UPPER DEVONIAN (FRASNIAN) SPORES FROM THE CARNARVON BASIN, WESTERN AUSTRALIA

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ABSTRACT

Microfloras rich in individuals but poor in species have been separated from marine Frasnian sediments in a borehole near Carnarvon, Western Australia. These are the oldest assemblages of isolated spores yet recorded from the Southern Hemisphere. Eight species of microspores have been described, three of which are considered to be new. A new genus, *Geminospora* Balme, has been proposed.

Comparisons may be drawn between these microfloras and Devonian assemblages from other parts of the world.

INTRODUCTION

THE oldest fossiliferous sediments exposed in the Carnarvon Basin occur in narrow linear outcrops along the north-eastern margin of the Basin (TEXT-FIG. 1). They overlie the Precambrian basement complex and dip fairly steeply to wards the west. Teichert (1949) first recognized the Devonian age of these strata and their stratigraphy was subsequently described by Condon (1954). A brief summary of Condon's data on the Devonian section in the north-eastern part of the Carnarvon Basin is presented in Table 1.

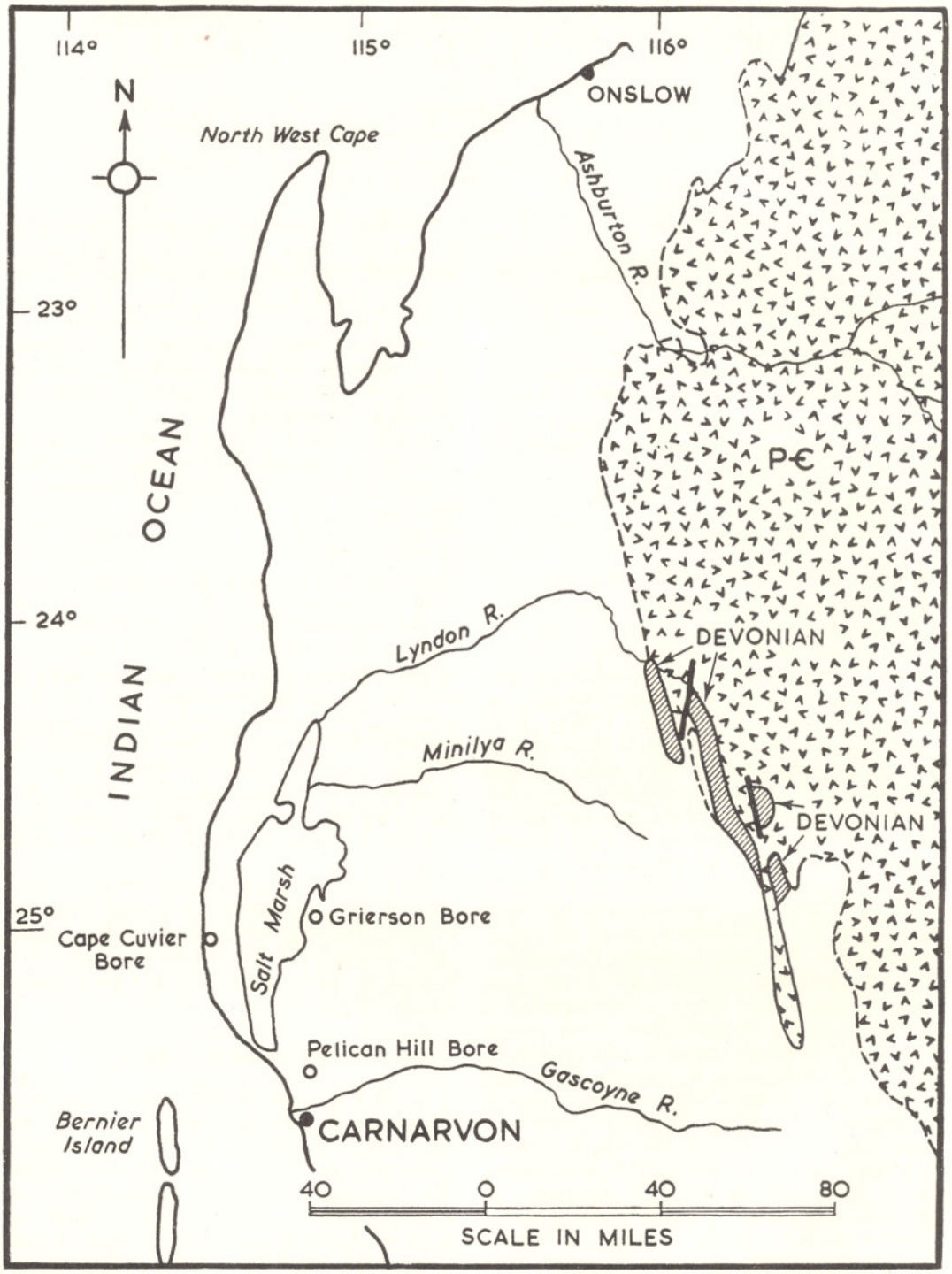
No evidence exists for the presence of time hiatuses within this sequence, and the four formations are considered to be of the same general age. Only the Gneudna Formation, however, contains invertebrate fossils and can be dated by direct palaeontological methods. Even so there have been minor differences between various authorities in their interpretations of faunas from the Gneudna Formation from a chronological standpoint. Teichert originally suggested that they indicated a Middle to Upper Devonian age and Hill (1954) considered corals from the unit to be Givetian, or possibly Frasnian. Later investigations, notably studies of the brachiopod faunas (GLENISTER, 1956), strongly suggest that the Gneudna Formation is of Frasnian age and probably a time-equivalent of part of the Chemung Stage of North America.

Sediments considered to correlate with part of the Devonian section described above have been encountered in a number of boreholes in coastal regions of the Carnarvon Basin (TEXT-FIG. 1). Palaeontological confirmation of these correlations is, nevertheless, with one exception, lacking. The exception is a fossiliferous sequence of marine sediments encountered in the Pelican Hill Borehole, situated about 10 miles north of Carnarvon. Although this bore was sunk during the years 1902-1903, the presence of Devonian strata within it was recognized comparatively recently when Thomas and Dickins (1954) discovered the brachiopod *Cyrtospirifer* in cores taken between the depths 1446 and 1496 ft. The Upper Devonian age of the sequence was thus established and Thomas and Dickins proposed a correlation of the sediments between 1406 and 2206 ft. with the Gneudna Formation. Recent palaeontological studies of further cores from the borehole have confirmed the conclusions of Thomas and Dickins (DICKINS & JONES reported in MCWHAE *et al.*, 1958) except that the Gneudna Formation is now considered to extend to 2363 ft. (P. E. PLAYFORD pers. comm.).

Both the microfloras discussed in this account were obtained from cores from the Pelican Hill Borehole stored in the collections of the West Australian Museum. Details of the two samples studied are given in the following section.

SAMPLES STUDIED

1. *Depth*: 1446-1496 ft.— Several pieces of core from the Museum collections bore this sampling depth, as did the material examined by Thomas and Dickins (1954). The specimen selected for palynological examination was a green, slightly calcareous siltstone, containing no obvious macrofossils. Other cores from the same sampling interval were crowded with specimens of *Cyrtospirifer gneudnaensis* Glenister, a species known only from the Gneudna Formation.



TEXT-FIG. 1. — Part of the Carnarvon Basin, Western Australia, showing the position of Pelican Hill and other borings thought to have penetrated Devonian sediments. Areas of exposed Devonian rocks are shown by diagonal shading.

TABLE 1 — DEVONIAN UNITS RECOGNIZED IN THE CARNARVON BASIN

Name of unit	Thickness in ft.	Dominant lithology	Geological age
Willaraddie Fm.	980	Quartz greywacke and arenaceous rock types	Upper Devonian ? Famennian
Munabia Sandstone	1820	Cross-bedded medium to coarse sandstone	Upper Devonian
Gneudna Fm.	1646	Limestone, dolomite, greywacke	Upper Devonian (Frasnian)
Nannyarra Greywacke	265	Greywacke, arkosic sandstone	Middle to Upper Devonian

2. *Depth* : 2174-2186 ft. — Although slightly darker green in colour, this specimen was lithologically similar to the previous sample. It contained no obvious invertebrate remains, but Dickins and Jones (in McWhae *et al.*, 1958) have reported Upper Devonian parallelodonts from the interval 2293-2307 ft.

TECHNIQUES

About 5 grams of each specimen were crushed and the carbonates removed by allowing the crushed samples to stand overnight in dilute acetic acid. The washed material was then boiled for about 10 minutes in 42 per cent hydrofluoric acid. After washing, soluble organic material was removed by treating the residue for three minutes in Schultze's solution followed by heating in 5 per cent sodium hydroxide. When the macerations had been washed free of alkali, they were stained with 0·5 per cent aqueous safranin and stored in glycerol and water, to which a drop of carbolic acid had been added.

Preliminary examinations were carried out on temporary mounts without a coverslip, using a low power objective (× 10 Leitz achromatic) and × 6 binocular eyepieces. Specimens to be described were removed by means of a dissecting needle and mounted individually as single spore slides. Subsequently, six whole assemblage slides were prepared from each residue. Three slides of assemblages from each sample are stored in the type collections of the Department of Geology (Slides 42336-42341 inclusive).

STORAGE OF MATERIAL

The cores from which the two microfloras were obtained are stored in the collections of the Western Australian Museum although small crushed duplicate samples are retained in the Department of Geology, University of Western Australia.

Holotype and paratypes of the species described are housed in the type collection of the Department of Geology, University of Western Australia.

SYSTEMATIC PALYNOLOGY

Turma *Triletes* (Reinsch) R. Potonié & Kremp, 1954

Genus *Leiotriletes* (Naumova) R. Potonié & Kremp, 1954

Leiotriletes cf. *L. simplex* Naumova, 1953

Pl. 1, Figs. 1, 2

Description — Spore simple, outline rounded triangular in polar view. Trilete, rays straight, extending almost to proximo-distal margin. Narrow, faintly discernible, lips, visible along the full length of each ray of the tetrad scar. Exine 1 μ thick, smooth.

Dimensions (10 specimens) — Median diameter 27-36 μ.

Figured Specimens — Slide Nos. 42319, 42332.

Locality — Core between 2174-2184 ft., Pelican Hill Borehole.

Discussion — *Leiotriletes* cf. *L. simplex* represents almost the ultimate in simplicity of a trilete pteridophyte-type spore. For this reason it is unlikely to have any interpretable significance, either palaeobotanical or stratigraphical. The Australian type does not seem separable in any obvious way from Naumova's species which is said to be abundant in Givetian and Frasnian sediments in the U.S.S.R.

Remarks — Present but rare in both the samples examined.

Genus *Apiculatisporis* R. Potonié & Kremp, 1956

***Apiculatisporis* sp.**

Pl. 1, Fig. 14

Description — Spore circular in polar view. Trilete, rays distinct extending to the margin of the flattened spore. No lip developed but a faint groove of commissure is visible in the figured specimen. Exine 2-3 μ thick, ornamented with sparsely distributed short cones. Cones about 1 μ high and 1 μ in basal diameter.

Dimensions (3 specimens) — Diameter 46-58 μ.

Figured Specimen — Slide No. 42322.

Genus *Retusotriletes* Naumova, 1953

***Retusotriletes* cf. *R. pychovii* Naumova**

Pl. 1, Figs. 3, 4

Retusotriletes pychovii Naumova, Akad. Nauk. S.S.S.R., Trudy Inst. Geol. Nauk. Geol. Ser. No. 60, 1953, p. 88, Tab. xiv, Fig. 5.

Description — Spore simple, circular in polar view. Trilete, rays straight, tectate, lips 1-2 μ wide. Contact areas clearly defined, depressed, bordered by well-defined arcuate curvaturae about 2 μ wide joining the ends of the three rays of the tetrad scar. Exine 2 μ thick, smooth.

Dimensions (4 specimens) — 58-67 μ.

Figured Specimens — Slides Nos. 42310, 42328.

Locality — Bore core at 1446-1496 ft., Pelican Hill Borehole.

Discussion — The genus *Retusotriletes* is an interesting one in view of its abundance in Middle and Upper Devonian sediments in the U.S.S.R. A similar situation may prevail in Canada, where Radforth and McGregor (1956) show the presence of spores with contact areas to be a notable feature of Middle and Upper Devonian microfloras.

The comparison of the Pelican Hill form with *Retusotriletes pychovii* must be a tentative one, as only four specimens were found during the examination of some forty slides. However, no obvious distinction seems to exist between the Australian form and Naumova's species from the Frasnian of the Russian Platform.

Remarks — *Retusotriletes* cf. *R. pychovii* occurred only in the upper of the two samples studied. Forms assignable to *Retusotriletes* have been also isolated from Famennian and Tournaisian sediments in the Fitzroy Basin although none of these is identical with the present species.

Genus *Geminospora* n. gen.

Type species *Geminospora lemurata* n. sp.

Diagnosis — The generic name *Geminospora* is proposed as a form genus to include isolated spores of unknown affinities having the following characters:

Outline rounded triangular to almost circular in polar view. Distal side hemispherical, proximal side flattened or pyramidal. Trilete, rays straight, strongly developed, sometimes extending to proximo-distal margin. Lips usually developed along the rays of the scar but this feature is not always visible. Exoexine heavily thickened, particularly on distal face, mesosporoid development is usual but not invariable. The mesosporoid appears, in entire specimens, as a faintly outlined rounded triangular body of variable diameter inside the central cavity of the spore. In broken specimens (Pl. 1, Fig. 8) it is seen to be thin-walled and smooth

Exoexine ornamented on distal side with close packed grana, short cones and infrabaculae. Proximal contact faces smooth or faintly ornamented.

Discussion — Mesosporoid development appears to be notable tendency in many Devonian groups of spores, and forms morphographically similar to *Geminospora lemurata* have been illustrated by Lang (1925), Thomson (1940), Eisenack (1944) and other authors. In itself, the development of a mesosporoid does not appear to be a sufficient criterion for the establishment of a new genus. Certainly it is the chief character of the megaspore genus *Duosporites* Høeg, Bose and Manum, but here the creation of the genus was clearly warranted on a combination of morphographic grounds. In their discussion of the species *Duosporites congoensis* Høeg, Bose and Manum (1955) considered the significance of mesosporoid development in fossil spores and noted a number of instances in which mesosporoids appear to be present in specimens assigned to *Laevigatisporites*, *Cystosporites*, and other genera. Some calamitalean spores illustrated by Hartung (1933) show evidence of a shrunken mesosporoid, and similar internal bodies have been seen by the present author

in specimens assignable on other characters to *Cirratriradites*. No purpose would be served and considerable confusion created if specimens were excluded from *Calamospora* and *Cirratriradites* merely because they, perhaps fortuitously, displayed a mesosporoid.

The characteristics of *Geminospora lemuarta*, however, are such that it cannot be easily accommodated in any existing spore genus. Apparently similar forms were included by Naumova in the genus *Archaeozonotriletes* Naum. This genus is, as Potonié (1958) has argued, a clumsy one, and includes species that clearly belong to validly published earlier genera. I prefer to accept the restriction of *Archaeozonotriletes* proposed by Potonié and *G. lemurata* is clearly quite different morphologically from *Archaeozonotriletes variabilis* Naum. the type species of *Archaeozonotriletes* (Naum.) R. Potonié.

***Geminospora lemurata* Balme n. sp.**

Pl. 1, Figs. 5-10

Description — Spore strongly rounded triangular in polar view. Distal side hemispherical, proximal side flattened or pyramidal with well-defined contact areas. Trilete, lip development sometimes present. Rays of scar straight extending almost to the proximo-distal margin. Incipient curvaturae present in some specimens. Exine two-layered, consisting of a heavily thickened exoexine, about 4 μ in thickness on the distal face and 2-3 μ on the proximal. Mesosporoid usually, although not invariably, visible as a faint circular body of variable diameter lying within the central cavity of the spore. Mesosporoid smooth, hyaline, with a wall about 1 μ thick.

Exoexine ornamented on the distal side with close-packed grana, minute cones, or infrabaculae. Basal diameter of individual ornamental element 1 μ or less, spaced 1-2 μ apart. Contact facets smooth.

Dimensions (50 specimens) — Total diameter 38-67 μ. Mean 53 μ.

Holotype — Slide No. 42314.

Paratype — Slide Nos. 42315, 42320.

Type Locality — Core between 2174 ft. and 2186 ft., Pelican Hill Borehole.

Discussion — Many previously illustrated Devonian spores bear a resemblance to at least certain specimens of *Geminospora lemurata*. Nevertheless the rather wide variation in both size and morphology displayed by the West Australian species makes comparisons difficult. Type VIA described by Thomson (1940) from the Givetian of Esthonia is morphographically similar to, if not identical with, *G. lemurata*. Radforth and McGregor (1956, Pl. III, Fig. 22) have also illustrated, without description, a form with a mesosporoid and what appears to be a granulate exoexine. Among Naumova's species both *Archaeozonotriles micromanifestus micromanifestus* and *A. micromanifestus minor* could, perhaps, be mistaken for *G. lemurata*. In both forms of *A. micromanifestus*, however, the granulate ornament covers both proximal and distal faces of the exoexine and the rays of the trilete scar are shown in all Naumova's illustrations as extending only to the periphery of the mesosporoid.

Remarks — *Geminospora lemurata* was overwhelmingly the most abundant species in both assemblages. It has not been found in the Upper Devonian (Famennian) of the Fitzroy Basin, Western Australia, and may, therefore, not range above the Frasnian.

Genus *Grandispora* Hoffmeister, Staplin & Malloy, 1955

***Grandispora* sp.**

Pl. 2, Fig. 20

Description — Spore body complex with a clear mesosporoid. Outline rounded triangular. Trilete, scar clearly defined, exoexine folded along one ray. A thin, rounded triangular mesosporoid is clearly developed within the central cavity of the spore. Exoexine about 2 μ thick, folded by compression, ornamented with densely packed stubby cones and infrabaculae.

Dimensions (single specimen) — Total diameter 145 μ. Mesosporoid diameter 84 μ.

Figured Specimen — Slide No. 42330.

Locality — Bore core at 1446 ft.-1496 ft., Pelican Hill Borehole.

Discussion — *Grandispora* sp. was represented by only one complete specimen in the assemblages examined. Forms of similar structure are, however, widely distributed in Upper Devonian and Lower Carboniferous sediments in other parts of the world. *G. spinosa*, the type species of *Grandispora*, came from the Upper Mississippian of Kentucky (HOFFMEISTER, STAPLIN & MALLOY, 1955b) and further species of *Grandispora* have been described by Hacquebard (1957) from Lower Carboniferous coals in Canada. *Archaeozonotriletes aculeatus* Naum. and

A. decumanus Naum., from the Frasnian of Russia, are also assignable to *Grandispora*.

Genus *Radiaspora* Hoffmeister, Staplin & Malloy, 1955

Hoffmeister, Staplin and Malloy (1955a) informally proposed the name "*Radiaspora*" for trilete spores characterized by "radial, spoke-like ribs on the distal surface". No type species was cited but a specimen was illustrated as "*Radiaspora* sp." R. Potonié (1958) noted the invalidity of the name *Radiaspora* but did not establish it because of the absence of a type species. A spore similar to "*Radiaspora* sp." had been previously figured by Naumova (1953, Table xxii, fig. 111) under the name *Stenozonotriletes ornatissimus*. However, Naumova gave no description and her name is judged to be a *nomen nudum*.

My original intention was to validate the name *Radiaspora* in the present paper. Some time after the preparation of my original manuscript, however, Dr. D. C. McGregor drew my attention to a group of Canadian Devonian spores resembling "*Radiaspora* sp." in all particulars except that the radial ribs were clearly borne on the *proximal* face. He has assigned spores of this type to a new genus *Emphanisporites*, in a paper awaiting publication.

The twelve radially ornamented specimens from my samples are all strongly compressed in a proximo-distal plane. I have re-examined them after hearing from Dr. McGregor, and, although I now incline to the view that the ribs are proximal, some uncertainty remains.

In view of the controversy over the morphology of these radially ornamented forms and the absence of definitive specimens in the Australian material, the informal name *Radiaspora* is retained.

Radiaspora sp. A

Pl. 1, Figs. 11, 12

Description — Spore simple, rounded triangular in polar view. Trilete, rays straight, extending to the proximo-distal margin. Weakly developed lips about 1 μ thick present along each of the trilete rays. Exine hyaline, about 3 μ thick, ornamented probably on the proximal side by ridges radiating in a spoke-like pattern from the pole. Ridges gradually expanding in width from less than 1 μ at the pole to about 5 μ at the proximodistal margin.

Dimensions (12 specimens) — Median diameter 44-57 μ (mean 48 μ).

Figured Specimens — Slide Nos. 42329, 42342.

Locality — Bore core 2174 ft. to 2186 ft., Pelican Hill Borehole.

Discussion — Dr. Hoffmeister, who has kindly examined photographs of *Radiaspora* sp. A, considers that it is very close to "*Radiaspora* sp." of Hoffmeister *et al.* (1955a). It may also be identical with *Stenozonotriletes ornatissimus* Naumova, although one cannot make detailed comparisons in view of the absence of description of this form.

Remarks — Although rare, *Radiaspora* sp. A was present in both the samples examined, it has not been found in any other sediments from Western Australia. I have seen specimens in material of possible Devonian Age from the Melrose district of Tasmania and also in Devonian shales from North Africa.

Radiaspora sp.

Pl. 1, Fig. 13

In the sample from the interval 1446 ft.-1496 ft. a single specimen of another species of *Radiaspora* was found. This resembled *Radiaspora* sp. A except, in its possession of a circumpolar, annular, flattened ridge about 6 μ wide on the distal side. This form of *Radiaspora* resembles one illustrated by Radforth and McGregor (1956, Pl. 1, Fig. 6). Sporotype K of Eisenack (1944) is somewhat similar to *Radiaspora* sp. but is larger and has heavier radiating ridges.

Figured Specimen — Slide No. 42334.

Genus *Chomotriletes* (Naumova, 1937) ex Naumova, 1953

Chomotriletes vedugensis Naumova

Pl. 2, Fig. 15

Chomotriletes vedugensis Naumova, Akad. Nauk. S.S.S.R., Trudy Inst. Geol. Nauk., Geol. Ser. No. 60, 1953, p. 58, tab. VII, figs. 21, 22.

Description — Spore simple, outline circular. No tetrad markings visible. Exine 2-3 μ thick ornamented by closely spaced concentric ridges about 3 μ wide. Ridges occasionally broken, about ten on either side of the spore body.

Dimensions (3 specimens) — 51-57 μ.

Figured Specimen — Slide No. 42335.

Locality — Bore core at 1446 ft.-1496 ft., Pelican Hill Borehole.

Discussion — The three specimens from the Pelican Hill Borehole agree so closely with Naumova's description of *Chomotriletes vedugensis* that no hesitation is felt in assigning them to the Russian species. *C. vedugensis* was described from the Frasnian Voroneg Beds of the U.S.S.R. and as far as one can judge from Naumova's paper it has not been found in the Famennian of Russia.

Similarly ornamented but much smaller forms are widespread although rare in the Australian Permian and have been figured by de Jersey (1946). Neither the Permian forms nor *Chomotriletes vedugensis* possess a clear tetrad mark and some doubt exists as to whether they are in fact spores. None the less there is a clear possibility that *C. vedugensis* has stratigraphical importance.

Remarks — *Chomotriletes vedugensis* was rare and seen only in the upper sample. It is not known from other Devonian localities in Western Australia.

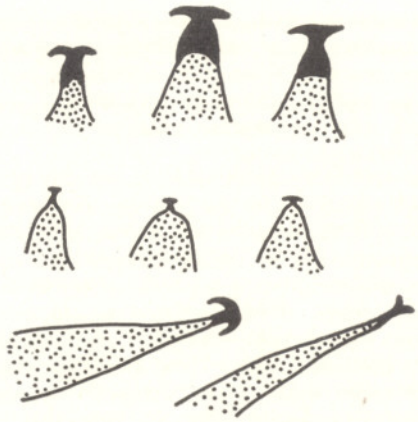
Genus *Spinozonotriletes* Hacquebard, 1957

***Spinozonotriletes carnarvonensis* Balme n. sp.**

Pl. 2, Figs. 17-19; Text-fig. 2

Description — Spore complex, consisting of a heavily spinose exoexine with a central mesospore. Outline generally rounded triangular to oval in polar view. Trilete, scar usually not clearly developed, rays sinuous, extending to the periphery of the spore, narrow raised lips along the full length of the trilete rays are visible in some specimens. Mesosporoid, oval or subcircular, outline sometimes indistinct, wall about 2 μ thick, apparently smooth.

Exoexine thick, surface rugose and ornamented with heavy slightly flattened spines, ranging in length between 5 and 40 μ. The spines are developed most prominently around the equator and on the distal face. Tips of the majority of the individual spines thickened and bifurcating into anchor-shaped terminal appendages (Text-fig. 2). The size and distinctness of the anchor-shaped appendages vary considerably from specimen to specimen. Nevertheless, the presence of spines with terminal bifurcations is a constant character in all the specimens assigned to *Spinozonotriletes carnarvonensis*.



Text-fig. 2. Diagram showing variations in the shape of the terminal thickenings of the appendages of *Spinozonotriletes carnarvonensis* n. sp. × 1000.

Dimensions (8 specimens) — Total maximum diameter including spines, 95-196 μ. Mesosporoid diameter, 56-96 μ.

Holotype — Slide No. 42325.

Paratypes — Slides Nos. 42326, 42327.

Locality — Bore core at 1446 ft.-1496 ft., Pelican Hill Borehole.

Discussion — Spores with heavy spinose, cylindrical or bladed appendages possessing bifurcating, anchor-shaped tips are important and striking components of Devonian microfloras. It is too early to strongly affirm that such forms are confined to the Devonian but they are certainly rare, if they occur at all, in later sediments. They were first recorded by Lang from the Middle Devonian Cromarty Fish Beds and his beautiful photograph (Lang, 1925, Pl. 11, Fig. 13) remains the classic illustration of this type of spore. References to spores with anchor- or grapnel-shaped processes are to be found in almost all subsequent account of Devonian microfloras although they are, surprisingly, not mentioned by Radforth and McGregor in their discussion of the morphologies of Devonian spores.

A remarkable feature of these spores is the wide diversity in morphology and size exhibited by forms having in common the feature of anchor-shaped appendages. The group includes large thick-walled megaspores (Nikitin, 1934, Chaloner, 1959), thinner-walled types with mesosporoid development (e.g. Lang, 1925, Eisenack, 1944, Høeg, 1942,

HOFFMEISTER *et al.*, 1955a, NAUMOVA, 1953) and another form exemplified by *Archaeotriletes crassus* Naum. in which no tetrad scar is visible and the appendages occur around the equatorial margin of an undifferentiated exine.

No satisfactory taxonomy of the group has yet evolved and the only genus of certain validity that includes spores with bifurcating appendages is *Nikitinsporites* Chaloner.* Naumova included a number of these forms in her genus *Archaeotriletes* which had a dubious status until emended and validated by R. Potonié (1958). The genotype chosen by Potonié was *Archaeotriletes conspicuus* Naum. a species in which the terminal " anchors " are not clearly developed and which is unusual in its possession of an equatorial membraneous flange. It seems clear, although it is not explicit in her definition, that Naumova intended the possession of anchor-shaped spines to be the main generic character of *Archaeotriletes*. However, some of Naumova's species of *Archaeotriletes* (e.g. *A. fidus*) are sufficiently different from *A. conspicuus* to warrant a separate generic status. Hacquebard (1957) created the genus *Spinozonotriletes* to include trilete spores with an indistinct central body and a heavy spinose " perispore ". The type species, *Spinozonotriletes uncatus* Hacq. came from the Mississippian of Nova Scotia and, although it is closely comparable to Devonian forms illustrated by Lang, Eisenack, Naumova and other authors, it does not show anchor-shaped terminations to its spines. By implication Hacquebard regards *Archaeotriletes aduncus* Naum. and Spore-type G of Lang (= *Triletes ancyreus* Eisenack in part) as falling into *Spinozonotriletes*, although a case may be made out, on stratigraphical grounds, for restricting *Spinozonotriletes* to forms in which the appendages do not bifurcate. I am reluctant to establish a new genus for the West Australian types because of the inadequate number of specimens available for study. They have, therefore, been assigned, for the present, to *Spinozonotriletes*.

Spinozonotriletes carnarvonensis resembles some of the specimens assigned by Eisenack to *Triletes ancyreus*; it is also similar to the smaller form of Lang's Spore-type G. It is difficult to compare *S. carnarvonensis* to any of Naumova's species but her Frasnian type *Archaeotriletes fidus* is perhaps closest to the Australian species. Hoffmeister and his co-authors illustrated several spores from the Upper Devonian of Alberta that belong to *Spinozonotriletes* in the sense in which the genus is used here. One of these (HOFFMEISTER *et al.*, 1955a, PL. 1, FIG. 6) may be identical with *S. carnarvonensis*.

Remarks — *Spinozonotriletes carnarvonensis* has been recognized in Australia only from the type locality, and spores with anchor-shaped appendages appear to be absent from Famennian sediments in Western Australia. Spores of the *Spinozonotriletes* type occur in Lower Carboniferous strata from the Bonaparte Gulf Basin, but these, like Hacquebard's species, have non-bifurcating spines.

Turma *Saccites* Erdtman, 1947

Genus *Endosporites* Wilson & Coe, 1940

***Endosporites* sp.**

Pl. 2, Fig. 16

Description — Spore complex, consisting of a thick-walled central body enveloped by a thin, finely ornamented bladder. Outline subcircular. Trilete rays strongly developed extending to, or just beyond, the margin of the central body. Wall of central body about 3 μ thick, smooth. Bladder thin with numerous compressional folds and a faintly developed marginal limbus. Surface of bladder infrapunctate.

Dimensions (3 specimens) — Total diameter 73-102 μ. Diameter of central body 61-87 μ.

Figured Specimen — Slide No. 42317.

Locality — Bore core at 2174 ft.-2186 ft., Pelican Hill Borehole.

Discussion — None of the three specimens of *Endosporites* sp. was preserved in its entirety, but there is little doubt that they belong to *Endosporites*. Basal Mississippian forms have been assigned to *Endosporites* by Hacquebard (1957). I am not aware of any previous record of the genus from Devonian sediments, although Hoffmeister *et al.* (1955a, CHART 1) suggest that it occurs in pre-Carboniferous deposits.

STRATIGRAPHICAL SIGNIFICANCE OF THE MICROFLORAS

No obvious basic differences exist between the two spore assemblages discussed in this

*Since this manuscript was prepared Richardson [*Palaeontology* **3**(1): 45-63, 1960] has described the genus *ancyrospora* and *S. carnarvonensis* could be appropriately assigned to this.

account. Both were dominated by the species *Geminospora lemurata* and neither showed great diversity. A few forms, most notably *Spinozonotriletes carnarvonensis*, occurred only in the upper sample, but these were rare species whose absence in the core from between 2174 and 2186 ft. cannot be held to be significant.

Three of the species described are sufficiently well-characterized and abundant to serve as a starting point for comparisons to previously described Devonian microfloras. These are *Radiaspora* sp. A, *Spinozonotriletes carnarvonensis*, and *Geminospora lemurata*. The genus *Radiaspora* has been recorded from Middle and Upper Devonian deposits in Russia, Western Europe and Canada, and I have seen it in Upper Devonian material from North Africa. It has been reported also from Carboniferous sediments in Oklahoma (HOFFMEISTER *et al.*, 1955) but this is the only published record of its occurrence in post-Devonian strata. Certainly it must be rare in the Carboniferous, a system which has been the subject of intensive palynological study during the past twenty years. Typically *Radiaspora* appears to be a Devonian genus, and from Naumova's charts it is chiefly a pre-Famennian form in the U.S.S.R.

The distribution of forms similar to *Spinozonotriletes carnarvonensis* has been briefly discussed in an earlier section of this paper. Spores with ornamental processes bearing anchor-shaped tips are characteristically Devonian, although it is more difficult to assess their stratigraphic range within that system. This is due partly to the fact that uppermost Devonian microfloras are unknown outside Russia, and partly because of the difficulty in dating precisely the continental sequences from which Devonian spore assemblages have been described. Coblenzian assemblages from West Germany (THOMSON, 1952) consist entirely of simple trilete forms, and the oldest well-dated occurrence of spores with anchor-shaped appendices is in the Eifelian Heisdorfer Beds (EISENACK, 1944, p. 116). Their widespread distribution in Middle Devonian strata is attested by a number of publications and discussed by Chaloner (1959). In Russia they appear, from Naumova's account, to be rare in the Givetian, attain their maximum diversity in the Frasnian and decline in abundance in the Famennian.

Geminospora lemurata is unlike any form found in post-Frasnian sediments from Australia, but is difficult to compare to previously described species. Almost certainly similar types occur in the European Devonian, for they are present in Devonian microfloras from North Africa. Thomson's type VIA from the Givetian of Esthonia may be identical with *G. lemurata* but one of the main characters of the Australian species, the restriction of ornament to the distal face, cannot be determined from casually selected photographs. The two forms of *Archaeozonotriletes micromanifestus*, illustrated by Naumova from the Middle and Upper Devonian of Russia, resemble *G. lemurata* in some ways. Here again, however, Naumova's stylized drawings and brief descriptions hinder close comparisons. *A. micromanifestus* is most abundant in Givetian and Lower Frasnian sediments in Russia, and forms with a thick granular exoexine, enclosing a central mesospore are rare in the Famennian.

With the possible exception of *Endosporites* sp. all the remaining species described from the Pelican Hill Borehole can be closely matched with forms occurring in Givetian and Frasnian deposits in Russia, Western Europe or North America. In view of the lack of diversity of the Pelican Hill microfloras, it would be unwise to base strong palaeofloristic conclusions on the evidence presented in this account. Nevertheless, there are grounds for suggesting that these Frasnian assemblages from Western Australia are relics of a similar flora to that which existed in the Northern Hemisphere during early Upper Devonian times.

A remarkable feature of the Frasnian microfloras from the Pelican Hill Borehole is their complete dissimilarity to rich Famennian assemblages, known from many localities in the Fitzroy Basin of Western Australia. It is conceivable that these divergences were controlled by palaeogeographic factors. On the other hand, the Famennian microfloras are comparable in many respects to assemblages of similar age in Russia. It is more likely, therefore, that the differences between Frasnian and Famennian microfloras in Western Australia have genuine stratigraphic significance. If so, considerable floral changes must have occurred during Upper Frasnian times leading to the establishment of a rich and diversified flora, persisting throughout the Famennian and probably into Lower Carboniferous time.

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EXPLANATION OF PLATES

PLATE 1

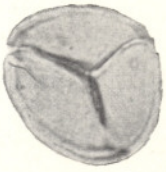
All magnifications 500×

1, 2. *Leiotriletes* cf. *L. simplex* Naum.
3, 4. *Retusotriletes* cf. *R. pychovii* Naum.
5. *Geminospora lemurata* n. gen. and n. sp., Holotype, proximal face showing smooth facets and mesosporoid.
6. *G. lemurata*, Holotype, showing ornamented distal side.
7. *G. lemurata*. Paratype, proximal view.
8. *G. lemurata*. Paratype, optical section of ruptured specimen showing mesosporoid.
9. *G. lemurata*. Distal view of specimen with coarser ornament.
10. *G. lemurata*. Proximal view.
11. *Radiaspora* sp. A.
12. *R.* sp. A.
13. *Radiaspora* sp.
14. *Apiculatisporis* sp.

PLATE 2

All magnifications 500× *except Fig.* 17

15. *Chomotriletes vedugensis* Naum.
16. *Endosporites* sp.
17. *Spinozonotriletes carnarvonensis* n. sp. Paratype. Magnification 250×.
18. *S. carnarvonensis*. Paratype.
19. *S. carnarvonensis*. Holotype.
20. *Grandispora* sp.



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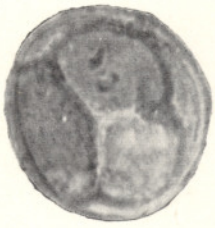

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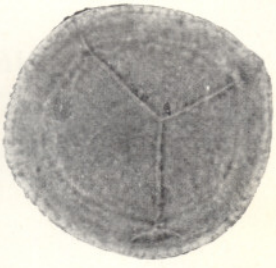

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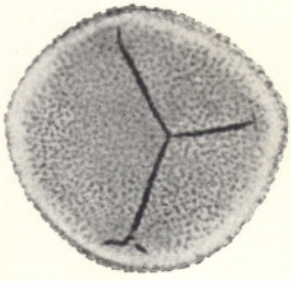

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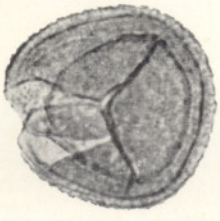

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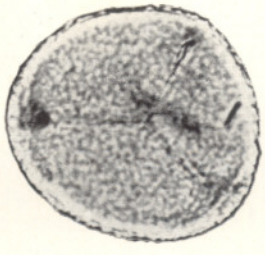

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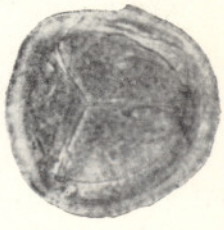

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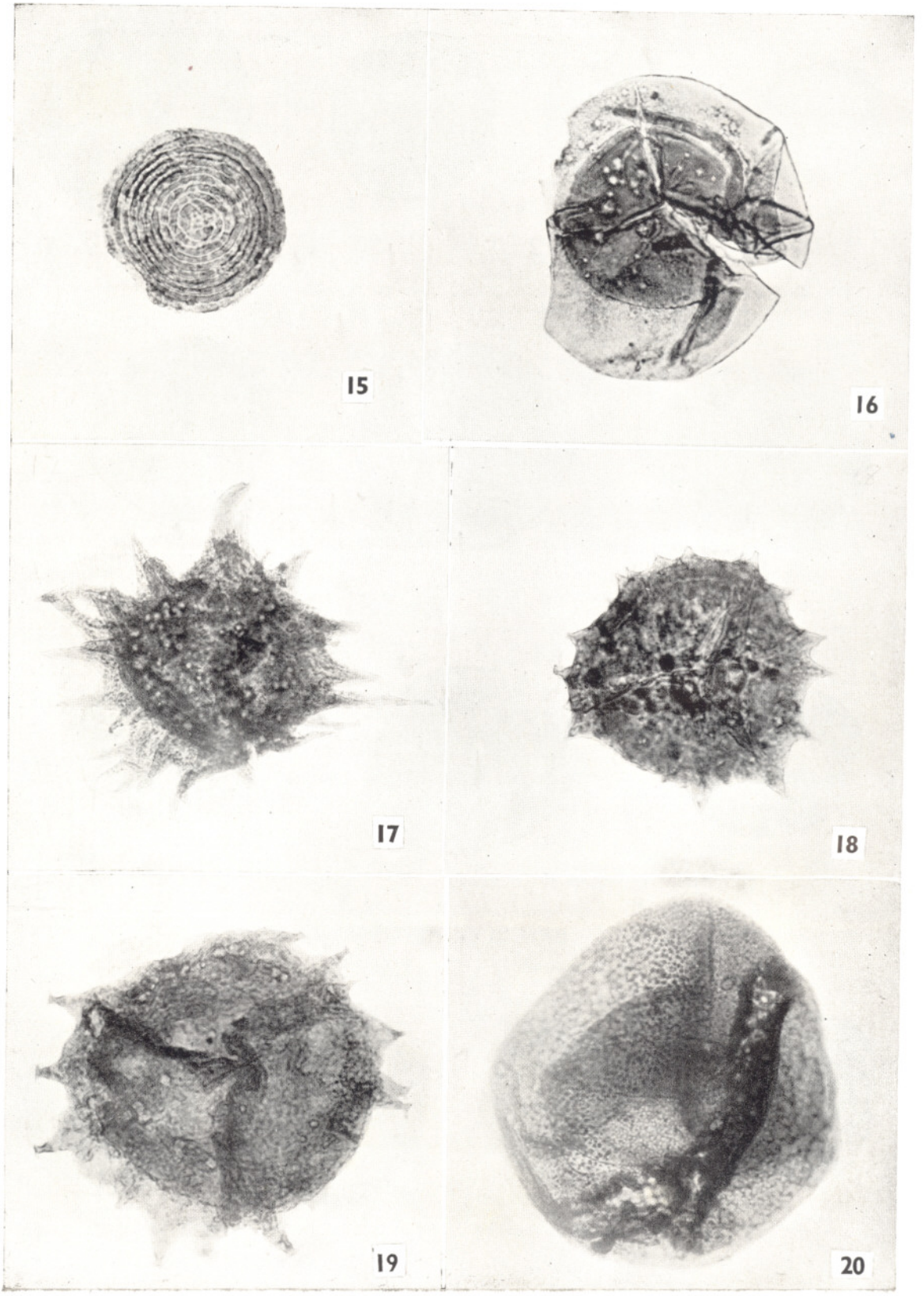
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