

Acritarch, chitinozoan and spore stratigraphy from the Middle and Late Devonian of northeast LibyaM. STREEL¹, F. PARIS², W. RIEGEL³ & M. VANGUESTAINE¹¹Laboratoire de Paléobotanique, Paléopalynologie et Micropaléontologie, Université, 7, Place du Vingt Août, B-4000 Liège, Belgique.²Laboratoire de Paléontologie et Stratigraphie, GRECO 7 du CNRS, Université de Rennes, 35042 Rennes Cedex, France.³Institut und Museum für Geologie und Paläontologie, Goldschmidtstrasse 3, D-3400 Göttingen, Fed. Rep. of Germany.**ABSTRACT**

Cuttings and cores from eleven exploration wells in northeast Libya are investigated. Compared with the Old Red Sandstone Continent (mainly the Ardenne-Rhine region) spore stratigraphy, most belong to the Middle Devonian. Frasnian and Famennian rocks are comparatively reduced. However acritarchs suggest the occurrence of Early Famennian sediments below spore dated uppermost Famennian (Strunian) interval at the top of the succession. Chitinozoan assemblages and concurrent or acme-range zones are proposed in the Middle Devonian to Frasnian interval.

INTRODUCTION

Cuttings and cores from eleven exploration wells* in northeast Libya have been investigated (see Fig. 1 for well location). Cores were restricted stratigraphically except in Well Al-37 which is used as a reference section for comparisons (Figs. 2 and 9). Preliminary data were published in Paris *et al.* 1985. In the present paper, it is intended to test the Old Red Sandstone Continent (mainly the Ardenne-Rhine regions) spore zonation scheme in the northern Gondwana region and later to relate some acritarch and chitinozoan biozones to this miospore zonation scheme.

SPORES (W. Riegel & M. Streel)

Attention is focussed on those species whose stratigraphical range in the Ardenne-Rhine regions is known to be of significance. Opper Zones and Interval Zones mentioned below refer to those published in Streel *et al.*, 1987.

1) Stratigraphic distribution of miospores in Well Al-37 (Fig. 2)

Amongst the miospore population recorded at 10,674 ft. (see also Paris *et al.* 1985, p. 49 and pls. 20 and 21) four stratigraphically significant species are noted: *Retusotriletes rugulatus*, *Calyptosporites proteus*, *Calyptosporites cf. velatus* and *Ancyrospora nettersheimensis*. Their collective ranges correspond to Opper Zone AP. (*Acinosporites apiculatus*-*Calyptosporites proteus*), or more precisely to the Interval Zone *Pro* (between the successive first occurrence of *C. proteus* and *C. velatus*) or to the Interval Zone *Vel* (between the successive first occurrences of *C.*

velatus and *Acinosporites macrospinosus*) depending on the exact status given to the specimens here referred to as *C. cf. velatus*. In terms of the conodont biostratigraphy, these Interval Zones range from the latest Emsian *patulus* to the Early Eifelian *costatus* Zones.

Considering the occurrence of *A. nettersheimensis* whose acme occurs above the base of the Eifelian in the type area (Riegel, 1982) it is suggested that this miospore population belongs to an Early Eifelian post *Cor* (*Hystricosporites cf. corystus*) Interval Zone within the limits of the Opper Zone AP.

The miospore population recorded at 9825 ft. contains *Acinosporites macrospinosus* (see Paris *et al.*, 1985, Pl. 29). Between 9825 ft. and 9615 ft., nine samples contain *Rhabdosporites langii* (see Paris *et al.*, 1985, Pl. 29). *Grandispora inculta* occurs in samples from 9642 ft. to 9615 ft. The joint occurrence of these three species corresponds to the Opper Zone AD (*Acinosporites acanthomammillatus* - *Densosporites devonicus*), or more precisely to the Interval Zone *Mac* (between the successive first occurrences of *A. macrospinosus* and *Hystricosporites reflexus*) or to the Interval Zone *Ref* (between the successive first occurrences of *H. reflexus* and *Geminispora lemurata*). In terms of conodont biostratigraphy, these Interval Zones range from the *costatus* to the *ensis* Zones mostly of Late Eifelian age. Because of the absence of *Geminispora lemurata*, this population is considered typical as belonging to a Late Eifelian pre-*Lem* (*G. lemurata*) Interval Zone within the limit of the Opper Zone AD. Questionable specimens of *Densosporites devonicus* and *Ancyrospora eurypterota* are present in these populations as well as typical specimens of "Emsian" *Emphanisporites annulatus* and "Eifelian" *Calyptosporites* sp. B (in Paris *et al.* 1985, Pl. 21).

Between 9257 ft. and 9282 ft., six samples have joint occurrences of *Rhabdosporites langii* and *Geminispora lemurata*. The absence of *Samarisporites triangulatus* refers this miospore population to the Interval Zone

* Miospore assemblages which can be positively assigned to the Early Devonian, were recorded from core material in well Al-33 [8079-8091 ft.]. The assemblage recovered contains a variety of azonate miospores together with species possessing an equatorial crassitude and rare species with zonate extensions [Richardson in Paris *et al.* 1985, p. 49 and plates 17, 18 and 19].

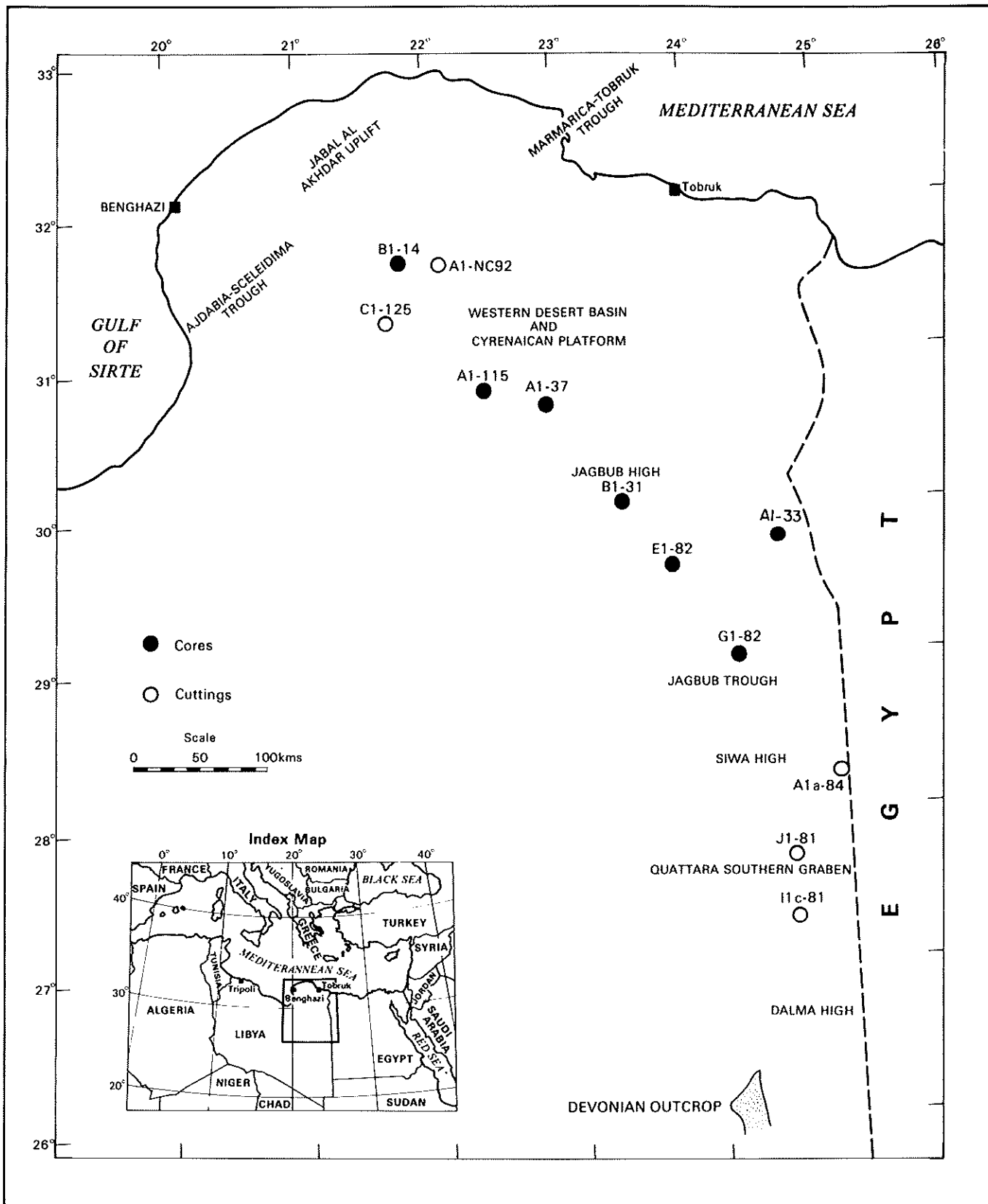


Fig. 1. Location of studied wells in northeast Libya.

Lem within the limit of the Opperl Zone AD. This Interval Zone corresponds to the *ensensis* to (middle ?) *varcus* conodont zones mainly of Early Givetian age.

Between 8805 ft. and 8814 ft., three samples have joint occurrences of *Geminospora lemurata*, *Archaeozonotrites variabilis*, *Samarisporites triangulatus*, *Verrucosispo-*

rites bulliferus and *Lophozonotriletes media*. The absence of the typical "Famennian" *Diducites versabilis* and *Knoxisporites dedaleus* refer this miospore population to the Opper Zone BM (*Verrucosisporites bulliferus* - *Lophozonotriletes media*) or to the succeeding unnamed Zone IV of the Boulonnais region (Loboziak, Strel & Vanguetaine, 1983). In terms of the conodont biostratigraphy, these Zones range from the Frasnian middle *asymmetricus* Zone to the Early Famennian upper (*P. triangularis* Zone).

Between 8414 ft. and 8421 ft., three samples contain among other species *Retispora lepidophyta*, *Rugospora flexuosa*, *Vallatisporites pusillites* and *Knoxisporites literatus* (illustrated in Paris *et al.* 1985, Pl. 30). These samples are assigned to the Interval Zone LL (*R. lepidophyta* - *K. literatus*) corresponding to the latest Famennian *praesulcata* conodont Zone.

2) Stratigraphical position of other Middle and Late Devonian (Frasnian-Early Famennian) cores and cuttings (Fig. 2)

Well JI-81A

10,180-10,850 ft. (cuttings)

The following species are recorded in assemblages from this interval: *Retusotriletes rugulatus*, *Dibolisporites* cf. *gibberosus* var. *major*, *Verrucosisporites scurrus*, *V.* cf. *premnus*, *Acinosporites lindlarensis* var. *treverica*, *Diatomozonotriletes* sp., (comparable with specimen figured in Paris *et al.* 1985, Pl. 24, Figs. 5, 6), *Camptozonotriletes* cf. *aliquantus*, *Grandispora* sp. A. in Paris *et al.* 1985, *Grandispora* sp. B. in Paris *et al.* 1985, *Geminospore lemurata*, *Ancyrospora nettersheimensis* ? and *Calyptosporites proteus*.

In addition to the species named above there is an abundance of representatives of *Emphanisporites* spp. (especially *E. rotatus*). Most of the species recorded in this interval have a range in the Old Red Sandstone Continent extending from the uppermost Emsian to the Middle Eifelian. Other species, i.e. *Geminospore lemurata*, *V.* cf. *premnus*, *V. scurrus* tend to occur in younger sediments (Mid-Eifelian to Early Givetian) and are present here as a result of caving.

Age

Early Eifelian (Opper Zones AP, Interval Zone post *Cor*)

Well IIC-81A

5660-6320 ft. (cuttings)

Miospore populations from this interval include *Retusotriletes distinctus*, *R.* cf. *rugulatus*, *Acinosporites acanthomammillatus*, *Calyptosporites velatus*, *Calyptosporites* sp. A., C. sp. B. in Paris *et al.* 1985, *Grandispora* cf. *inculta* and *Perotriletes* cf. *ergatus*. From the evidence of the ranges of the species in the Old Red Sandstone region, a Late Eifelian age is suggested for this interval. It is noteworthy that *Calyptosporites* sp. A and B become very abundant at the 5660 ft. level, which is therefore very

similar in palynologic aspect to the situation in Core 7 of Well EI-82 (see below).

Age

Late Eifelian (Opper Zone AD, Interval Zone pre *Lem*).

Well EI-82

4314 ft. = 1319 m (Core 7)

The assemblage recovered from this core sample contains *Retusotriletes actinomorphus*, *R. triangulatus*, *Apiculiretusispora plicata*, *A.* cf. *brandtii*, *A. brandtii*, *D. echinaceus*, *Raistrickia aratra*, *Verrucosisporites scurrus*, *Acinosporites* cf. *apiculatus*, *A. acanthomammillatus*, *Emphanisporites spinaeformis*, *Grandispora libyensis* and *Geminospore lemurata* (including *G. tuberculata*) which suggests an Early Givetian age for this interval.

Age

Early Givetian (Opper Zone AD, Interval Zone *Lem*)

Well GI-82

8320 ft. = 2849 m (Core 7)

The limited miospore population recovered from this sample contains *Verrucosisporites* cf. *premnus*, *Samarisporites* sp., *Spinozonotriletes* sp. and *Geminospore lemurata*, an association which supports an Early Givetian age assignment.

Age

Early Givetian (Opper Zone AD, Interval Zone *Lem*)

Well BI-31

5267-5277 ft. (Core 1)

The stratigraphically significant taxa present in this sample include *Dibolisporites* cf. *gibberosus* var. *major* ?, *Acinosporites lindlarensis* (cf.), *Calyptosporites* cf. *velatus* and *Geminospore lemurata*, indicating an Early Givetian age.

Age

Early Givetian (Opper Zone AD, Interval Zone *Lem*)

Well BI-14

13,073-13,093 ft. (Core 7)

Spores from this section are dark in colour but relatively well preserved. Thick-walled forms are common but frequently opaque and difficult to identify.

Considerable environmental differences exist within this interval with the variations in the proportion of acritarchs to spores reflecting fluctuations in marine and terrestrial influences. No significant biostratigraphical changes were noted although *Rhabdosporites langii* was found only below 13,080 ft.

Species recorded in Well BI-14 (Core 7) which are of stratigraphical value in the Old Red Sandstone Continent include *Retusotriletes rugulatus*, *Dibolisporites echi-*

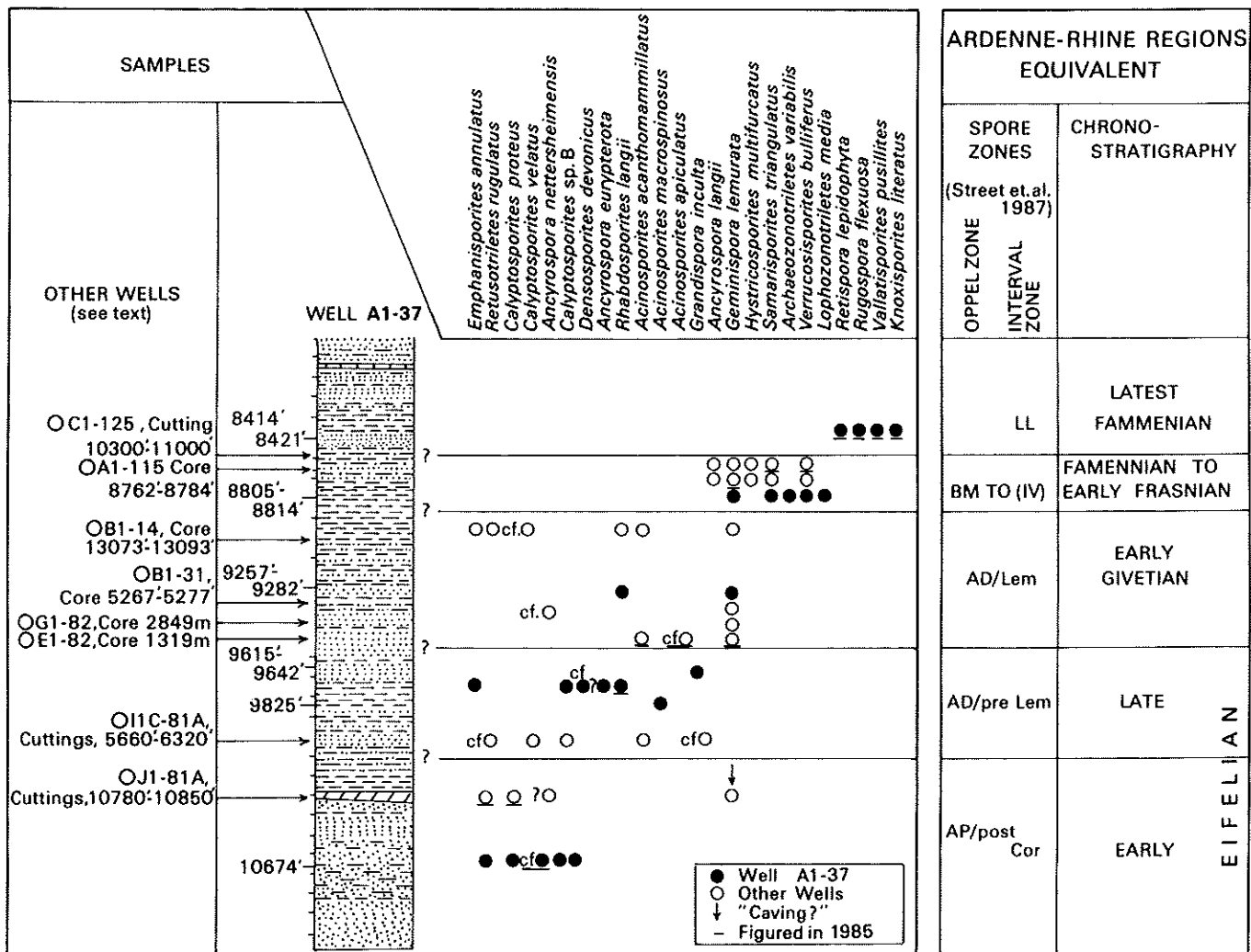


Fig. 2. Comparison of miospore data in northeast Libya and Ardenne Rhine regions.

naceus, *Verrucosisporites* cf. *premnus*, *Raistrickia aratra*, *Emphanisporites annulatus*, *Acinosporites acanthomammillatus*, *Spinozonotriletes* cf. *arduinnae*, *Calyptosporites* cf. *proteus*, *Rhabdosporites* spp., *Geminispora lemurata* and *Ancyrospora* cf. *ancyrea*.

In addition to the above association, most of the samples from this interval contain large numbers of several species of *Apiculiretusispora* together with *Emphanisporites rotatus*, *Retusotriletes triangulatus* and some *Calyptosporites* sp. Most of these forms have a Late Eifelian to Givetian range in the Old Red Sandstone regions. On the basis of abundance and variety of verrucate forms (*Verrucosisporites* and *Raistrickia*) and *Geminispora*, a Givetian age is favoured.

Age

Early Givetian (OppeL zone AD, Interval Zone *Lem*)

Well A1-115

8762-8784 ft. (Core 4)

In addition to *Geminispora lemurata* and *Ancyrospora langii*, these samples contain *Hystricosporites multifur-*

catus, *Samarisporites triangulatus* and *Verrucosisporites bulliferus*.

Age

Frasnian to Early Famennian ?

Well C1-125

10,300-11,000 ft. (Cuttings)

The samples from this interval contain *Geminispora lemurata* and *Ancyrospora langii* together with *Hystricosporites multifurcatus*, *Samarisporites triangulatus* and *Verrucosisporites bulliferus*. Rare specimens of *Retispora lepidophyta* found in this interval are considered to be the result of caving.

Age

Frasnian to early Famennian ?

3) Late Famennian cores and cuttings

In Well B1-14, seven samples between 12,262 ft. and 12,282 ft. and twelve samples from cores between 12,498

ft. and 12,509 ft. contain spores characteristic of Opper Zone VCo (*Rugospora versabilis* - *Grandispora cornuta*), occurring together with *Rugospora flexuosa* and several species of *Spelaeotriletes*. The youngest series of samples also contain *Vallatisporites pusillites* but no *Retispora lepidophyta* and are equated with the Late Famennian *postera* to *expansa* conodont zones.

In Well AI-NC92, twenty one samples from cores between 12,953 ft. to 13,043 ft. allow the recognition of the Opper Zones VCo below 13,020 ft. and LV (*R. lepidophyta* - *Apiculiretusispora verrucosa*) above 13,000 ft.

Seventeen samples of cuttings from the 1700 ft. interval between 9300 ft. and 11,000 ft. in Well CI-125 were examined. The upper 400 ft. belong to the Opper Zone LV whilst below 9700 ft. caving is responsible for the introduction of specimens of *R. lepidophyta* in presumed Opper Zone VCo assemblages.

In Well Ala-84, samples from cuttings ranging from 5680 ft. to 6870 ft. are also assigned to Opper Zone LV.

4) Comparison with some miospore assemblages (palynozones) of western Libya

Most of the characteristic zonal spores recorded in northeast Libya also occur in the Rhadames Basin of western Libya (Massa & Moreau-Benoit, 1976, Moreau-Benoit, 1979, 1980). Of particular interest are their palynozones 4 to 6 believed to range in age from the Couvinian to the Late Givetian. These palynozones do not contain *Geminospira lemurata*, a species which is only recorded from palynozones 7 [Lower Frasnian?] to 10 [Early Famennian?]

In the following chart, an alternative interpretation based only on the comments and photographs published by Massa & Moreau-Benoit is suggested, including a new interpretation of the age of the Aouinet Ouenine Formations I to III.

Palynological data and age given by Massa and Moreau-Benoit 1976 and Moreau-Benoit 1979, 1980	Revised Zonation and Age
AOUINET OUEENINE III late. (zone 8) (Late Frasnian) Variety of verrucate forms - 1976, Pl. 6, Fig. 2, Fig. 3 <i>Grandispora libyensis</i> - 1980, Pl. 11, Figs. 2, 3	Opper Zone AD Interval Zone <i>Lem</i> Early Givetian
AOUINET OUEENINE III early. (zone 7) (Early Frasnian) Verrucate forms - 1976, Pl. 5, Fig. 6 <i>Rhabdosporites langii</i> - 1980, Pl. 10, Fig. 5	Opper Zone AD Interval Zone <i>Lem</i> Early Givetian

No <i>Ancyrospora langii</i> No <i>Samarisporites triangulatus</i> No <i>Verrucosisporites bulliferus</i>	} 1976, p. 306
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AOUINET OUEENINE II late. (zone 6) (Late Givetian) Small <i>Rhabdosporites</i> ? 1980, Pl. 10, Fig. 4 Verrucate forms (<i>Lophozonotriletes</i> spp.) 1976, p. 304	Opper Zone AD Interval Zone pre <i>Lem</i> Late Eifelian
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No <i>Samarisporites triangulatus</i> No <i>Archaeozonotriletes variabilis</i>	} 1976, p. 304
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AOUINET OUEENINE II early. (zone 5) (Early Givetian) <i>Acinosporites acanthomammillatus</i> 1976, Pl. 4, Fig. 11	Opper Zone AD Interval Zone pre <i>Lem</i> Late Eifelian
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<i>Emphanisporites annulatus</i> <i>Rhabdosporites langii</i>	} 1976, p. 303
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AOUINET OUEENINE I (zone 4) (Couvinian) <i>Diatomozonotriletes</i> sp. 1976, Pl. 4, Fig. 6 <i>Ancyrospora nettersheimensis</i> 1976, Pl. 4, Fig. 4	Opper Zones AP to AD Early Eifelian
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<i>Emphanisporites annulatus</i> <i>Calyptosporites proteus</i> <i>Acinosporites acanthomammillatus</i>	} 1976, p. 302
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The Aouinet Ouenine Formation IV which equates with palynozones 9 and 10 (? Famennian) contains many species with Givetian or Frasnian affinities i.e. *Geminospira lemurata*, *Rhabdosporites parvulus*, *Hystricosporites multifurcatus* and *Verrucosisporites bulliferus*.

5) Conclusions

The miospore zonation scheme established for the Middle and Late Devonian in the Ardenne-Rhine region on the southeastern margin of the Old Red Sandstone

Continent can obviously be applied to the northern part of the Gondwana Province. Whilst these proposals suggest that selected species may have considerable value for interregional correlations, significant differences are encountered in comparisons of total assemblages between the two regions.

ACRITARCHS (M. Vanguetaine)

1) Introduction

Acritarch populations have been investigated in fifteen samples from the following four wells: Well AI-NC92: 10,400-10,500 ft. (cuttings), Well CI-125: 9800-10,600 ft. (cuttings), Well AI-115: 8772 ft., 8774 ft. and 8784 ft. (cores) and Well AI-37: 8805 ft., 8810 ft. and 8814 ft. (cores). The most significant species present in assemblages from well CI-125 and AI-115 have been illustrated previously in Paris *et al.* (1985).

All the samples are homogeneous carrying one single assemblage in which *Veryhachium downiei* and *Gorgonisphaeridium* types are abundant. A detailed list of species in each sample is not therefore provided.

The large acanthomorphs (*Diexallophasis*, *Baltisphaeridium*, *Puteoscortum*, *Hercyniana*, . . .) are rather rare in northwest Libya in contrast to the assemblages of the Late Frasnian and Early Famennian offshore facies in other regions e.g. Belgium (viz. Vanguetaine *et al.* 1983, Martin 1985). How far this is the result of facies control rather than differences in age is a matter of discussion (see below).

This paper is concerned only with the stratigraphic and palaeogeographic implications of these acritarch assemblages. A short note is however devoted to a strange monospecific cluster of *Veryhachium downiei*.

2) Stratigraphy

Fig. 3 shows the stratigraphic distribution of fourteen selected acritarch species, their stratigraphic significance is discussed below.

Michrhystridium stellatum and *Veryhachium downiei* are long ranging species known not only throughout the Devonian but also in older and younger strata.

Diexallophasis remota is recorded from the Ordovician to the Famennian (Vanguetaine *et al.*, 1983).

SPECIES		STRATIGRAPHY													
		<i>Michrhystridium stellatum</i>	<i>Veryhachium downiei</i>	<i>Diexallophasis remota</i>	<i>Stellinium micropolygonale</i>	<i>Umbellaspheeridium deflandrei</i>	<i>Horologinella horologia</i>	<i>Unellium winslowae</i>	<i>Hercyniana sprucegrovensis</i>	<i>Tornacia stela</i>	<i>Solisphaeridium apodasmion</i>	<i>Veryhachium pannuceum</i>	<i>Crassianguilina tessellata</i>	<i>Horologinella quadrispina</i>	<i>Villosacapsula globosa</i>
UPPER DEVONIAN	STRUNIAN														
	FAMENNIAN														
	FRASNIAN														
MIDDLE DEVONIAN															
LOWER DEVONIAN															

Fig. 3. Known stratigraphic range of selected acritarch species occurring in the studied sections.

Stellinium micropolygonale extends from the Early Devonian to the Strunian, uppermost Devonian (Vanguetaine, 1978).

Umbellasphaeridium deflandrei were described in the "Calcaire d'Angers" France of so-called Emsian age (Moreau-Benoit, 1967). On spore evidence (large zoned forms) a Middle Devonian age would be more appropriate. *U. deflandrei* is also found associated with Strunian miospores in Algeria (Jardine *et al.*, 1974).

Horologinella horologia and *Umbellasphaeridium deflandrei* have the same range in Algeria.

Unellium winslowae extends from the Middle Devonian (Rauscher & Doubinger, 1969) to the Strunian (Vanguetaine, Tohogne Borehole, unpublished).

Hercyniana sprucegrovensis is known in the Frasnian (Staplin, 1961) and the Famennian (Vanguetaine *et al.*, 1983).

Solisphaeridium apodasmion and *Tornacia stela* are identified in the Frasnian of Western Germany (Amirie, 1984). *Veryhachium pannuceum* was recorded from the Frasnian of Cornwall (Le Gall, *et al.*, 1985 as *Arkonias virgata*). *Tornacia stela* is known to extend up to the Famennian (the supposed age of the Chagrin Shale of Ohio *viz.* Vanguetaine, 1986). *Solisphaeridium apodasmion* has been recorded in the Famennian of Belgium (Vanguetaine *et al.*, 1983). *Veryhachium pannuceum* is known to extend into the Strunian (Vanguetaine, 1978).

Crassianguilina tasselita and *Horologinella quadrispina* have been recorded associated with Frasnian (Paris *et al.*, 1985) and Strunian spores (Jardine *et al.*, 1974).

Villosacapsula globosa has a very narrow range in Belgium being restricted to the Late Frasnian and earliest Famennian (Vanguetaine *et al.*, 1983).

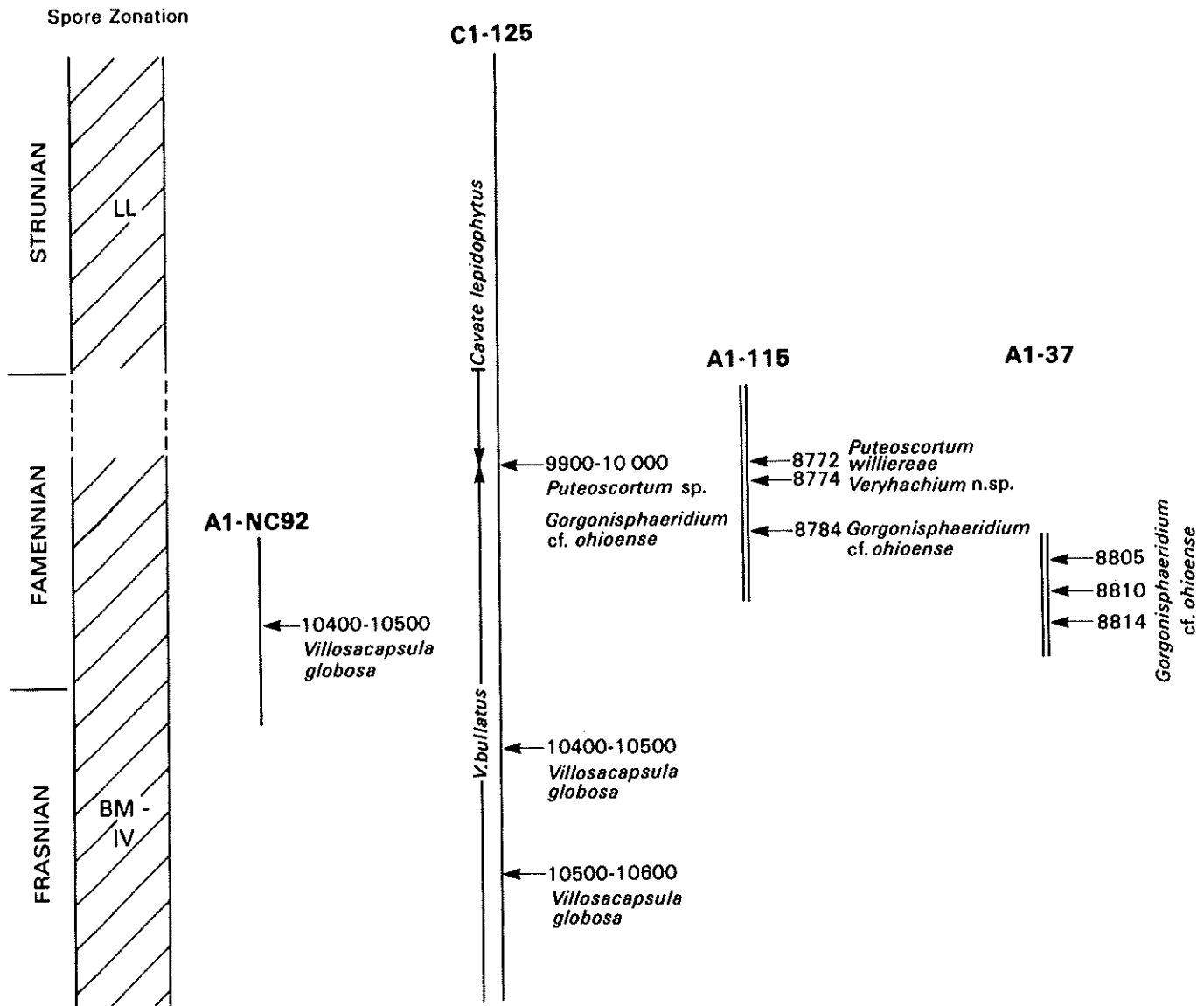


Fig. 4. Probable stratigraphic assignment of the studied sections including data on some provisionally determined acritarch species.

LATE FRASNIAN	gigas	u	Vj	I	↑ <i>Villosacapsula globosa</i> ↓
		l	Vg	II	
EARLY FAMENNIAN	triangularis	m	Bm	III	↑ <i>Puteoscortum williereae</i> ↓
		u	Bb	IV	
		l	Pw		
LATE FAMENNIAN	crepida	m		V	

Fig. 5. Known stratigraphic range of two acritarch species in the Late Devonian of Belgium (after Vanguetaine 1986).

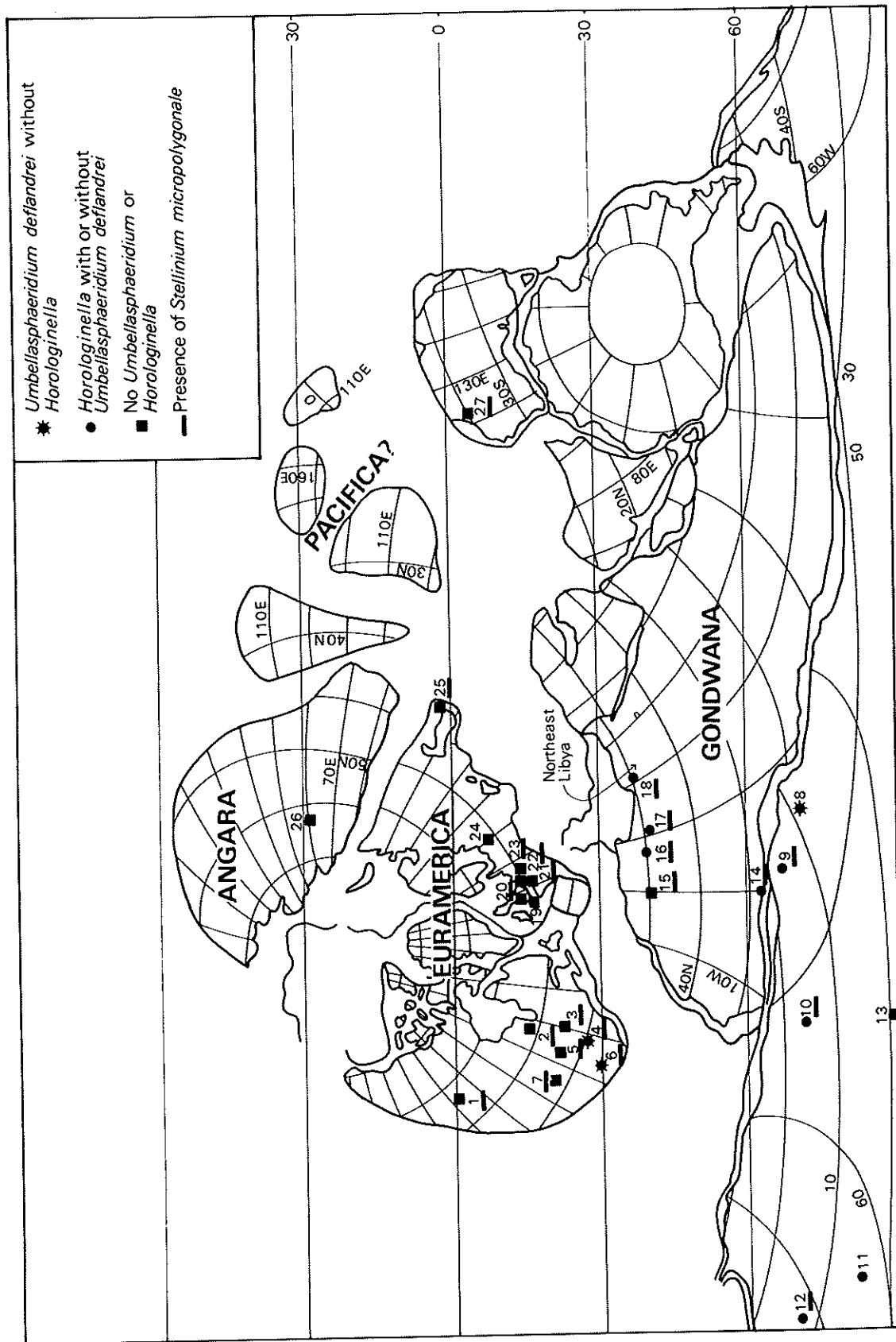
On Fig. 3, seven species have long stratigraphical ranges which include the Middle Devonian whilst a further six have ranges which are restricted to the Late Devonian. One (*Villosacapsula globosa*, see also Fig. 4) is known only in Belgium (Fig. 5) in the transitional layers between the Frasnian and the Famennian stages and might therefore be of considerable value in the correlation of the Libyan assemblages.

On Fig. 4, the occurrences of *V. globosa* (Well CI-125: 10,400 ft. to 10,600 ft. and Well AI-NC92: 10,400 ft. to 10,500 ft.) are noted respectively immediately below and above the Frasnian/Famennian boundary as proposed by Paris *et al.* (1985).

The occurrence of *Puteoscortum williereae* (Well AI-115: 8772 ft. to 8784 ft.) indicates an early (upper *Palmatolepis triangularis* Conodont Zone) to middle (*rhomboidea-marginifera* Conodont Zones) Famennian age (Vanguetaine, 1986). *Veryhachium* sp. nov. A (Pl. 31, Fig. 3 in Paris *et al.*, 1986) has been recorded from the Belgian uppermost Early Famennian (Vanguetaine un-

Fig. 6. Geographic location of published records of the Devonian acritarch taxa (slightly modified cylindrical equidistant 360 m.y, Frasnian, maps of Smith, Hurley & Briden 1980, see Streeel 1986).

1. Alberta, Canada (Staplin 1961)
2. Ontario, Canada (Wood 1984)
3. Ontario, Canada (Legault & Norris 1982)
4. Ohio, U.S.A. (Wicander 1974; Molyneux, Manger & Owens 1984; Wood 1984)
5. Indiana, U.S.A. (Wicander & Loeblich 1977)
6. Tennessee, U.S.A. (Reaugh 1978)
7. Iowa, U.S.A. (Wicander & Playford 1985)
8. Tucano-Jatoba Basin, Brazil (Regali 1964)
9. Parnaiba Basin, Brazil (Daemon 1974)
10. Amazon Basin, Brazil (Daemon 1974)
11. Bolivia (Boneta 1979)
12. Oriente Basin, Peru (Beju *in* Wood 1984)
13. Paraguay (Pothe de Baldis 1979)
14. Keta Basin, Ghana (Bär and Riegel 1974; Anan-Yorke 1974)
15. Mac-Mahon Basin, Algeria (Lanzoni & Magloire 1969)
16. Illizi-Tinrhert Basin, Algeria (Jardiné *et al.* 1974; Attar *et al.* 1980)
17. Rhadames Basin, Western Libya (Moreau-Benoit 1984; Massa & Moreau Benoit 1985)
18. Eastern Libya (Paris *et al.* 1984 and this study)
19. Cornwall, U. K. (Turner *et al.* 1979; Le Gall *et al.* 1985)
20. England, U. K. (Owens *et al.* 1977)
21. Pas-de-Calais, France (Combaz & Streeel 1970)
22. Belgium (Vanguetaine *in* Kimpe *et al.* 1978; Vanguetaine 1978; Vanguetaine *et al.* 1983; Martin 1981, 1982 and 1985)
23. Western Germany (Pichler 1971; Riegel 1974; Jux 1975, 1984; Amirie 1984)



24. Poland (Gorka 1974)
25. Iran (Coquel *et al.* 1972)
26. Siberia (Sheshegova 1971)
27. Western Australia (Playford & Dring 1981; Playford 1981).

published). However its occurrence in the present study in the same samples as the "Frasnian" spore *Verrucosporites bulliferus* suggests the older age as more probable.

The occurrence of *Puteoscortum* sp. (Well CI-125: 9900–10,000 ft.) and of *Gorgonisphaeridium* (Well AI-37) with large appendages (similar to *G. ohioense* which is known only from the Famennian of the U.S.A., see Wicander 1974, Wicander & Loeblich 1977 and Vanguetaine 1986) also suggest a Famennian age.

3) Palaeogeography

Figs. 6 and 7 show the geographic distribution of the fourteen selected species discussed above. A review of these figures allows the following conclusions to be drawn.

Despite the fact that data are not available from the Angara and the hypothetical Pacifica provinces, it is obvious that the geographic distribution pattern is uneven. Compared to the cosmopolitan species (Fig. 7: group C on the right and Fig. 6: distribution of *Stellinium micropolygonale*) other components (groups A and B) have a somewhat restricted distribution. Among these, the species of group A, which are morphologically easy to recognize, are only known from the northern part of Africa and South America (Western Gondwana). One species (*Umbellasphaeridium deflandrei*) is also identified at the southern edge of Euramerica.

A Late Devonian Gondwanian province can be recognized which is clearly distinct from the Euramerican Province characterised by the absence of *Horologinella*.

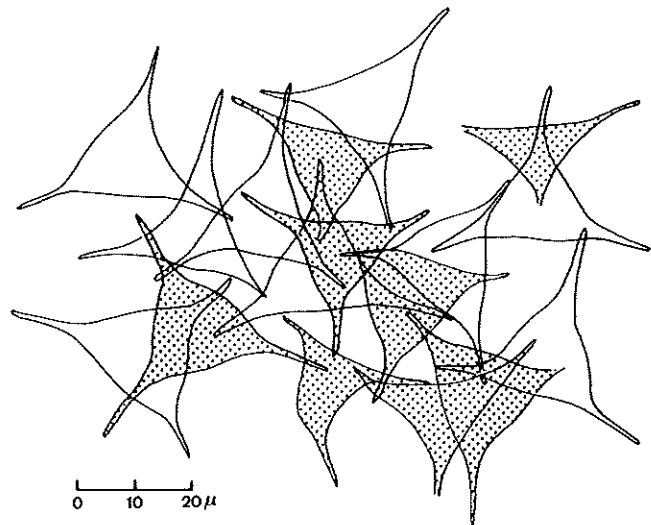


Fig. 8. "Camera lucida" drawing of 17 of the 25 specimens of *Veryhachium downiei* composing a cluster (see also Pl. 21, Fig. 7). Dotted specimens oriented with their basis up, white specimens oriented with their basis down.

4) Cluster of *Veryhachium downiei*

In the sample from Well CI-125 from 10,300 ft. to 10,400 ft., a strange cluster of some twenty five specimens of *Veryhachium downiei* has been observed (Pl. 21, Fig. 7). This species and another one, *V. pannuceum*, are represented frequently in the sample by isolated individ-

Fig. 7. Comparison of Late Devonian Libyan acritarch assemblage with other published Late Devonian acritarch assemblage (specimens between brackets are here renamed).

+ = species recorded in other regions

(+) = specimens originally not determined or attributed to this species following detailed reinterpretation.

Veryhachium pannuceum as ? *Neoveryhachium* sp 1, p. 166, Pl. 2: Fig. 1 in Pöthe de Baldis (1979); as *Arkonion virgata*, Pl. I, Figs. 4 & 8 in Gall et al. (1985).

Villosacapsula globosa as *Villosacapsula* ? *ceratioides* p. 5 & 6, Pl. I, Fig. 12 in Martin 1982.

Diexallophasis remota as *Veryhachium cleopatra* p. 6, Pl. II, Figs. 1-3 in Stockmans & Willière 1969; as *Veryhachium cleopatra*, p. 5, Pl. IV, Fig. 29 in Stockmans & Willière 1974; as *Exochoderma cleopatra* p. 20-21, Pl. III, Figs. 1-6, 8, 9 in Martin 1985; as *Exochoderma irregulare*, p. 23, Pl. I, Fig. 3 in Martin 1981; as *Diexallophasis cleopatra*, p. 96, Pl. 13, Fig. 10 in Kimpe et al. 1978; as *Evittia geometrica* p. 29-30, Pl. 6, Fig. 13, Pl. 7, Figs. 3-8, Text-Fig. 5 in Playford 1981.

Hercyniana sprucegrovensis as *Baltisphaeridium paleozoicum*, p. 56, Pl. I, Fig. 12, Text-Fig. 13 in Stockmans & Willière 1962; as *Baltisphaeridium paleozoicum* p. 17, Pl. I, Figs. 5-7, 11, 15, III, Fig. 13 in Stockmans & Willière 1974; as *Baltisphaeridium paleozoicum* p. 51, Pl. XIV, Figs. 1-3, Pl. XVI, Fig. 13, Pl. XVIII, Fig. 5 in Sheshhegova (1971).

Stellinium micropolygonale, generally assigned to *Stellinium octoaster* or *Veryhachium octoaster* in various publications not cited here.

	Crassiangulina tessellata	Horologinella horologia	Horologinella quadrispina	Umbellisphaeridium deflandrei	Solisphaeridium apadasmion	Tornacia stela	Veryhachium pannuceum	Villasacapsula globosa	Dixallophasis remota	Hercyniana sprucegrovensis	Micrhystridium stellatum	Stellinium micropolygonale	Uncellium winslowae	Veryhachium downiei
	A				B				C					
Lanzoni & Magloire (1969) Mac-Mahon Basin, Algeria (15)	+	+	+	+								(+)		
Jardine <i>et al.</i> (1974), Attar <i>et al.</i> (1981) Illizi-Tinrhert Basin, Algeria (16)		+		+					+			(+)	+	
Anan-York (1974), Bar & Riegel (1974) Ghana (14)				+					+		+	(+)		+
Moreau Benoit (1984), Massa & Moreau Benoit (1985) Western Libya (17)				+					+			(+)		+
Regale (1964), Brito (1965, 1976) Brazil (8)				+					+			(+)		
Daemon (1974) Brazil (9) (10)				+								(+)		
Boneta (1975) Bolivia (11)		+					(+)				+			
Pöthe de Baldis (1979) Paraguay (13)				+					+			(+)		
Wood (1984) Peru (12)				+					+			(+)		
Staplin (1961) Alberta, Canada (1)										+		(+)	+	+
Legault & Norris (1982), Wood (1984) Ontario, Canada (2) (3)										+		(+)	+	+
Wicander (1974), Molyneux <i>et al.</i> (1984) Ohio, U.S.A. (4)					+	+						+		
Wicander & Loeblich (1977) Indiana, U.S.A. (5)					+		+					(+)		
Wicander & Playford (1985) Iowa, U.S.A. (7)											+	+	+	
Reaugh <i>in</i> Wood (1984) Tennessee, U.S.A.				+								(+)		
Wood (1984) Ohio and Michigan, U.S.A. (4)				+								(+)		
Stockmans & Williere (1960, 1962a, 1962b, 1969, 1974) Belgium (22)					+		+	+	(+)	(+)	+	+		+
Vanguetaine <i>in</i> Kimpe <i>et al.</i> (1978) Vanguetaine (1978), Vanguetaine <i>et al.</i> (1983) Belgium (22)							+	+	+	+		+		+
Martin (1981, 1982, 1985) Belgium (22)								(+)	(+)	+	+	+		+
Combaz & Streel (1970) Pas de Calais, France (21)												(+)		+
Owens <i>et al.</i> (1977) Oxford, England (20)												(+)		+
Gall <i>et al.</i> (1985), Turner <i>et al.</i> (1979) Cornwall, England (19)							(+)						+	+
Deunff (1981), Deunff <i>in</i> Brice <i>et al.</i> (1979) Loboziak <i>et al.</i> (1983) Boulonnais, France (21)									+		+	(+)		
Pichler (1971), Riegel (1974) Jux (1975, 1984) (1984) Western Germany (23)					+	+	+			+	+	+		+
Gorka (1974) Poland (24)														+
Coquel <i>et al.</i> (1977) Iran (25)												(+)		
Sheshgova (1971) Siberia (26)									(+)	+				
Playford & Dring (1981) Playford (1981) Western Australia (27)									(+)		+	+	+	+

uals, but the cluster only contains *V. downiei*. Clusters of non-sphaeromorphic acritarchs have also been observed in well preserved material by Deunff (1968), Downie (1973) and Rasul (1974). Obviously such a cluster cannot be the result of some artificial grouping during the process of thanatocoenose or during the maceration of the sample. Moreover, as shown on Fig. 8, the internal arrangement of the specimens within the cluster is so regular that it could not result from any fortuitous aggregation process. Indeed some of the specimens have their base oriented on one side whilst others have their base oriented to the opposed side. Often the impression is given that one specimen has its counter part turned by 180°.

If such observation could be confirmed, some light may be thrown on the biological affinities of these acritarchs. Acritarchs probably embrace cyst remains of unicellular marine algae of different origins. Most are compared to the Prasinophyceae or to the Dinoflagellates. The last one however produce, each year, one single independent cell whilst Prasinophyceae produce many zoospores. This cluster therefore suggests a Prasinophyceae affinity for *Veryhachium downiei*.

CHITINOZOA (F. Paris)

Chitinozoan assemblages from seventeen core and cutting samples of Devonian age from wells CI-125, AI-37, BI-31 and GI-82 (Fig. 1) have been investigated. Rock samples were only available from Well AI-37 so that techniques specifically for chitinozoan preparation have been carried out only on this material. Palynological residues were available for the other three wells; consequently, the abundance of the chitinozoans and the relative frequency of each recorded taxon are simply estimated in these residues. Some obviously cavate specimens recovered in Late Ordovician cuttings from Well JI-81A are also briefly mentioned.

Despite a marked flattening of the vesicles, the preservation of the chitinozoans is excellent, due to the very low maturation level of the organic matter.

Middle and Late Devonian chitinozoan assemblages are fairly poorly documented in North Africa and, to a lesser extent in western Europe and North America and the stratigraphical control of the rare data available is frequently inadequate. So far, neither standard nor local chitinozoan biozonations have been proposed for the Middle and Late Devonian. However, as is the case in northeast Libya, chitinozoans frequently occur together with rich spore assemblages which may allow their stratigraphical potential to be improved by reference to the well established miospore biozonation scheme.

Six informal biostratigraphical subdivisions are distinguished in the investigated material. When a single fossiliferous sample was available (e.g. in wells BI-31 and GI-82) these subdivisions are simply called "assemblage". In other cases (wells AI-37, CI-125) the recorded taxa are referred to informal concurrent-range-biozones or acme-range-biozones.

1) *Alpenachitina eisenacki* Assemblage

The occurrence of this species is deduced from cavate individuals recorded in Late Ordovician cuttings from Well JI-81A (cf. Paris, Pl. 28, Fig. 1-2 in Paris *et al.* 1985). *A. eisenacki* is a diagnostic species reported for Late Eifelian-Givetian strata of North Africa and North America (see the distribution of this taxon in Jenkins & Legault 1979).

In Well JI-81A, the assemblage with *A. eisenacki*, in all likelihood, is located at approximately 10,000 ft. in the argillaceous deposits resting unconformably on Late Ordovician strata (El-Arnauti & Shelmani 1985, Fig. 6). Eifelian spores are reported from this well. Thus, *A. eisenacki* assemblage is the oldest chitinozoan assemblage so far encountered in the material available from northeast Libya.

2) *Eisenackitina castor* Acme-Range Biozone

Further taxonomic investigations, complete with a well documented synonymy are still needed for this species, therefore in the present paper it is used in the sense adopted by Legault (1973). Because of its abundance and its peculiar morphology with regard to other chitinozoan species commonly reported in the Middle Devonian, *E. castor* (sensu Legault 1973) is selected as the index-species of the rich chitinozoan assemblage (cf. Fig. 9) observed in Core 20 (9840 ft.) from Well AI-37. In this sample *E. castor* is predominant (65% of the recorded individuals). It is accompanied by several forms belonging to *Gotlandochitina* (*G. milanensis*, *G. sp. A*, *G. sp. B*) and by a few representatives of *Hoegisphaera glabra*, *Fungochitina pilosa* and *Ancyrochitina* spp. (viz Paris, Pl. 27-28, in Paris *et al.* 1985). At the present time, the diverse Devonian forms of *Gotlandochitina* recorded are of limited stratigraphical value as they were commonly labelled as *Angochitina devonica* in previous papers. On the other hand *E. castor* is a more diagnostic taxon for correlation purposes. This species occurs in the lower part of the Aouinet-Ouenine II Formation, referred to the Early Givetian* of the Rhadames Basin in western Libya (Massa & Moreau-Benoit 1976). It is abundant in the Bell, Rockport Quarry and Arkona Members of the Hamilton Formation (Ontario, Canada), of Givetian age (Legault 1973). In U.S.A., *E. castor* is reported from the Givetian Silica Formation of Ohio (Wood 1974). This species may also occur in Well Atiavi I of Ghana (Anan-Yorke 1974), if one accepts the synonymy between *Eisenackitina* sp. I Anan-Yorke (1974) and *E. castor* (sensu Legault 1973).

The data provided by the chitinozoa are not in agreement with the known range of the miospores reported from Well AI-37 (Core 20) which are believed to be of Late Eifelian age.

3) *Fungochitina pilosa* Acme-Range-Biozone

The index species was recovered in wells AI-37 and CI-125 but its acme biozone is restricted to Core 18 of

* See discussion of this age in "spore" sector of this paper.

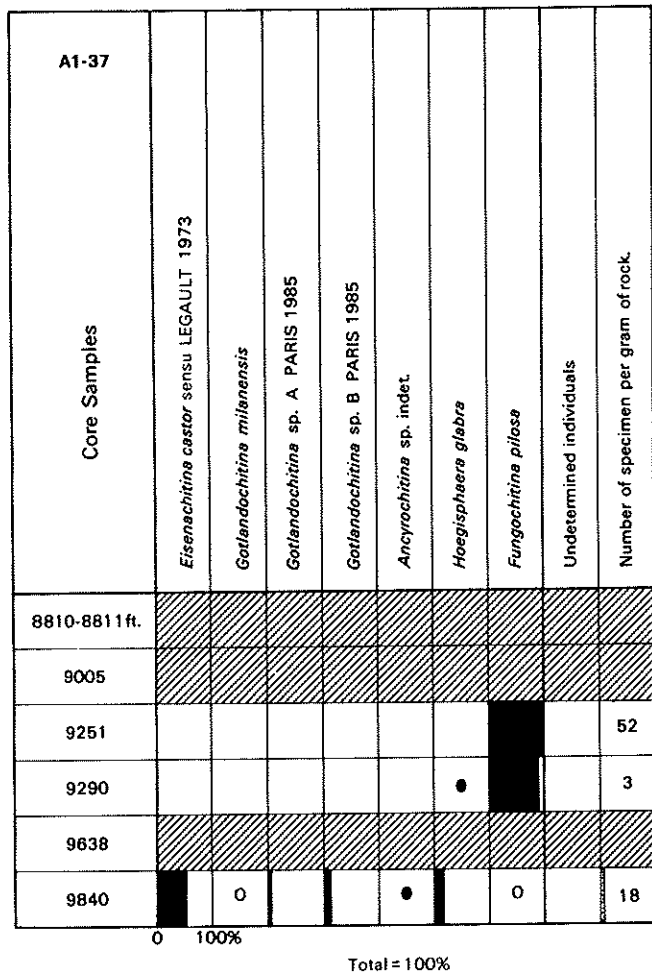


Fig. 9. Devonian chitinozoans from Well A1-37 and their relative frequency.

Well A1-37 and probably to the lowest cutting sample (10,900 ft.-11,000 ft.) of Well C1-125. In Well A1-37, *F. pilosa* represents 95% of the chitinozoans recorded in the sample at 9290 ft. and all of the numerous population (52 specimens per gram of rock) of the sample at 9251 ft. The exact range of the acme biozone of *F. pilosa* cannot be documented in Well A1-37 as samples from Cores 19 (9638 ft.), 17 (9005 ft.) and 16 (8810-8811 ft.), which yield numerous spores, are devoid of chitinozoans (? environmental control).

In the cutting samples from Well C1-125 (11,000 ft.-10,300 ft.) *F. pilosa* is represented in the youngest investigated sample (10,300 ft.-10,400 ft.) but it is only dominant (65% of the population) in the oldest cuttings (10,900 ft.-11,000 ft.) (Fig. 10).

F. pilosa is a long ranging form, reported from Late Emsian to the Late Frasnian (see references in Jenkins & Legault 1979). The Frasnian specimens however display peculiar features: their collarete frequently flares orally while their pilous ornamentation becomes more robust (resembling alpha based spines) and more sparsely distributed (see Paris *et al.* 1985, Pl. 28, Fig. 3, 4 and 10).

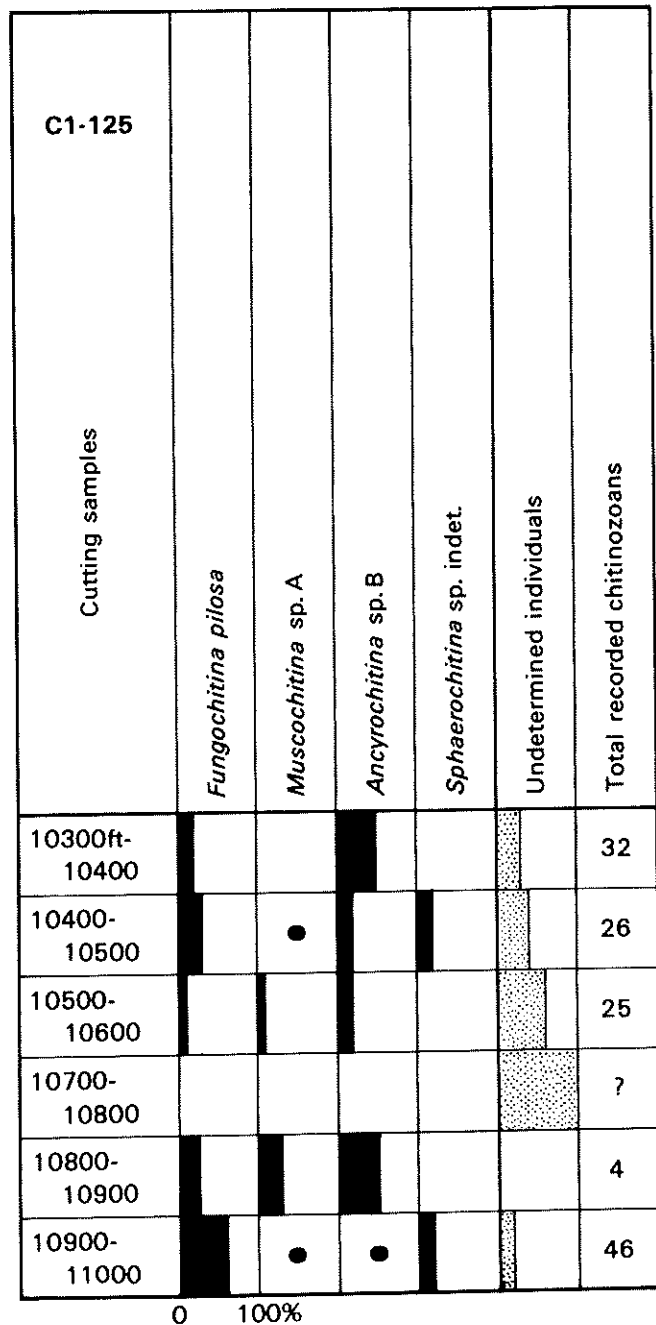


Fig. 10. Devonian chitinozoans from Well C1-125 and their relative frequency.

Further investigations based on a more complete sequence could reveal the existence of two distinct forms as suggested by K. Boumendjel (unpublished data from the Illizi Basin, southeastern Algeria).

At the present time *F. pilosa* is not stratigraphically diagnostic, but the independent control provided by the miospores occurring in the same samples in Well A1-37 (Core 18) suggests a Givetian age for this interval.

4) *Ancyrochitina* sp. A Assemblage

This assemblage is restricted to Core 7 (2849 ft. 2 in.) of Well G1-82 (the other two samples investigated: 2849 ft.

3 in. and 2849 ft. 5 in. yield numerous spores but no chitinozoans).

Ancyrochitina sp. A is the main component of the poor population (36 individuals) recovered from Well GI-82. The numerous stubby and bifurcated processes located on its aboral margin are a distinctive figure, never observed in previously described *Ancyrochitina* species. A more or less related form occurs in the Frasnian of the Boulonnais, northern France (Paris 1988). At the present time, this taxon cannot be therefore used for reliable stratigraphical assignments. The material of Well GI-82 is here referred to the Givetian, based on the associated miospore data.

5) *Angochitina cyrenaicensis* Assemblage

This species is very abundant (330 recorded individuals) in the monospecific chitinozoan assemblage of Core I (5267 ft.-5277 ft.) from Well BI-31. A second sample (5276 ft.-5277 ft.) from the same core was barren of chitinozoans. *A. cyrenaicensis* is also represented in the Gazelle Formation, in the Illizi Basin, southeastern Algeria (K. Boumendjel pers. comm.) where it occurs together with *F. pilosa* below the Famennian *F. fenestrata* chitinozoan biozone (Boumendjel 1985). Spores indicate that Core I from Well BI-31 is of Givetian age.

6) *Ancyrochitina* sp. B - *Muscochitina* sp. A Concurrent-Range-Biozone

This biozone is documented by material from six cutting samples (10,300 ft.-10,400 ft.; 10,400 ft.-10,500 ft.; 10,500 ft.-10,600 ft.; 10,700 ft.-10,800 ft.; 10,800 ft.-10,900 ft. and 10,900 ft.- 11,000 ft.) from Well CI-125 (Fig. 10). The two index-taxa may be new species but since they were only recovered from cuttings where problems of caving may exist, they are kept in open nomenclature. *Ancyrochitina* sp. B displays similarities with some specimens of *A. striata* described by Taugourdeau (1963) from Saharan subsurface strata in the Edjelé region referred to as Famennian (see discussion in Paris - this volume).

The *Ancyrochitina* sp. B - *Muscochitina* sp. A concurrent-range-biozone seems to slightly overlap the *F. pilosa* acme zone in the oldest investigated palynological residue (10,900 ft.-11,000 ft.) from Well CI-125. *A. sp. B* is therefore the main component (65% of the whole population) of the youngest investigated cutting sample (10,300 ft.-10,400 ft.). The relative frequency of the taxa in such poor assemblage (less than 50 individuals recorded in the richest residue; see Fig. 10) has, however, to be used with caution.

By themselves these chitinozoans are not stratigraphically diagnostic, but the morphology of the associated *F. pilosa* specimens suggests a Frasnian age for the material from Well CI-125. The spores and acritarchs recorded in the same samples (see Streel & Vanguetaine, Pl. 29 and 31, in Paris *et al.* 1985) are indicative of a Late Frasnian age if none of the material is caved.

To summarize, the Middle and Late Devonian chitinozoan assemblages recovered from the subsurface of

northeast Libya do not facilitate precise age determinations. This results mainly from the scarcity of suitable published data dealing with contemporaneous material. The fact that Late Devonian chitinozoans are rather poorly known may explain the occurrence of several new taxa among such reduced populations.

The main interest of the chitinozoan assemblages documented in the present paper consists above all in their association with rich spore assemblages which allow precise age determination by reference to the well established European miospore zonation scheme.

CONCLUSIONS

In conclusion, it is important to emphasize some characteristics of the Devonian deposits in the investigated area:

1) The relative thickness of the Eifelian deposits (more than 300 m in Well AI-37) compared to the Givetian and Frasnian deposits (together less than 300 m in Well AI-37).

2) The poor development of deposits between earliest and latest Famennian (about 100 m in Well AI-37, 60 m in Well CI-125).

3) The even poorer development of Late Devonian deposits in the northernmost Well BI-14 where only 200 m separate the Late Famennian from the Early Givetian. This last observation may be a reflection of the different ages of occurrence of the contact between continental facies (without acritarchs) on marine facies (with acritarchs). This contact is in the Late Famennian VCo Opper Zone in Well BI-14, in latest Famennian LV Opper Zone in Well AI NC 92. This change observed in wells that are relatively close together suggests active tectonic movements in this area during Famennian times.

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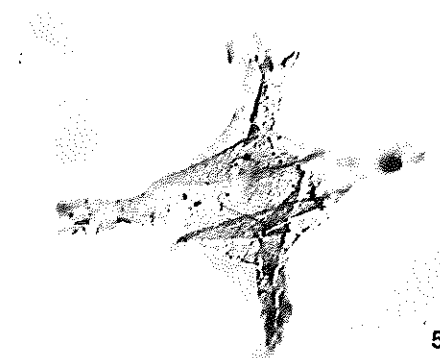
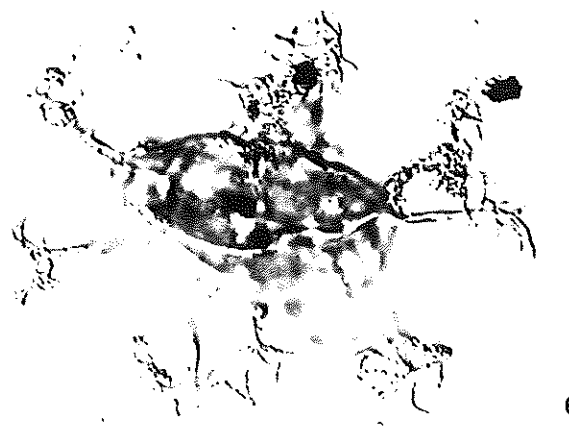
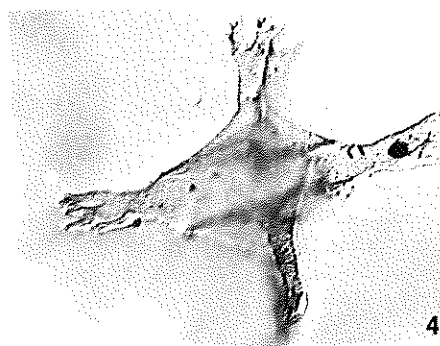
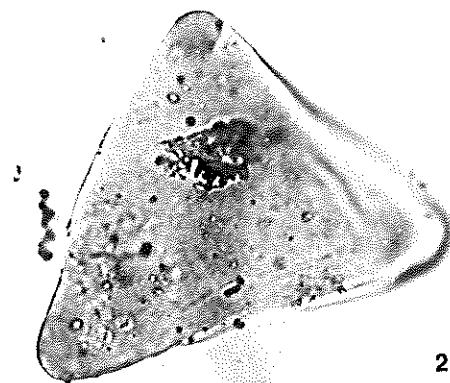
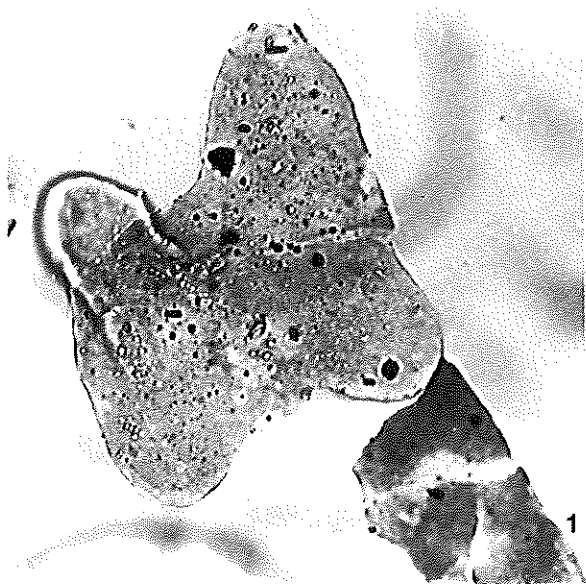
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Explanation of Plate 21

(Figures 1, 2, 3 and 6 are $\times 1000$; figures 4, 5 and 7 $\times 500$)

- Fig. 1. *Horologinella horologia* (Staplin) Jardiné *et al.* 1972, A1-37, 8810 ft., Slide 693, R47/3, (Note the lateral excystment structure), AGC 1074.
- Fig. 2. *Crassiangulina tessellata* Jardiné *et al.* 1972, A1-115, 8774 ft., Slide 1, U32/1, AGC 1075.
- Fig. 3. *Horologinella quadrispina* Jardiné *et al.* 1972, A1-37, 8814 ft., Slide 694, L44/3, AGC 1076.
- Fig. 4. and 5. *Diexallophasis remota* (Deunff) Playford 1977, CI-125, 1156, 10,500-10,600 ft., Slide 19,524, Q40/4, AGC 1077.
- Fig. 6. *Puteoscutum cf. williereae* Martin 1981, A1-115, 8772 ft., Slide 1, F30, (Focus on the distal ramifications of the processes; note that the lower third of the processes stem is hollow but does not communicate with the central body cavity), AGC 1078.
- Fig. 7. *Veryhachium downiei* Stockmans & Willière 1962, CI-125, 1154, 10,300-10,400 ft., Slide 19,522, F54/1, (A cluster of about 25 specimens where individuals seem disposed at 180° to each other), AGC 1079.



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