAK *et al.*, (1983, p. 179). In the absence of *Visbysphaera? occultata* and *Ephelopalla media*, the badly preserved assemblages are questionably, and for want of better evidence, placed in palynoflora I (MARTIN, 1985). The first three taxa are known from the middle part of the Frasnian onwards, and only the levels of first appearances confirmed with reference to the conodont zonation are considered here; their order of succession is insufficiently known to justify proposing any biostratigraphic subdivisions. The appearances of *Visbysphaera? fecunda* and of *Villosacapsula ceratioides* in northeastern France (LE HERISSE & DEUNFF, 1988) are both the oldest and the best dated with reference to the conodont zonation (BRICE *et al.*, 1980). At Ferques, in the Boulonnais, the entry of the former species, at the top of the Beaulieu Formation and with an impoverished conodont fauna, is above a level attributable to the top of the *Pa. transitans* Zone or to the *Pa. punctata* Zone, and below the Early *Pa. hassi* Zone. The appearance of *Villosacapsula ceratioides* in the Ferques Formation follows that of *Visbysphaera? fecunda*; it is located in the above mentioned conodont interval or belongs to the Early *Pa. hassi* Zone (LE HERISSE & DEUNFF, 1988, p. 107, table I, p. 140). In Belgium the first conodont-dated record of these two acritarch species and *Villosacapsula globosa* is a little higher in the middle part of the Frasnian. A level in the Boussu-en-Fagne Member of the Grand-Breux Formation, immediately north of Frasnes (MARTIN, 1982, sample FM-79-6-1), which may be correlated with the upper part of the Ferques Formation (COEN-AUBERT, 1994, table 1), contains numerous specimens of *Visbysphaera? fecunda* and *Villosacapsula ceratioides*, and very rare *V. globosa*. The sample is situated a little less than 10 m below the Neuville Formation (sensu BOULVAIN, COEN & COEN-AUBERT in BOULVAIN *et al.*, 1993), itself dated as *Pa. jamiae* Zone to Early *Pa. rhenana* Zone in the Frasnes area (SANDBERG *et al.*, 1992), and Late *Pa. hassi* Zone to *Pa. jamiae* Zone at Nismes (HELSEN & BULTYNCK, 1992).

←

Table 3 — Range chart of acritarchs and chitinozoans at Senzeilles east cutting. (Number of specimens: rr = 1; r = 2–19; c = 20–100; cc = more than 100).

PALYNOFLORA II (approximately Zone Vg)

In the western cutting, the entry of *Visbysphaera? occultata* (Pl. 1, Figs. 2, 3, 6, 7, 9), 0.70 m above the base of member 1 of the Senzeilles Formation, precedes slightly that of *Ephelopalla media* (Pl. 2, Figs. 1-10). With reference to the ostracod samples of CASIER (1992), the former species starts between S95 and S96, and the latter between S99 and S100. The same author placed the Frasnian/Famennian boundary slightly less than 1 metre higher, between samples S100 and S101, on the basis of the renewal of macrofauna underlined by SARTENAER (1960). In the eastern cutting, *Visbysphaera? occultata* is abundant from the beginning of member 1 of the Senzeilles Formation, and *Ephelopalla media* appears at the summit of the same member, 0.50 m below the first Famennian level belonging to the Early *Pa. triangularis* Zone. No other significant appearance of acritarch taxa is known from deposits of this conodont zone or (MARTIN, 1985) in succeeding strata of the Middle *Pa. triangularis* Zone, as the distinction between two varieties, *Ephelopalla media praemedia* and *E. media media* (VANGUESTAINE *et al.*, 1983, p. 128), often difficult to observe when the continuous variation in the species is not sufficiently well preserved, could not be established here. With reservations, due to the unsatisfactory state of preservation of the acritarchs and the relative spacing of collecting, the sample located 0.50 m below the top of member 1 in the eastern cutting, below the first bed containing the Early *Pa. triangularis* Zone and marking the appearance of *Ephelopalla media*, could correspond to that situated 2,80 m above the base of member 1 in the western cutting. All samples from the eastern cutting, as well as those (FM-79-10-1 to FM-79-10-4) from the western extension of the reference section published by BULTYNCK & MARTIN (in MARTIN, 1985) lack *Villosacapsula ceratioides*, which has been recognised very sporadically in the Senzeilles area up to a level between the zones of *Ptychomaletoechia gonthieri* and *P. dumontii* (MARTIN, 1985, sample FM-80-8-12); they contain often numerous *Villosacapsula globosa* and *Visbysphaera? occultata* as well as *Exochoderma cleopatra*. *Ephelopalla media*, variably represented from 2 m above the base of the cutting, becomes abundant in the upper part of deposits dated as Early *Pa. triangularis* Zone, starting with FM-88-7-5. Beginning with the appearance of *Visbysphaera? occultata*, the levels belong to palynoflora II (MARTIN, 1985) or to Zone Vg (VANGUESTAINE *et al.*, 1983), accepting informally that the latter begins at the appearance of the taxon. The original definition of this assemblage zone takes account of the entry of new taxa (*Villosacapsula? occultata*, *Ephelopalla media praemedia*) and the relative frequency (*Villosacapsula globosa*) or re-appearance (*Exochoderma cleopatra*) of species known from earlier in the Frasnian. At Senzeilles the first occurrence of *Visbysphaera? occultata* is imprecise in terms of conodont zones but is probably slightly older than in the condensed sections at Hony and Sinsin. According to VANGUESTAINE *et al.*, (1983) and STREEL & VANGUES-

TAINE (1989), the species appears at Hony just above bed 48b with conodonts of the Early *Pa. triangularis* Zone, and at Sinsin between the last bed with *Pa. linguiformis* and the first with *Pa. triangularis*, at a level closer to the former than to the latter. The entry of *Ephelopalla media*, as emphasised by VANGUESTAINE *et al.*, (1983, p. 148), is situated slightly above that of *Visbysphaera? occultata* at Senzeilles, Hony and Sinsin.

Chitinozoans

The chitinozoans are badly preserved and do not permit chronostratigraphic distinctions to be made between the different levels in the Senzeilles cuttings. All determinable specimens belong to the Subfamily Angochitininae PARIS, 1981, and are relatively small, with an overall length of some 130 to 200 µm. In the Matagne Member, where they are relatively less rare, and in members 1 and 2 of the western cutting, the assemblage contains: *Sphaerochitina* cf. *S. sphaerocephala* (EISENACK) EISENACK, 1955 sensu MARTIN, 1982 (Pl. 3, Figs. 1-3); *Angochitina* sp. 1 (Pl. 3, Figs. 6, 7, 10, 11) with spines that are distally coalescent but tend to be bifid proximally; *Angochitina* sp. 2 (Pl. 3, Figs. 4, 9, 12, 14-16) whose spines have a free distal extremity and a base that is often bifid; and *Gotlandochitina* sp. (Pl. 3, Figs. 5, 13, 17) with robust spines, variably aligned and always incomplete. Only the last genus has been determined in member 1 at the eastern cutting.

This angochitininid assemblage differs essentially from that, equally badly preserved, from the lower part of the Matagne Member immediately north of Frasnes (MARTIN, 1982), in the presence of specimens of *Angochitina* sp. 1 and sp. 2 with denser ornamentation, and in the absence of *Angochitina devonica* EISENACK, 1955 and *Hoegisphaera glabra* STAPLIN, 1962. Upper Devonian chitinozoans are relatively little documented (BOUMENDJEL *et al.*, 1988) and there is no detailed published information concerning them at the Frasnian/Famennian boundary dated in terms of conodont biozones. A report by PARIS & ELAOUAD-DEBBAJ to the Devonian Subcommission (IUGS, Washington, 1989) provides preliminary information on the ranges of chitinozoans at the El Atrous section, Tafilalt, Morocco. In addition to the local reworking present in all levels investigated they indicated an important change in the genera of the Angochitininae, beginning in the Lower *Pa. triangularis* Zone; this could not be confirmed at Senzeilles. In the trench "C" of the La Serre section (Montagne Noire), close to the Frasnian-Famennian stratotype at Coumiac, Paris *et al.*, (1994), mention a chitinozoan bloom dominated by one undesignated species of *Angochitina* in the first Famennian bed.

Systematic Palaeontology Conodonts

Representatives of conodont taxa from the Senzeilles Formation at Senzeilles (Table 1) and the Matagne Member at Neuville are figured (Plates 4 to 9). Descriptions and discussions refer mainly to Pa elements of the genus *Palmatolepis*, on which biostratigraphic interpretation and correlations are based. Synonymies are limited to the original reference and to figured specimens from sections with which we established correlations or that are relevant to the description of the new forms recognized.

Figured specimens are in the collections of the Micropalaeontology - Palaeobotany Section, Institut royal des Sciences naturelles de Belgique.

Genus *Ancyrognathus* BRANSON & MEHL, 1934

Ancyrognathus ? cryptus ZIEGLER, 1962
Pl. 7, Fig. 12.

v.* 1962 *Ancyrognathus crypta* n. sp. - ZIEGLER, pp. 49-50, pl. 9, figs. 2-6.

DISCUSSION: The single, figured Pa element agrees closely with the holotype of the species. Assignment to *Ancyrognathus* is questioned because the Pa element of *A.? cryptus* lacks a lateral lobe, developed in typical representatives of the genus.

Ancyrognathus ubiquitus SANDBERG, ZIEGLER & DREESEN, 1988
Pl. 9, Fig. 12.

* 1988 *Ancyrognathus ubiquitus* n. sp. SANDBERG, ZIEGLER & DREESEN — SANDBERG *et al.*, pp. 297 — 298, pl. 1, figs. 5, 6; pl. 2, figs. 1-7.
1990 *Ancyrognathus ubiquitus* SANDBERG, ZIEGLER & DREESEN 1988 — SCHINDLER, pl. 5, fig. 7.
1990a *Ancyrognathus ubiquitus* SANDBERG, ZIEGLER & DREESEN 1988 — KLAPPER, p. 1021, figs. 6.11-6.12.
1992 *Ancyroides ubiquitus* (SANDBERG, ZIEGLER & DREESEN, 1988) — SANDBERG *et al.*, p. 60, pl. 9, figs. 7-9, text-fig. 11.

DISCUSSION: Identification of the single specimen from the Matagne Member in the Neuville section is based on the oval outline of the platform, the short high blade, the attenuating lateral lobe and the prominent carinae on the posterior platform and lateral lobe.

Genus *Palmatolepis* ULRICH & BASSLER, 1926

Palmatolepis clarki ZIEGLER, 1962
Pl. 7, Fig. 11.

v.* 1962 *Palmatolepis marginata clarki* n. subsp. - ZIEGLER, pp. 62-65, pl. 2, figs. 20-22, 24-25 (only;

non figs. 23, 26, 27 = *Pa. protorhomboidea* form a)

1984 *Palmatolepis delicatula clarki* ZIEGLER, 1962 - DREESEN, pl. 1,figs. 10, 13 (only; fig 12 = *Pa. protorhomboidea*; figs. 11, 15 = juvenile specimens of *Palmatolepis* sp.).

1990 *Palmatolepis clarki* ZIEGLER, 1962a - ZIEGLER & SANDBERG, p. 66, pl. 16, fig. 7.

DISCUSSION: Specimens assigned here to *Pa. clarki* show features in the emended diagnosis by ZIEGLER & SANDBERG (1990): the elongated platform, the fortified inner anterior platform margin and the short outer lobe, especially demarcated anteriorly. In *Pa. protorhomboidea* form a the outer lobe is not well defined anteriorly.

Palmatolepis delicatula delicatula BRANSON & MEHL, 1934

Pl. 7, Figs. 6-7.

* 1934 *Palmatolepis delicatula* BRANSON and MEHL, n. sp. - BRANSON & MEHL, p. 237, pl. 18, figs. 4,10.

v. 1962 *Palmatolepis marginata marginata* STAUFFER - ZIEGLER, pp. 61-62, pl. 2, figs. 17,18 (only; figs. 13-16, 19 = *Pa. delicatula platys*).

1984 *Palmatolepis delicatula delicatula* BRANSON & MEHL, 1934 - DUSAR & DREESEN, pl. 2, fig. 9.

1988 *Palmatolepis delicatula* BRANSON & MEHL - BULTYNCK, pl. A2/2, fig. 2 (only; fig. 5 = juvenile specimen of *Palmatolepis* sp.).

1990 *Palmatolepis delicatula delicatula* BRANSON & MEHL, 1934 - ZIEGLER & SANDBERG, p. 67, pl. 17, figs. 1-3.

DISCUSSION: Present identification of *Pa. delicatula delicatula* is based mainly on the concept of the Pa element of the taxon published since ZIEGLER (1962), including small forms with a wide, more or less triangular outer platform and no well differentiated outer lobe. The platform is rather thick, its upper surface smooth or delicately ornamented, and the posterior carina generally does not reach the posterior tip.

The identity of the type material of *Pa. delicatula* is not sufficiently documented (ZIEGLER & SANDBERG, 1990, p. 66, remarks; KLAPPER *et al.*, 1993, p. 437) and in the latter publication,*Pa. delicatula delicatula* as used here is written in quotation marks.

Palmatolepis linguiformis MÜLLER, 1956

Pl. 9,Fig. 11.

* 1956 *Palmatolepis (Palmatolepis) linguiformis* n. sp. - MÜLLER, pp. 24-25, pl. 7,figs 1-7.

1990 *Palmatolepis linguiformis* MÜLLER, 1956 - ZIEGLER & SANDBERG, pp. 59-60, pl. 14, figs. 8-10.

DISCUSSION: Two specimens from the Matagne Member in the Neuville section most resemble some of the types (MÜLLER, 1956, pl. 7, figs. 2, 3, 6) with a more or less smooth platform surface. The species is recorded for the first time in Belgium.

Palmatolepis praetriangularis ZIEGLER & SANDBERG, 1988

Pl. 4, Figs. 1-9.

* 1988 *Palmatolepis praetriangularis* n. sp. ZIEGLER & SANDBERG - SANDBERG *et al.*, pp. 298-299, pl. 1, figs. 1-4.

1990 *Palmatolepis praetriangularis* ZIEGLER & SANDBERG, 1988 - SCHINDLER, pl. 5, fig. 6.

1990 *Palmatolepis praetriangularis* ZIEGLER & SANDBERG, 1988 — ZIEGLER & SANDBERG, p. 64.

DISCUSSION: Most specimens from Senzeilles assigned here to *Pa. praetriangularis* demonstrate perfectly features in the original diagnosis. Larger specimens in our collection are characterised by a relatively narrow elongated platform and a relatively long outer lobe. The inner-posterior platform is horizontal to slightly concave, the outer-posterior platform slightly convex, and the posterior carina horizontal or slightly declined.

On the basis of the latter characteristics, the Pa element of *Pa. praetriangularis* is separated from *Pa. triangularis*, contrary to the opinion of KLAPPER *et al.*, (1993, p. 436).

Palmatolepis protorhomboidea SANDBERG & ZIEGLER, 1973

Pl. 7, Figs. 8-10; Pl. 8, Figs. 1,? 2-3.

v. 1962 *Palmatolepis marginata clarki* n. subsp. - ZIEGLER, pp. 62-65, pl. 2,figs. 23, 26-27 (only).

1965 *Palmatolepis delicatula clarki* ZIEGLER - BOUCKAERT & ZIEGLER, pl. 2, fig. 4.

* 1973 *Palmatolepis delicatula protorhomboidea* n. subsp. - SANDBERG & ZIEGLER, p. 103, pl. 1, figs. 14-19.

1973 *Palmatolepis delicatula clarki* ZIEGLER, 1962 - SANDBERG & ZIEGLER, pl. 1, fig. 13.

1984 *Palmatolepis delicatula clarki* ZIEGLER, 1962 - DREESEN, pl. 1, fig. 12 (only).

1984 *Palmatolepis delicatula clarki* ZIEGLER, 1962 – DUSAR & DREESEN, pl. 2, fig. 8.

1988 *Palmatolepis clarki* ZIEGLER, 1962 – BULTYNCK, pl. A2/2, figs. 3-4, 9-10.

1990 *Palmatolepis protorhomboidea* SANDBERG & ZIEGLER, 1973 – ZIEGLER & SANDBERG, pp. 68-69, pl. 17, figs. 8-11.

DISCUSSION: Specimens identified here as *Pa. protorhomboidea* form a were formerly included in *Pa. clarki*. They have a more or less rhomboidal platform outline, a mostly narrow posterior tip, a poorly differentiated outer lobe, raised platform margins ornamented with nodes or ridges, and are common in the upper part of the Early *Pa. triangularis* Zone at Senzeilles. In the lower part of the Middle *Pa. triangularis* Zone they occur with specimens designated here as *Pa. protorhomboidea* form b which

have a smooth or shagreen surface and a parapet on the inner anterior platform and are similar to the holotype and most paratypes of the species. The Pb element (Pl. 8, Figs. 2-3) occurs with form a in sample 88-1-g and probably belongs to the conodont apparatus of *Pa. protorhomboidea* form a.
See also *Pa. clarki*.

Palmatolepis subrecta MILLER & YOUNGQUIST, 1947
Pl. 9, Fig. 10.

* 1947 *Palmatolepis subrecta* MILLER & YOUNGQUIST, n. sp. - MILLER & YOUNGQUIST, pp. 513-514, pl. 75,figs. 7-11.

DISCUSSION: Specimens identified here as *Pa. subrecta* are from sample 6 (MOURAVIEFF, 1974, p. 8) of the Wérin Member in the old railway section at Senzeilles and from the Matagne Member in the Neuville railway section. The range of variation of the Pa elements includes forms, figured here, identical in platform outline with the lectotype reillustrated by ZIEGLER & SANDBERG (1990, pl. 11, fig. 3) and by KLAPPER & FOSTER (1993, fig. 18.5).

Palmatolepis triangularis SANNEMANN, 1955
Pl. 4, Figs. 10-11; Pl. 5, Figs. 1-9; Pl. 6, Figs. 1-7.

* 1955 *Palmatolepis triangularis* n. sp. - SANNEMANN, pp. 327-328, pl. 24, fig. 3.
v. 1962 *Palmatolepis triangularis* SANNEMANN - ZIEGLER, pp. 83-85, pl. 1, figs. 1-5, 7-16 (only; fig. 6=?); pl. 2, figs. 1, 4-5 (only; fig. 2-3=?).
1965 *Palmatolepis triangularis* SANNEMANN - BOUCKAERT & ZIEGLER, pl. 1, figs. 1-4; 5-6?
1965 *Palmatolepis triangularis* transitional forms to *P. quadrantinodosalobata* SANNEMANN - BOUCKAERT & ZIEGLER, pl. 1, figs. 7?, 8.
1966 *Palmatolepis triangularis* SANNEMANN, 1955 - GLENISTER & KLAPPER, pp. 825-826, pl. 92, figs. 17-18.
1971 *Palmatolepis triangularis* SANNEMANN, 1955– SZULCZEWSKI, p. 43, pl. 12, figs. 1-2; pl. 13, figs. 10-11; pl. 14, fig. 5.
1976 *Palmatolepis triangularis* SANNEMANN, 1955 - DRUCE, pp. 174-175, pl. 61, figs. 1-3; pl. 62, fig. 2.
1984 *Palmatolepis triangularis* SANNEMANN, 1955 - DUSAR & DREESEN, pl. 2, fig. 7.
1988 *Palmatolepis triangularis* SANNEMANN, 1955 - BULTYNCK, pl. A2/1, figs. 3-4, 14; pl. A2/2, figs. 1,11.
1988 *Palmatolepis rhenana* BISCHOFF, 1956 - *Pa.triangularis* SANNEMANN, 1955 - BULTYNCK, pl. A2/1, fig. 2.
1988 *Palmatolepis triangularis* SANNEMANN, 1955 - *P. quadrantinodosalobata* SANNEMANN 1955 - BULTYNCK, pl. A2/1, figs. 5-6, 17; pl. A2/2, fig. 12.
1990 *Palmatolepis triangularis* SANNEMANN, 1955 – ZIEGLER & SANDBERG, pp. 64-65, pl. 14, figs. 1-2, 4-5 (only; fig. 3 = *Palmatolepis* n. sp. a).
1992 *Palmatolepis triangularis* SANNEMANN, 1955 - SAVAGE, p. 291, figs. 1-5; 6-17?

DESCRIPTION: The platform, excluding lobe, is oval-shaped, mostly elongated with narrow posterior tip. The carina is slightly to moderately sigmoidal, the adcarinal area behind the central node is inclined gently or abruptly upwards, and the posterior tip is horizontal or flexed up or down. The outer lobe is well demarcated, directed laterally or slightly anteriorly and situated mainly in the anterior half of the platform. Variation in size of the outer lobe ranges from relatively long (more than one half the length between central node and tip of outer lobe) to short (about one third the length central node - tip outer lobe). Specimens with long to medium size lobe are designated here as form a, and those with short lobe as form b. The latter have a broad shallow sinus in front of the lobe, and in form a the sinus can be very deep. In both forms the blade declines gradually into the anterior carina with more or less fused nodes, and the posterior carina is a low, thin ridge. The platform surface of adult specimens is covered with nodes and irregular ridges; that of juvenile specimens may be smooth.

DISCUSSION: *Pa. triangularis* form a is the only representative of the species in the lower part of the Early *Pa. triangularis* Zone at Senzeilles; forms a and b occur together from the upper part of the zone onwards, form b being less frequent. Both forms were recognised in reference samples from Coumiac and Steinbruch Schmidt and are figured here; their distribution is discussed on p. 11. Most specimens figured in previous literature belong to form a; typical forms b were illustrated by GLENISTER & KLAPPER (1966, pl. 92, fig. 17), SZULCZEWSKI (1971, pl. 13, fig. 11) and by ZIEGLER & SANDBERG (1990, pl. 14, fig. 5).

Specimens with rounded, broad short platform included in *Pa. triangularis* by ZIEGLER & SANDBERG (1990, pl. 14, fig. 3) are described here as *Palmatolepis* n. sp. a.

The Pb element (Pl. 8, fig. 4) is associated with Pa elements of *Pa. triangularis*.

Palmatolepis n.sp. a
Pl. 6, Figs. 8-10; Pl. 7, Figs. 1-5.

1990 *Palmatolepis triangularis* SANNEMANN, 1955 - ZIEGLER & SANDBERG, pl. 14, fig. 3 (only; figs. 1-2, 4-5 = *Pa. triangularis*).

DESCRIPTION: In representative specimens of *Palmatolepis* n.sp. a the platform is rounded, broad and relatively short; the inner platform margin is nearly semicircular and the outer posterior-platform margin convex. The posterior end of the platform is mostly rounded, but an incipient or short posterior tip may be present. The anterior inner-platform surface is slightly convex, separated from the carina by a narrow, shallow adcarinal trough. The rounded outer lobe is short to moderately long, directed laterally or slightly forwards. The blade-carina is moderately sigmoidal and the posterior carina weak,

not reaching the posterior end. The posterior platform is flat or inclined slightly upwards.

DISCUSSION: Using convential morphologic criteria for separating late Frasnian *Palmatolepis* taxa (e.g. *Pa. subrecta-Pa. rotunda*), the platform outline of *Palmatolepis* n.sp. a is too different to be included in the ''normal'' range of variation of *Pa. triangularis*. The general platform outline resembles that of *Pa. rotunda* and some Pa elements of *Pa. bogartensis* (STAUFFER, 1938) *in* KLAPPER & FOSTER (1993, e.g. figs. 13.9, 13). In the two latter taxa the posterior platform slopes downwards. At Senzeilles, *Palmatolepis* n.sp. a ranges from the lowest sample of the Early *Pa. triangularis* zone into the Upper *Pa. triangularis* Zone (sample 8 in BULTYNCK, 1988, p. 22, fig. A2/3).

Genus *Polygnathus* HINDE, 1879

Polygnathus aequalis KLAPPER & LANE, 1985
Pl. 8, Figs. 7-10.

* 1985 *Polygnathus aequalis* n.sp. - KLAPPER & LANE, pp. 930-932, figs. 16.7-16.14.

DISCUSSION: Specimens identified here as *Po. aequalis* differ slightly from most of the types in having shallower adcarinal troughs. The dextrally convex specimen (Pl. 8, fig. 8) is characteristically wider than the sinistrally convex specimen (Pl. 8, fig. 7).

Polygnathus aff. ***Po. sinuosus*** SZULCZEWSKI, 1971
Pl. 8, fig. 11.

v. aff. 1971 *Polygnathus sinuosus* sp.n. - SZULCZEWSKI, p. 52, figs. 2-4.

DISCUSSION: A single specimen form Senzeilles resembles *Po. sinuosus* in having a high free blade, a narrow elongated platform, and a high, denticulate carina that is curved and extends beyond the platform. The specimen differs in having a longer platform with no nodes on the margins, and the blade carina is less sigmoidal. The platform of *Po. sinuosus wadleighensis* SAVAGE, 1987 is wider, shorter and characteristically ornamented.

Conclusions

GOSSELET's (1877-1880) original Frasnian/Famennian boundary and the revised (so-called ''historical'') boundary of SARTENAER (1960), 0.75 m below the former and based on the renewal of the brachiopod fauna above the Matagne Shales, have been re-assessed in two new nearby cuttings. Conodonts from the original boundary level belong to the Early *Pa. triangularis* Zone and are best compared with those in the lowest 3 cm of the basal Famennian in the GSSP at Coumiac (KLAPPER, 1990b; KLAPPER *et al.*, 1993). The four lowest Famennian conodont samples at Senzeilles are characterised by relatively high icriodid (63-38%) and palmatolepid (58-30%) percentages. The palmatolepid percentages are much higher than in other Frasnian/Famennian boundary sections in Belgium, such as Hony (4,5-2,5%) and Sinsin (7-1%) (SANDBERG *et al.*, 1988, pp. 282-283), and suggest more distal shelf conditions at Senzeilles. The ''historical'' boundary is interpreted here as the end of the late Frasnian extinction event, represented at Senzeilles by the Matagne Member and the lowest 3 m of the Senzeilles Formation. In a nearby section at Neuville *Palmatolepis linguiformis* was recorded from a sample within the Matagne Member. The latter, much reduced at Senzeilles and Neuville in the Philippeville Massif, probably represents only the upper part of the member in the Frasnes area, where the exposed portion, about 42 m thick, belongs to the southern border of the Dinant Synclinorium. In a section at Frasnes (SARTENAER, 1974, p. 4) the base of the Matagne Member is characterised by the appearance of *Ancyrognathus asymmetricus* ULRICH & BASSLER, 1926, indicating probably the late *Palmatolepis rhenana* Zone (MOURAVIEFF, 1974, p. 6).

The Matagne Shales may represent not only the Upper Kellwasser event as proposed by SANDBERG *et al.*, (1992, p. 46, fig. 21) but also the Lower Kellwasser event.

Of the acritarchs, the species which enters closest to, and slightly below, the Frasnian/Famennian boundary is *Visbysphaera? occultata*, whose appearance marks the base of palynoflora II. At Senzeilles its first occurrence below the first bed of the Early *Pa. triangularis* Zone is imprecise in terms of conodont zones. In the west cutting at Senzeilles it is located within member 1 of the Senzeilles Formation, slightly more than 2 m below the ''historical'' stage boundary as indicated by the appearance of a new macrofauna (CASIER, 1992). In the east cutting it is recognised from the base upwards of the exposed portion of member 1, 2.50 m below the first bed of the Early *Pa. triangularis* Zone, and 1.80 m below the ''historical'' boundary.

Poorly preserved angochitinid chitinozoans from the Senzeilles cuttings do not permit late Frasnian and early Famennian strata to be differentiated chronostratigraphically with confidence.

Glass spherules, similar to microtektites, described by CLAEYS *et al.*, (1992) from the Senzeilles Formation at Senzeilles are from a level just below our sample 79-10-3 (Fig. 3), assigned here to the uppermost part of the Early *Pa. triangularis* Zone and do not represent a meteorite impact that could have caused the late Frasnian extinctions.

The conodont succession now established in the east cutting at Senzeilles permits a revision of VANGUESTAINE *et al.* 's (1983, p. 132) proposed correlation between SARTENAER's early Famennian rhynchonellid zones and ZIEGLER & SANDBERG's palmatolepid conodont zonation. The *Pampeocilorhynchus lecomptei* zone is entirely with-

in the Early *Pa. triangularis* Zone, the *Eoparaphorhynchus praetriaequalis* Zone corresponds to the upper part of the Early *Pa. triangularis* Zone and the lowest part of the Middle *Pa. triangularis* Zone.

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Explanation of Plates

Plate 1

Figs. 1, 4, 5, 8, 11, 13, 14 — *Villosacapsula globosa* Vanguestaine *et al.*, 1983.
Fig. 1: I.R.Sc.N.B. N° b 2244, FM-89-1-10, x 1000. Figs. 4, 5: I.R.Sc.N.B. N° b 2245, FM-89-1-10. Fig. 4: detail of upper part of Fig. 5, x 3000. Fig. 5: excystment slit partly open, x 1000. Fig. 8: I.R.Sc.N.B. N° b 2246, excystment slit partly open, FM-89-1-10, x 1000. Figs. 11, 13: I.R.Sc.N.B. N° b 2247, FM-88-7-6. Fig. 11: x 1000. Fig. 13: detail of lower right part of Fig. 11, with anastomosed ornamentation locally preserved, x 5000. Fig. 14: I.R.Sc.N.B. N° b 2248, excystment slit starting to open, FM-89-1-10, x 1000.

Figs. 2, 3, 6, 7, 9 — *Visbysphaera*? *occultata* Martin, 1985.
FM-89-1-10. Fig. 2, 6: I.R.Sc.N.B. N° b 2249. Fig. 2: detail of upper left part of Fig. 6, x 3000. Fig. 6: x 1000. Figs. 3, 7: I.R.Sc.N.B. N° b 2250. Fig. 3: detail of lower right part of Fig. 7, x 3000. Fig. 7: x 1000. Fig. 9: I.R.Sc.N.B. N° b 2251, x 1000.

Figs. 10, 12, 15 — *Villosacapsula ceratioides* (Stockmans & Williere) Loeblich & Tappan, 1976.
FM-89-1-2. Fig. 10: I.R.Sc.N.B. N° b 2242, x 1500. Fig. 12, 15: I.R.Sc.N.B. N° b 2243. Fig. 12: x 1000. Fig. 15: detail of upper right part of Fig. 12, x 4000.

Plate 2

Ephelopalla media (Stockmans & Williere) Martin, 1985

Figs. 1-10 — FM-88-7-6. All specimens show a variably preserved honeycomb pattern of ornamentation on the central body; the irregularly distributed perforations are a secondary feature related to preservation. All except that in Fig. 3 show an excystment slit.
Fig. 1, 4: I.R.Sc.N.B. N° b 2252. Fig. 1: x 1000. Fig. 4: detail of lower part of Fig. 1, x 4000. Figs. 2, 5: I.R.Sc.N.B. N° b 2253, honeycomb pattern of ornamentation present on proximal part of processes. Fig. 2: x 1000. Fig. 5: detail of upper left part of Fig. 2, x 3000. Fig. 3: I.R.Sc.N.B. N° b 2254, x 1000. Figs. 6, 8: I.R.Sc.N.B. N° b 2255. Fig. 6: detail of left part of Fig. 8, x 3000. Fig. 8: x 1000. Figs. 7, 9: I.R.Sc.N.B. N° b 2256. Fig. 7: detail of lower right part of Fig. 9, x 4000. Fig. 9: x 1000. Fig. 10: I.R.Sc.N.B. N° b 2257, x 1000.

Plate 3

Figs. 1-3 — *Sphaerochitina* cf. *S. sphaerocephala* (Eisenack, 1932) *sensu* Martin, 1985.
x 300, Fig. 1: I.R.Sc.N.B. N° b 2269, FM-89-1-1. Fig. 2: I.R.Sc.N.B. N° b 2270, FM-89-1-3. Fig. 3: I.R.Sc.N.B. N° 2271, FM-89-1-1.

Figs. 4, 9, 12, 14-16 — *Angochitina* sp. 2.
FM-89-1-2, Fig. 4, 9: I.R.Sc.N.B. N° b 2262. Fig. 4: x 300. Fig. 9: detail of central part of Fig. 4, x 1000. Fig. 12: I.R.Sc.N.B. N° b 2263, x 300. Figs. 14, 15: I.R.Sc.N.B. N° b 2264. Fig. 14: detail of upper right part of Fig. 15, x 2000. Fig. 15: x 300. Fig. 16: I.R.Sc.N.B. N° b 2265, x 300.

Fig. 6, 7, 10, 11 — *Angochitina* sp. 1.
Fig. 6: I.R.Sc.N.B. N° b 2259, FM-89-1-3, x 500. Fig. 7: I.R.Sc.N.B. N° b 2260, FM-89-1-3, x 300. Figs. 10, 11: I.R.Sc.N.B. N° b 2261, FM-89-1-2. Fig. 10: detail of central part of Fig. 11, x 2000. Fig. 11: x 300.

Fig. 5, 13, 17 — *Gotlandochitina* sp..
FM-88-7-13, x 400, Fig. 5: I.R.Sc.N.B. N° b 2266. Fig. 13: I.R.Sc.N.B. N° b 2267. Fig. 17: I.R.Sc.N.B. N° b 2268.

Fig. 8 — Angochitinidae gen. et sp. indet.. I.R.Sc.N.B. N° b 2258, FM-88-7-6, x 400.

Plate 4

All magnifications are x 80. S: conodont sample number Senzeilles, east cutting; MN: sample number Upper Coumiac Quarry (Klapper, 1990b).

Figs. 1-9 — *Palmatolepis praetriangularis* Ziegler & Sandberg, 1988.
Figs. 1-3: upper views of I.R.Sc.N.B. N°b 2804, b 2805, b 2806, S 89-4. Fig. 4: outer lateral view of I.R.Sc.N.B. N°b

2807,S 89-4. Figs. 5, 6: upper views of I.R.Sc.N.B. N°b 2808, b 28O9, S 89-4. Figs.7-9: upper views and lateral view of I.R.Sc.N.B. N°b 2810, b 2811, b 2812, MN 32a-1.

Figs. 10-11 — *Palmatolepis triangularis* SANNEMANN, 1955 form a.
Lateral and upper views of I.R.Sc.N.B. N°b 2813, b 2814, S 89-4.

PLATE 5

All magnifications are x 80. S: conodont sample number Senzeilles, east cutting. Upper views.

Figs. 1-7 — *Palmatolepis triangularis* SANNEMANN, 1955 form a.
Figs. 1-5: I.R.Sc.N.B. N°b 2815, b 2816, b 2817, b 2818, b 2819, S 89-4. Figs. 6-7: I.R.Sc.N.B. N°b 2820, b 2821, S 88-1-c.

Figs. 8, 9 — *Palmatolepis triangularis* SANNEMANN, 1955 form b.
I.R.Sc.N.B. N°b 2822, b 2823, S 88-1-g.

PLATE 6

All magnifications are x 80. S: conodont sample number Senzeilles, east cutting; MN: sample number Upper Coumiac Quarry (KLAPPER, 1990b); STS: bed number Steinbruch Schmidt (SANDBERG *et al.*, 1988). Upper views.

Figs. 1, 6, 7 — *Palmatolepis triangularis* SANNEMANN, 1955 form a.
I.R.Sc.N.B. N°b 2824, MN 32a-1; N°b 2829, MN 32a-2-3; N°b 2830, STS A.

Fig. 2 — *Palmatolepis triangularis* SANNEMANN, 1955.
I.R.Sc.N.B. N°b 2825, MN 32a-1, specimen intermediate between the a and b forms.

Figs. 3-5 — *Palmatolepis triangularis* SANNEMANN, 1955 form b.
I.R.Sc.N.B. N°b 2826, MN 32a-2-3; N°b 2827, STS A; N°b 2828, STS C.

Figs. 8-10 — *Palmatolepis* n.sp.a.
I.R.Sc.N.B. N°b 2831, MN 32a-1; N°b 2832, STS A; N°b 2833, MN 32a-1.

PLATE 7

All magnifications are x 80. S: conodont sample number Senzeilles, east cutting or ''Coupe-témoin''. Upper views.

Figs. 1-5 — *Palmatolepis* n.sp. a.
I.R.Sc.N.B. N°b 2834, S 88-2-b; N°b 2835, S 88-1-a; N°b 2836, S 88-2-b; N°b 2837, N°b 2838, S 88-1-g.

Figs. 6, 7 — *Palmatolepis delicatula delicatula* BRANSON & MEHL, 1934.
I.R.Sc.N.B. N°b 2839, S 88-2-b; N°b 2840, S 78-18, S 78-23.

Fig. 8 — *Palmatolepis protorhomboidea* SANDBERG & ZIEGLER, 1973 form b.
I.R.Sc.N.B. N°b 2841.

Figs. 9, 10 — *Palmatolepis protorhomboidea* SANDBERG & ZIEGLER, 1973 from a.
I.R.Sc.N.B. N°b 2842, N°b 2843, S 88-1-g.

Fig. 11 — *Palmatolepis clarki* ZIEGLER, 1962.
I.R.Sc.N.B. N°b 2844, S 78-18.

Fig. 12 — *Ancyrognathus*? *cryptus* ZIEGLER, 1962.
I.R.Sc.N.B. N°b 2845, S 78-18.

PLATE 8

All magnifications are x 80. S: conodont sample number Senzeilles, east cutting. Upper views, except figs. 2, 3, 4, 9, 12, lateral views.

Figs. 9, 10 — *Palmatolepis protorhomboidea* SANDBERG & ZIEGLER, 1973 form a.
I.R.Sc.N.B. N°b 2846, S 88-2-b; N°b 2847, N°b 2848, Pb elements, S 88-1-g.

Fig. 4 — ?*Palmatolepis triangularis* SANNEMANN, 1955 Pb element.
I.R.Sc.N.B. N°b 2849, S 88-1-g.

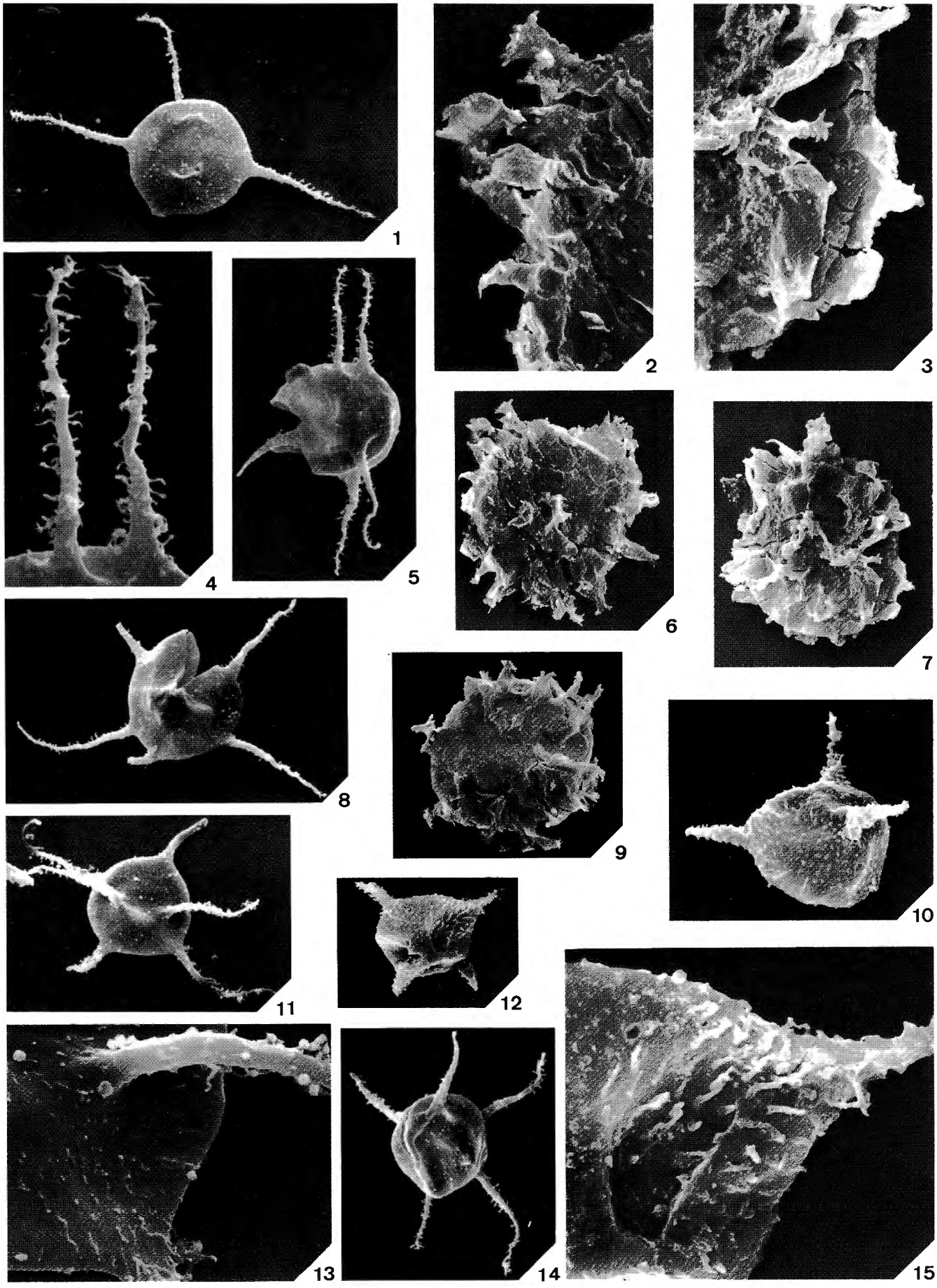
Figs. 5, 6 — *Polygnathus brevilaminus* BRANSON & MEHL, 1934.
I.R.Sc.N.B. N°b 2850, S 89-4; N°b 2851, S 88-1-g.
Figs. 7-10 — *Polygnathus aequalis* KLAPPER & LANE, 1985.
I.R.Sc.N.B. N°b 2852, N°b 2853, S 89-4; N°b 2854, N°b 2855, S 88-1-g.
Fig. 11 — *Polygnathus* aff. *Po. sinuosus* SZULCZEWSKI, 1971.
I.R.Sc.N.B. N°b 2856, S 89-4.
Fig. 12 — *Mehlina* sp.a.
I.R.Sc.N.B. N°b 2857, S 89-4.
Fig. 13 — *Polygnathus* aff. *Po. planirostratus* DREESEN & DUSAR, 1974.
I.R.Sc.N.B. Nb2858, S 88-2-b.

PLATE 9

All magnifications are x 80. S: conodont sample number Senzeilles, east cutting; NV: Neuville, southern railway section. Upper views, except figs. 1a, 3-5, lateral views.

Figs. 1a-b, 2-5, 9 — *Icriodus iowaensis iowaensis* YOUNGQUIST & PETERSON, 1947.
I.R.Sc.N.B. N°b 2859, S 89-4; N°b 2861, N°b 2862, N°b 2863, coniform elements, S 89-4; N°b 2864, S 89-4.
Fig. 6 — *Icriodus alternatus alternatus* BRANSON & MEHL, 1934.
I.R.Sc.N.B. N°b 2865, S 89-4.
Fig. 7,8 — *Icriodus alternatus helmsi* SANDBERG & DREESEN, 1984.
I.R.Sc.N.B. N°b 2866, N°b 2867, S 89-4.
Fig. 10 — *Palmatolepis subrecta* MILLER & YOUNGQUIST, 1947.
I.R.Sc.N.B. N°b 2868, NV 45.
Fig. 11 — *Palmatolepis linguiformis* MÜLLER, 1956.
I.R.Sc.N.B. N°b 2869, NV 45.
Fig. 12 — *Ancyrognathus ubiquitus* SANDBERG, ZIEGLER & DREESEN, 1988.
I.R.Sc.N.B. N°b 2870, NV 45.

Plate 1.



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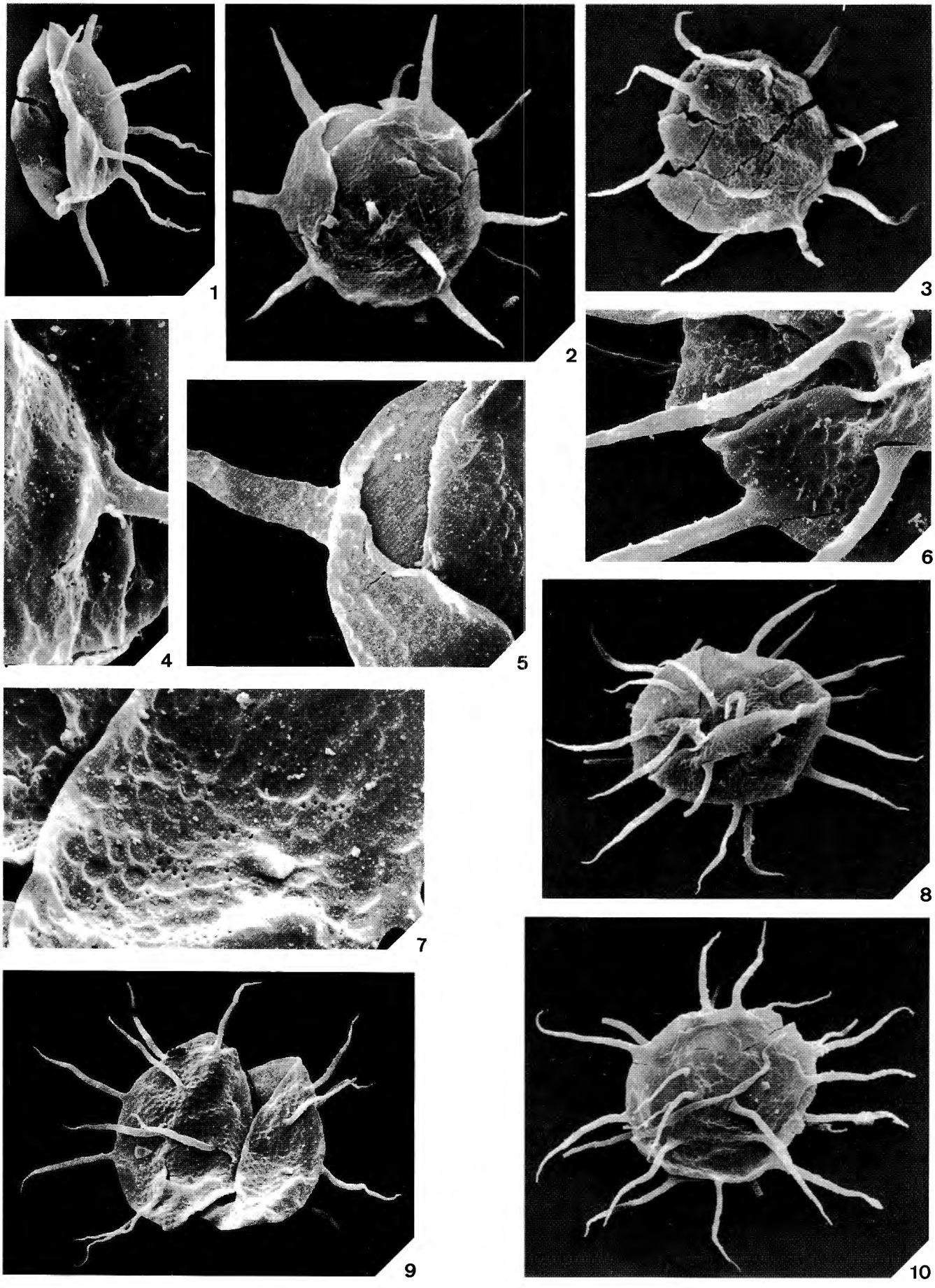

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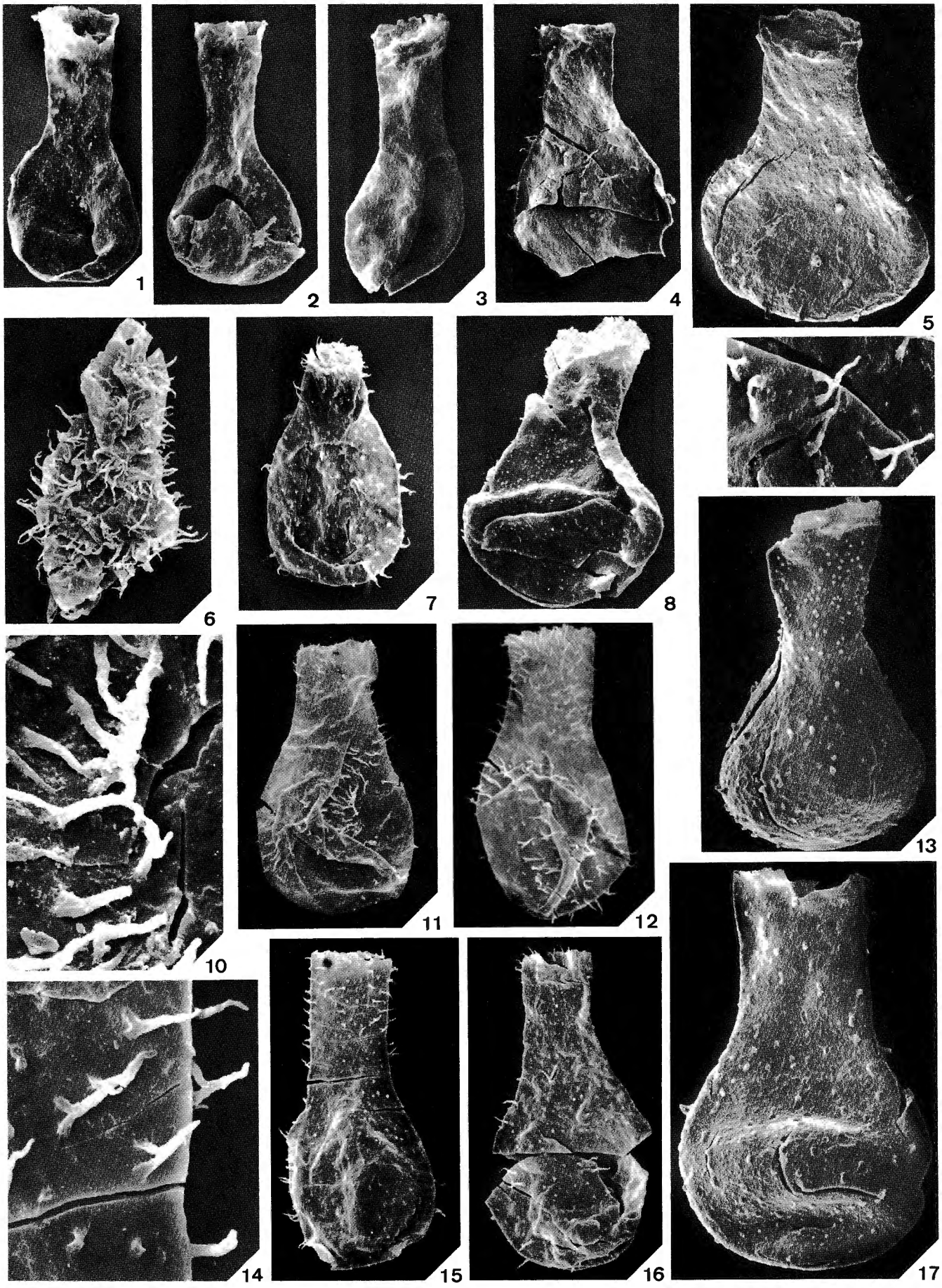

Plate 4.

Plate 5.

Plate 6.

Plate 7.

Plate 8.

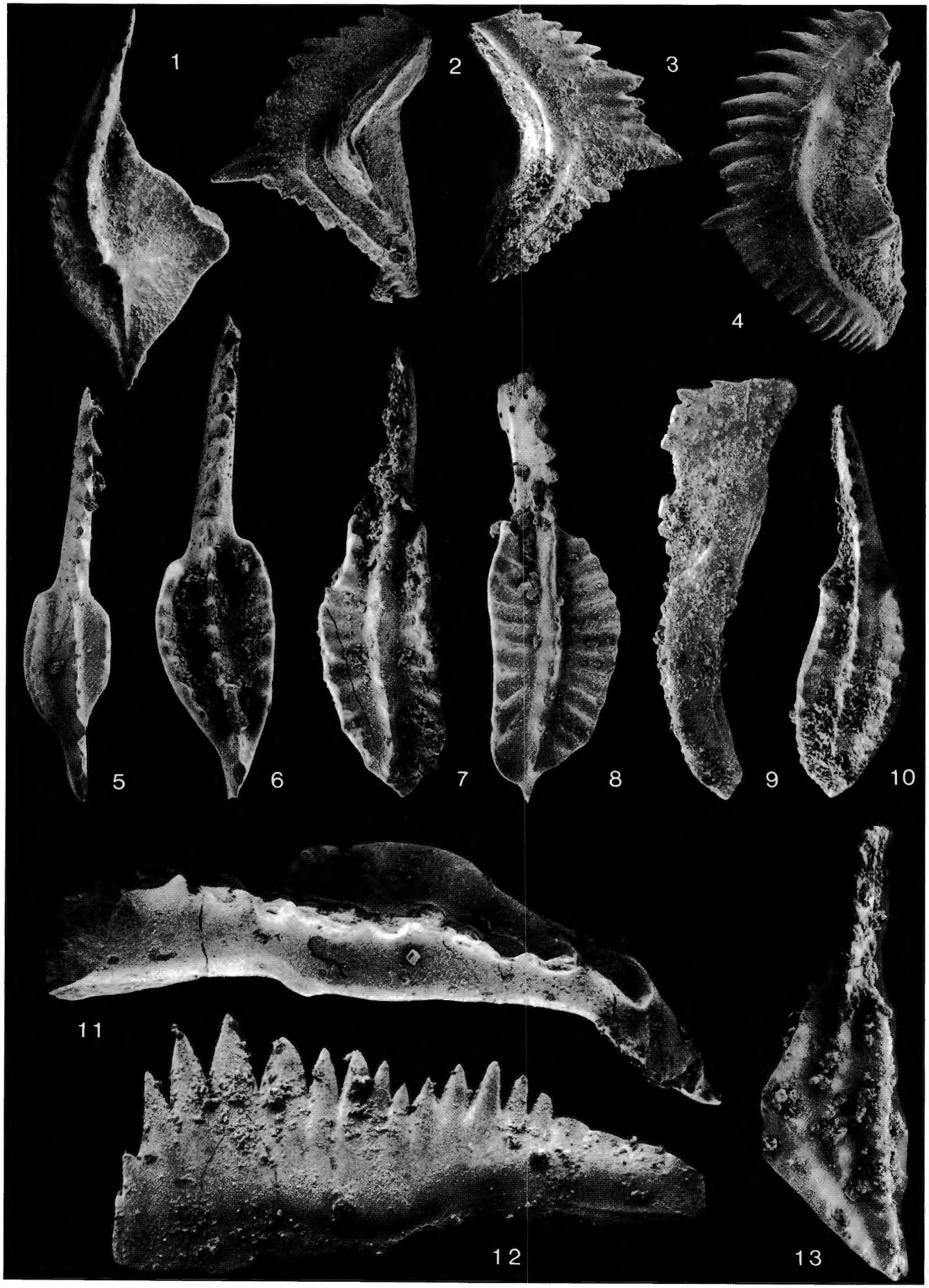

Plate 9.