

THE GEOLOGY AND LATE PRECAMBRIAN FAUNA OF THE EDIACARA FOSSIL RESERVE

By M. F. GLAESSNER, UNIVERSITY OF ADELAIDE, AND B. DAILY,
SOUTH AUSTRALIAN MUSEUM

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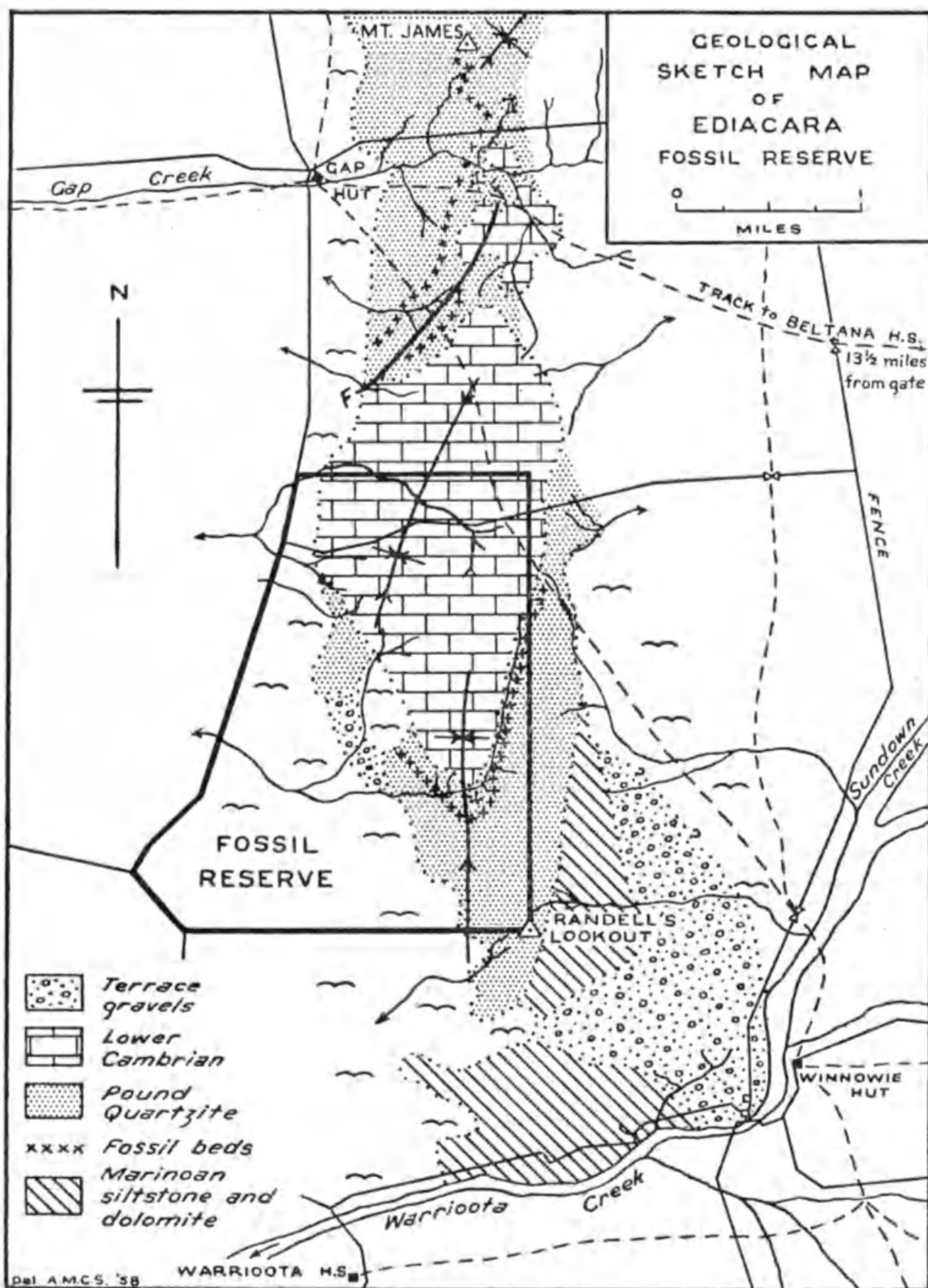
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INTRODUCTION

More than a decade has passed since Sprigg (1947) first found fossilized soft-bodied animals in what were then believed to be Lower Cambrian quartzites near the old Ediacara mining areas, some 380 miles (by road) north of Adelaide. In recent years the significance of these finds has received recognition in the palaeontological literature. At the same time further collecting has revived interest in the area and in May 1958, in view of its scientific importance, the area of the original discovery was proclaimed a fossil reserve, to be under the control of the Minister of Education and the authorities of the South Australian Museum.

It was considered desirable to give now a brief account of the geology of the fossil reserve and the surrounding areas. This was compiled by the authors on the basis of field observations which they made first separately and then jointly (October 1958). This account is followed by a review of the fauna and its significance, including



descriptions of two identified and several other new species. For this part one of the authors (M.F.G.) is alone responsible, but he had the benefit of stimulating discussions of palaeontological problems and observations with his colleague.

Information and material were kindly placed at our disposal by Mr. R. C. Sprigg and Geosurveys of Australia Ltd., Mr. H. Mincham and Mr. B. Flounders who generously presented their rich private collections from Ediacara to the South Australian Museum, and Mr. I. M. Thomas of the Zoology Department, University of Adelaide. Dr. W. Häntzschel of the Geologisches Staatsinstitut in Hamburg and Dr. W. Struve of the Senckenbergisches Museum, Frankfurt, supplied casts, and Dr. F. C. Truter and Professor S. W. Carey sent photographs of South African fossils. Miss A. M. C. Swan (Geology Department, University of Adelaide) painstakingly drew the geological sketch map. Photographs not acknowledged to others in the explanations to the plates were produced by Miss M. P. Boyce at the South Australian Museum.

GEOLOGY

By M. F. GLAESSNER AND B. DAILY

1. STRATIGRAPHIC SEQUENCE

a. Adelaide System

The oldest rocks exposed in the area are red and purple well-bedded siltstones and sandstones. They are exposed in cliffs along the Warrioota Creek and on the hill slopes along its banks south of Randell's Lookout, as well as along the eastern foot of the range which culminates in this hill. Strong folding, the encroachment of sand dunes from the west and deep weathering in the east obscure the succession. Current-bedding is well developed and flute casts up to 2 in. in diameter, the direction of which indicates currents coming from the west, are seen on lower surfaces of some beds. Ripple marks are often found, trending N-S and also E-W. The siltstones contain large nodules and veins of barytes. These beds are overlain by well-bedded olive- to buff-coloured dolomites. This part of the sequence is assigned to the *Marinoan Series* of the Adelaide System (fig. 1).

Fig. 1. Geological sketch map of Ediacara Fossil Reserve and surrounding areas. The co-ordinates of Mount James are 138° 09' E, 30° 46' S. Lands Department maps and aerial photographs and maps published by Segnit and Broadhurst have been used. F—F Gap Creek Fault.

It is followed by typically developed *Pound Quartzite* which forms the hilly slopes around Randell's Lookout in the south and Mount James in the north. The thickness of this formation is estimated to be about 2,000ft. The quartzites vary from thick-bedded to flaggy, with crossbedding, ripple marks, and mud pellets on the bedding planes. Casts of worm burrows were observed about 300ft. above its base near Randell's Lookout. Beds with abundant small siliceous nodules are scattered throughout the sequence. A prominent band of white quartzite forms a conspicuous zone in the upper part where red laminated siltstones also appear.

The *fossiliferous member* occurs 100-200ft. below the top of the formation. It is a fine- to coarse-grained quartzitic sandstone or quartzite, with varying amounts of weathered feldspars and irregular very thin argillaceous partings and lenses. The sandstone is white to grey when fresh and weathers to a deep rusty red to purple, with black stains in depressions. Exposed surfaces are bleached. The weathering produces flags of varying sizes which are rarely more than 2in. thick. Exposures of beds *in situ* on steep hill slopes show that the individual bedding planes are uneven and wavy and the beds are very strongly lenticular. Cross-bedding of various orders is present throughout. The better developed bedding planes are covered with ripples which are more or less irregular, with crests up to 2in. distant. A bed with contorted slump rolls up to 10ft. long was found near the southern end of the outcrop of the fossiliferous member. Slump structures also occur commonly towards the base of the fossiliferous member at the northern end of the area.

The beds above the fossiliferous member include lenticular bodies of more solidly silicified quartzite, some of which are distinguished in Segnit's mapping as "quartzite" from the "sandstone" of the rest of the formation. One of them forms a spectacular cliff about $\frac{3}{4}$ mile south of Gap Creek. Silicification is not confined to a single stratigraphic horizon but extends through at least the top 10ft. of the fossiliferous member in some places.

Broadhurst (1947) recognized the occurrence of *transition beds* between the (Pound) quartzite and the overlying (Ajax) limestones (which had not been named at that time). Such passage beds are now widely known throughout the Flinders Ranges and also at Kulpara on Yorke Peninsula (Daily 1956). Their occurrence proves that there is no stratigraphic break below the Lower Cambrian Ajax Limestone, as Segnit (1939) had suggested. Mineralization is frequent at this horizon but it is believed to be related to hydrological

conditions and the pronounced change in permeability and porosity on this boundary rather than to exposure and weathering. In agreement with regional observations, the top of the transition beds is now taken as the top of the Pound Quartzite and is placed a little lower than in Broadhurst's mapping. The position of the transition beds is shown in the sections (fig. 2). They can be described as interbedded sandstones and sandy and silty dolomites. They are white,

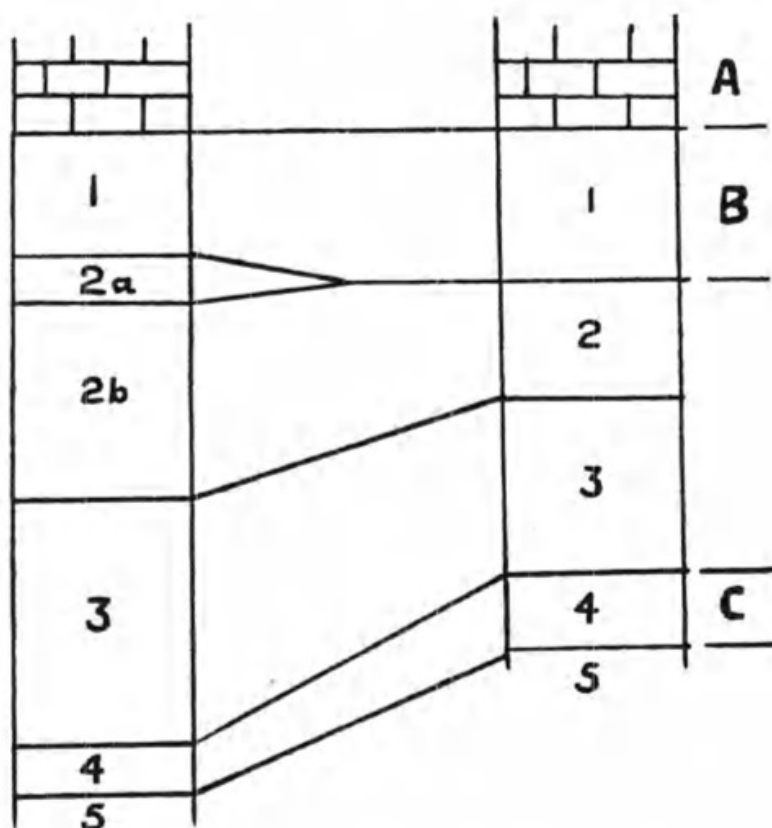


Fig. 2. Measured sections of the fossiliferous member of the Pound Quartzite and overlying strata. Left: Adit near south workings of the old Ediacara mine, near the southern end of the Cambrian outcrop. Right: In Gap Creek Fault valley, one mile south of Gap Creek. Top: Cross-bedded and well-bedded sandy and oolitic dolomitic limestone. 1—Interbedded argillaceous sandstone and sandy dolomitic limestone. 2a—Quartzite band. 2, 2b—White knotty sandstone. 3—White and reddish quartzite. 4—Fossiliferous flaggy quartzite, cross-bedded and ripple-marked. 5—Unfossiliferous white to red and purple quartzites and sandstones. A—Lower Cambrian, B—Passage Beds, C—Fossiliferous Member. Scale—1 in. to 100 ft.

yellow and purple, often leached, soft and poorly exposed while the overlying dolomites are hard and form good outcrops.

b. Lower Cambrian

Occupying the central position of the area and conformable with the underlying Pound Sandstone is a sequence of limestones and dolomitised limestones estimated by Broadhurst (1947) to be about 530ft. thick. On lithological and faunal grounds these beds are correlated with part of the Ajax Limestone which is exposed in the Mount Scott Range, 18 miles to the north-east.

The base of the Ajax Limestone is taken at the horizon where carbonate deposition becomes dominant and continuous. The Ajax Limestone is variable in colour and composition. It exhibits all gradations from a yellowish coloured dolomitised limestone, particularly near the base, to grey, blue-grey and buff coloured limestones above, either siliceous, dolomitised or both. Oolitic, often cross-bedded dolomitic limestones with well rounded quartz grains occur commonly at the base of the formation. Nodular structures, possibly referable to algae, intraformationally brecciated limestones, and large nodules of chalcedony are conspicuous features of the Ajax Limestone in this area as they are in the same formation in the Mount Scott Range (Daily, 1956).

Poorly preserved Cambrian fossils have been found in the uppermost 60ft. of the Ajax Limestone, the remainder of the formation still being under investigation. The fossils occur sporadically within grey and buff coloured partially dolomitised limestones but concentrations of small shell fragments are found in small lenses. The fossils include silicified archaeocyathids, phosphatic brachiopod fragments, and phosphatic-shelled tubular organisms of unknown affinities. A new brachiopod genus, represented by forms to which Tate referred as "*Ambonychia macroptera*," ranges throughout the 60ft. of beds investigated whilst a representative of another new brachiopod genus, known as *Micromitra* (*Paterina*) *etheridgei* (Tate), together with the enigmatic tubular organisms have been found in the top 30ft.

The "*Ambonychia*," "*Micromitra*" and tubular organisms are characteristic elements of the Lower Cambrian "Faunal Assemblage No. 2" (Daily, 1956), with which this assemblage is correlated. It is widespread and has been found in the Ajax Limestone near Mount Scott, in the Kulpara Limestone at Ardrossan and Curramulka, and in the Wilkawillina Limestone near Wirrealpa.

c. Cainozoic Gravels

A large area between Winnowie Hut and Randell's Lookout is covered with coarse, well-rounded quartz gravels. They form conspicuous cliffs near the bed of Warrioota Creek, opposite and above Winnowie Hut. Near the head of one of the minor tributaries of this creek where it is deeply entrenched, the base of the gravels is seen at least 100ft. above the level of the creek, resting on about 6ft. of strongly silicified quartz conglomerate which is lensing in a more sandy matrix. This conglomerate, in turn, overlies deeply weathered and mottled Marinoan silty shales which are here exposed to a depth of 30ft. The silicified sandstones and conglomerates have also been observed elsewhere in the area, *e.g.*, on low hills in the headwaters of the creek which flows around the southern end of the Cambrian dolomite outcrop. No direct evidence of their age has been found but they are thought to be part of the widespread mid-Tertiary continental sedimentary formations which elsewhere contain plant remains and which are invariably converted by silicification into part of the "duricrust" of inland Australia.

The overlying terrace gravels are not related to recent drainage which has eroded them deeply. They could be either Late Tertiary or Pleistocene. No fossils have been found in them but in September 1958 Dr. R. Horwitz found a piece of freshwater limestone with abundant gastropods west of Winnowie Hut near the boundary between the terrace gravels and the Marinoan dolomite outcrops, and identical rocks were subsequently found *in situ* about $\frac{1}{2}$ mile west of the southern end of the Cambrian dolomite outcrop. At this locality, thin lenses of similar freshwater limestone with gastropods outcrop at the base of a terrace gravel which resembles closely that which was first found near Winnowie Hut. The gastropods have not been identified.

2. STRUCTURE

Earlier observers have already recognized the structure of the area as essentially synclinal. It is, however, not a simple syncline, nor is it as extensively faulted as Segnit's map (1939) had indicated. The axis of the syncline trends northward in the south, from near Warrioota Creek, but it is offset to the west and shows a more north-easterly trend in the central area, and a similar shift occurs near Mount James. The dips are generally low, between 10° and 20° , but the east flank is steeper, with dips up to 30° . There is only one distinct fault in the area. It trends SW from near Gap Creek. It was recognized by Segnit and correctly mapped by Broadhurst.

The faults shown on Segnit's map near Mount James and around the southern end of the Cambrian outcrop do not exist and the individual beds can be followed around it easily. The Marinoan siltstones and sandstones along Warrioota Creek are more strongly folded than the overlying formations and steeper dips and closer folds can be seen in the cliffs. It may be assumed that there is some incompetent folding of the softer siltstones beneath the hard quartzite but the structure of a large area occupied by Marinoan south of Warrioota Creek remains unexamined. Both limbs of the Ediacara Syncline disappear under alluvium. The flanking anticlines have not been observed.

3. DISTRIBUTION OF THE FOSSILIFEROUS STRATA

The fossiliferous member in the upper part of the Pound Quartzite was first discovered near the southern end of the Lower Cambrian dolomite outcrop. From that point on the creek which cuts across it and which leaves a small west-dipping outlier of dolomite on a low hill on its southern bank, the fossiliferous band can be easily followed up the creek northward to its headwaters. It may continue a short distance further up the east flank but it becomes difficult to follow where the soil cover of the eastern plains encroaches on the bedrock. The actual occurrence of fossils depends on the flagginess of the rock and decreases markedly where the rock becomes slightly more massive. On the western limb of the structure the fossiliferous band can be followed across a hill north of the main creek until it disappears under a patch of talus from the Cambrian dolomite hills.

The fossiliferous beds are also well developed near the northern end of the main dolomite outcrop. Here they are locally duplicated by a normal fault. This explains the reference by Sprigg (1949, p. 73) to two distinct fossiliferous horizons found by Mawson "in the northern extensions of the fossil occurrences". They can be followed north across Gap Creek and up the southern slopes of Mount James where they are less rich owing to a gradual change in lithology and where they are cut off by erosion and obscured by talus from above. The entire northern outcrop of the fossiliferous strata is outside the fossil reserve area.

The horizon in the Pound Quartzite corresponding to the fossiliferous member has been seen in many parts of the Flinders Ranges but has not been found anywhere, except on the north-western end of the Mount Scott Range, to be developed in the flaggy facies which has proved surprisingly suitable for the preservation of fossils.

Two areas nearer to Ediacara where the Cambrian-Precambrian transition is likely to be exposed and where it could contain equivalents of the fossiliferous member remain to be examined. They are in the southern extension of the range of hills about 8 miles south of Warrioota Creek near Mount Michael, and near Beltana Hill about 4 miles south of Beltana H.S.

FAUNA

By M. F. GLAESSNER

1. ANNOTATED CATALOGUE OF GENERA (with descriptions of two new species)

It is estimated that to date about 800 specimens of fossils have been collected from the fossiliferous member near the top of the Pound Quartzite at Ediacara. The study of such abundant material will take several years and will require extensive comparative investigations on recent as well as fossil specimens. The work of the last 12 months has, however, revealed several facts of outstanding significance which make it desirable to review briefly our present knowledge of this fauna.

1. The fauna consists not only of Medusae believed to represent the Scyphozoa and Hydrozoa but there are also Anthozoa (Octocorallia) and Annelida and at least two entirely new types of invertebrates.

2. Certainly one and possibly more elements of this fauna show relations to the fauna of the Nama System of South Africa.

3. Stratigraphic and palaeontological evidence supports the placing of this fauna in the Late Precambrian rather than the Lower Cambrian.

Apart from factual evidence in support of these statements, it seems desirable to record here some observations on the type specimens of Sprigg's fossils from Ediacara (1947, 1949). These types are deposited in the palaeontological collections of the University of Adelaide. Sprigg considered all his species as probable hydrozoan or scyphozoan medusae. Their taxonomic position was recently reconsidered by Harrington and Moore (1956) and briefly reviewed by Caster (1957). There has not yet been an opportunity of making careful comparisons between the types and the abundant new material of medusa-like fossils. Such further studies are

expected to influence morphological interpretations and systematic placement of at least some of the taxa, on the specific as well as on higher levels. As a basis for such future work, an annotated catalogue of all genera described by Sprigg and others is here given in alphabetical order; descriptions of some of the new forms are included in it. Numbers prefixed "P" refer to specimens in the South Australian Museum. Others refer to Adelaide University palaeontological collections.

Beltanella Sprigg

Beltanella Sprigg, 1947, Trans. Roy. Soc. S. Aust., 71, p. 218.

Beltanella Sprigg, 1949, Trans. Roy. Soc. S. Aust., 73, p. 81.

Beltanella Harrington and Moore, 1956, Treatise Inv. Paleont., p. F70.

This genus was placed by Sprigg in the Suborder Trachymedusae (Trachymedusina) and left in this position by the later authors. There is only one species, *B. gilesi* Sprigg, represented by a single specimen, and no further specimens have been assigned to it. (Holotype No. T 3-2056.)

Cyclomedusa Sprigg

Cyclomedusa Sprigg, 1947, Trans. Roy. Soc. S. Aust., 71, p. 220.

Cyclomedusa Sprigg, 1949, Trans. Roy. Soc. S. Aust., 73, p. 91.

Cyclomedusa Harrington and Moore, 1956, Treatise Inv. Paleont., p. F153.

Ediacaria (part) Harrington and Moore, 1956, Treatise Inv. Paleont., p. F74.

This genus (type species *C. davidi* Sprigg, Holotype No. T 5) was described by Sprigg (1949) together with other "medusoid problematica", and Harrington and Moore discussed it under the heading "Medusae incertae sedis". These later authors combined the species *C. radiata* with *Tateana inflata* and considered both as "exumbrellar impressions" of *Ediacaria flindersi*. A preliminary study of the types indicates that Sprigg had correctly placed *C. radiata* in the same genus as *C. davidi*. *Tateana inflata* does not seem to be distinguishable generically and possibly even specifically from *C. radiata*. Fossils of the same general type, with variations due to preservation, are found very commonly and are well represented in the new collections. The holotype of the third species, *C. gigantea* (No. 2035) is not easily matched by any other specimen. This applies at present also to the two incomplete specimens described by Sprigg

(1947, pl. 5) as *Ediacaria flindersi*. It is therefore undesirable to accept Harrington and Moore's procedure and to place the species *C. radiata* and the genus *Tateana* in the synonymy of *Ediacaria flindersi*. Russian workers on Lower Cambrian faunas, particularly I. Zhuravleva, (personal communication) have expressed the opinion that *Cyclomedusa* may be related to certain saucer-shaped Archaeocyatha which they have found in shale and sand facies of the Lower Cambrian. The external resemblance is undeniable but no evidence of the distinctive double wall of the Archaeocyatha has been found in *Cyclomedusa*.

Dickinsonia Sprigg

Dickinsonia Sprigg, 1947, Trans. Roy. Soc. S. Aust., 71, p. 221.

Dickinsonia Sprigg, 1949, Trans. Roy. Soc. S. Aust., 73, p. 95.

Dickinsonia Harrington and Moore, 1955, Kansas Geol. Survey, Bull. 114, pt. 5.

Dickinsonia Harrington and Moore, 1956, Treatise Inv. Paleont., p. F24.

Dickinsonia Glaessner, 1958, Trans. Roy. Soc. S. Aust., 81, p. 188.

Dickinsonia Glaessner, 1959, Geol. Rundschau, 47.

Sprigg (1949) had considered the affinities of this genus as "extremely uncertain" but had concluded that "the coelenterate category seems the most logical association for the present". Harrington and Moore established for the genus *Dickinsonia* the new Class Dipleurozoa. I have stated that it resembles certain worms more than any coelenterates. No finality can be reached until the entire material which now amounts to well over 100 specimens ranging in length from 10 to 330 mm. is examined. The type species is *D. costata* Sprigg (Holotype No. T 6-2055).

Ediacaria Sprigg

Ediacaria Sprigg, 1947, Trans. Roy. Soc. S. Aust., 71, p. 215.

Ediacaria Sprigg, 1949, Trans. Roy. Soc. S. Aust., 73, p. 83.

Ediacaria (part) Harrington and Moore, 1956, Treatise Inv. Paleont., p. F74.

The genus which is represented by the imperfectly preserved holotype of *E. flindersi* Sprigg (No. T 1) and one other doubtful specimen, was considered by Sprigg as representing the Semaestomatida but listed under Trachylinida incertae sedis by Harrington

and Moore, who placed in its synonymy the genus *Tateana* and the species *Cyclomedusa radiata*. I have stated above that they cannot be separated from other *Cyclomedusa*. At present no other specimens can be identified as *Ediacaria* and its reconstruction (Sprigg, 1949, fig. 5) rests on uncertain grounds.

Madigania Sprigg

(See *Spriggia* Southcott)

Medusina Walcott

(See *Protolyella* Torrell)

Papilionata Sprigg

Papilionata Sprigg, 1947, Trans. Roy. Soc. S. Aust., 71, p. 233.

This genus was described for the single specimen of its type species *P. eyrei* Sprigg (No. T 8). It was not mentioned by Sprigg in 1949 and was listed by Harrington and Moore (1956, p. F159) as "problematic form of unknown affinities, not a medusoid". It appears to be a poorly and incompletely preserved specimen of a *Dickinsonia*.

Parvancorina Glaessner

Pl. xlvii, figs. 5, 6

Parvancorina Glaessner, 1958, Trans. Roy. Soc. S. Aust., 81, p. 187.

Parvancorina, Glaessner, 1959, Geol. Rundschau, 47.

This form, of unknown affinities, originally described from a single specimen, is now represented by 16 individuals ranging in length to 25 mm. The only additional morphological detail which has been observed is a division of the two lateral areas by about 7 or more fine oblique lines on either side of the main anchor-shaped depression. They are slightly convex towards the narrow (posterior?) end of the body and join the lateral margins at approximately right angles. They may represent traces of appendages. The main anchor-shaped depression is unsegmented in all specimens. The type species is *P. minchami* Glaessner (Holotype No. P 12774).

Protodipleurosoma Sprigg

Protodipleurosoma Sprigg, 1949, Trans. Roy. Soc. S. Aust., 73, p. 79.

Protodipleurosoma Harrington and Moore, 1956, Treatise Inv. Paleont., p. F79, F87.

This is a rare form which has been assigned to the Leptomedusae, i.e., the medusoid forms of Calyptoblastina (Hydroida). The genus was based on a single specimen of its type species, *P. wardi* Sprigg. (Holotype No. T 36-2023.)

Protolyella Torrell

Harrington and Moore (1956, p. F153) have shown that Walcott's name *Medusina* which Sprigg (1949, pp. 89, 90) had used for three new species, is inapplicable. They extended the generic concept of *Protolyella* to accommodate them. A preliminary study of the types shows that "*M.*" *asteroides* (Holotype No. T 40-2021) is probably identical with "*M.*" *mawsoni* (Holotype No. T 39), while the position of the third species, "*M.*" *filamentus* (Holotype No. T 68) is in doubt. The examination of the numerous new specimens should clarify the status of these species.

Protoniobia Sprigg

Protoniobia Sprigg, 1949, Trans. Roy. Soc. S. Aust., 73, p. 77, 79.

At the end of his description of *Protoniobia wadea* from Western Australia Sprigg states: "A second example of *Protoniobia* has been discovered amongst material from Ediacara . . . The example occurs on the same quartzite fragment as fossil No. 2010". This fossil, now numbered T10-2010 is a hypotype of *Cyclomedusa radiata*. The small specimen on the same rock face is not a *Protoniobia* but represents the new form described below as *Tribrachidium heraldicum* nov. gen., nov. spec.

Pseudorhizostomites Sprigg

Pseudorhizostomites Sprigg, 1949, Trans. Roy. Soc. S. Aust., 73, p. 87.

Pseudorhizostomites Harrington and Moore, 1956, Treatise Inv. Paleont., p. F52.

Sprigg has compared this monotypic genus with the Jurassic *Rhizostomites* and placed it in the "Rhizostomae" (Scyphozoa). Harrington and Moore considered these fossils as "Scyphomedusae incertae sedis". Recent collecting has proved them to be common; some 75 specimens are known. They show no trace of any umbrellar margin. The branching of the grooves is variable and the centre is usually depressed. Some specimens, however, show a more or less irregular convex area in or near the centre. "*Medusina*" *filamentus* closely resembles these specimens which also provide a link with *Pseudorhopilema* which cannot be distinguished from *Pseudorhizostomites*.

Pseudorhopilema Sprigg

Pseudorhopilema Sprigg, 1949, Trans. Roy. Soc. S. Aust., 73, p. 88.

Pseudorhopilema Harrington and Moore, 1956, Treatise Inv. Paleont., p. F51.

This genus and its type species, *P. chapmani* Sprigg, are based on a single, somewhat eroded specimen (No. T 74-2036). There seems to be intergrading between the typical specimens of *Pseudorhizostomites* with depressed centres and others with the branching impressions extending around convexities. These forms are generally much less regular than had been expected on the basis of the first few specimens. The separation of the genus *Pseudorhopilema* from *Pseudorhizostomites* cannot be maintained.

Pteridinium Gürich

Pteridium Gürich, 1930, Zeitschr. deutsch. Geol. Ges. 82, p. 637 (nom. preocc., non Scopoli 1777).

Pteridinium Gürich, 1933, Palaeont. Zeitschr., 15, p. 144.

Pteridinium Richter, 1955, Senckenb. Leth., 36, p. 246.

This genus was established for specimens which have since been lost. Richter later discussed it in great detail on the basis of relatively abundant material from the type locality in the Kuibis quartzite of the Nama System of South Africa, from which he selected a neotype (Richter 1955, pl. 1, fig. 1). This genus is included in the present catalogue because of the close resemblance with the neotype of two specimens (pl. xlv, figs. 3, 4) on one slab (No. P 12744). Neither these nor any other specimens in the present collection resemble closely such specimens as were figured by Richter (1955) on pls. 3-6. The problems connected with their peculiar preservation and *Conularia*-like appearance are beyond the scope of this discussion.

The present specimens are each about 70 mm. long and 16-17 mm. wide. They show a median depression which takes a more or less indistinct zig-zag course, as a result of weaker transversal furrows joining it alternately, separating between them faint and slightly curved elevated transverse ribs which are about 2 mm. wide. 8 or 9 ribs occupy about 20 mm. along the axis. The lateral margins are indistinct but there is a gentle convergence towards that end which is faced by the concave side of the curvature of the lateral ribs. In the specimen in which the ribs are less faint, they extend 4 mm. and then flatten out markedly.

The differences between these specimens and the neotype of *Pteridinium simplex* Gürich are their smaller size, less distinct and narrower ribs, and narrower shape. The specimens from Ediacara may be referred to as *Pteridinium* sp. Gürich and Richter have considered *Pteridinium* as closely related to *Rangea*. This view is undoubtedly correct and on the South Australian material alone no generic distinction would have been made.

Rangea Gürich

Rangea Gürich, 1930, C.R. 15th Int. Geol. Congr., 2, p. 680.

Rangea Gürich, 1930, Zeitschr. deutsch. Geol. Ges., 82, p. 637.

Rangea Gürich, 1933, Palaeont. Zeitschr., 15, p. 139.

Rangea Richter, 1955, Senckenb. Leth., 36, p. 264.

Rangea Wells and Hill, 1956, Treatise Inv. Paleont., p. F478.

The most striking and unexpected discovery is the common occurrence of representatives of the genus *Rangea* in the Ediacara fauna. This genus was first described from the Kuibis quartzite of the Nama System of South-west Africa, where it is rare. About 40 specimens of fossils which cannot be generically separated from *Rangea* are now known from Ediacara. Sprigg (1949, p. 73) has referred to some of them as algae. Gürich compared *Rangea* (type species *R. schneiderhöhni* Gürich) with the Ctenophora, without assigning it to any Class. Richter (1955) placed it with *Pteridinium* in a new family Pteridiniidae which he assigned to the Order Gorgonaria, Suborder Holaxonia, of the Anthozoa (Octocorallia). This family is not mentioned in the Treatise on Invertebrate Paleontology where Wells and Hill (1956) refer to Gürich's comparison of *Rangea* with Ctenophora as very doubtful. The new material makes it possible to assign the genus to the Order Pennatulacea of the Anthozoa (Octocorallia).

Rangea arborea sp. nov.

Plate xliii, figs. 1-4; pl. xlv, figs. 1-3; pl. xlv, figs. 1, 2; pl. xlv, fig. 1.

(a) Description

This description is based on a large number of specimens, some of which differ considerably in appearance. Existing transitions indicate that at least some of these differences are not of any taxonomic value but due to differences in preservation. Others may

indicate the presence of more than one species but all available specimens are more or less incomplete and there is not enough evidence, particularly from measurements, on which to base specific diagnoses.

The species *Rangia arborea* is characterized by a leaf-shaped *main body* consisting typically of a *median field*, the sides of which converge towards the distal end. It may appear convex (pl. xlv, fig. 1; pl. xliii, fig. 4) or concave (pl. xliii, fig. 1), and may have a zig-zag shaped structure impressed on it (pl. xlv, fig. 2), or it may consist only of such a structure (pl. xliii, fig. 3) or become reduced to a zig-zag groove (pl. xlv, fig. 1). A variable number of transversely directed *lateral furrows* divide the lateral portions of the leaf into convex or flatly moulded areas or *branches*. The furrows extend from the median field or groove outward at angles varying between 60° and 80° . The bases of the branches overlap the median field partially, giving the impression of being inserted in it with their narrowing, down-turned bases (pl. xliii, fig. 4). They alternate in position on the sides of the axis, irregularly or more regularly, which accounts for the zig-zag structure. In the best-preserved specimens a division of some of the lateral branches by closely set *secondary furrows* is seen. They are 1-3 mm. apart, mostly more distinct on the proximal margins of the branch, and set at approximately right angles to the lateral furrows so that they trend obliquely across the leaf from the outer margin inward towards the axis. Other specimens (pl. xlv, figs. 2, 3) show hardly any trace of secondary furrows and the lateral furrows grade into bundles of fine grooves arising from the median field in a similar manner to that observed in more typical forms. This field may also be marked by similar but longitudinally directed grooves. The entire structure appears to consist mainly of impressions of bundles of spicules, some of which may be up to 40 mm. long. Details of their shape and surface sculpture cannot be recognized, as the width of the individual grooves is close to or even less than the average grain size of the quartzitic matrix.

The lateral margins of the main body are often clearly marked by more or less sinuous lines. The ratio of length to width appears to have been variable and some leaves are broad while others are very long and narrow. As all specimens are incomplete, this ratio cannot now be used for specific distinctions. The width of the branches also varies conspicuously but is believed to be to some extent a function of growth. Several specimens have a *peduncle* attached to

the proximal end. It can be up to 12 in. (30 cm.) long, with parallel sides, and about 20 mm. wide. In other specimens the peduncle is shorter or less well defined, or the proximal end of the main body is obscured or broken off. The maximum width of the body is about 4½ in. (over 11 cm.), the maximum length (without peduncle) about 9 in. (23 cm.) but all specimens are incomplete. Holotype: No. P 12891.

(b) Comparison

Because of the marked differences of opinion concerning the morphology and taxonomy of *Rangea*, a neutral terminology was used in the description of the new species. It will also be used in its comparison with *R. schneiderhöhni* Gürich. This species shows clearly the leaf-shaped main body with its median field, and the lateral branches which are separated by transverse lateral furrows and subdivided by secondary furrows arising from their proximal margins. The similarity in these characters is the basis for the generic identification of the new form with the genus *Rangea*. In addition, there is the downward turn and the narrowing of the bases of the lateral branches and their partial overlap over the median field in the distal part of the body which puzzled Richter (1955, p. 266). The differences are considered as specific. They are seen mainly in the more regular arrangement of the lateral branches, the more distinct secondary furrows, and the sharp outer margin, with certain lateral impressions ("Aussenfeld") beyond it in *R. schneiderhöhni*. In comparing a single specimen (*R. schneiderhöhni forma turgida* Gürich is too obviously distorted to be of much use) with the rich new material it is difficult to decide which of its features may be due to accidents of preservation of this individual. Such an accident may explain the lateral projections which are seen only on one side of the holotype specimen, and also the duplication of some furrows. However, the regular outline and the arrangement of furrows shown by this specimen have no parallel among the many specimens from Ediacara and specific distinction seems justified on this basis. *Rangea? brevior* Gürich, a single specimen which has since been lost, cannot be considered.

(c) Interpretation

Gürich had considered, and rightly rejected, the possibility of his specimens representing tracks (1930a, p. 679; 1933, p. 141). He then compared them briefly with *Pennatulula* but rejected this as a lead to

their interpretation because they showed clearly an outer margin of the leaf-shaped body. He interpreted them as meridional sectors of melon-like bodies, and this led him to a comparison with the Ctenophora.

Richter (1955, p. 266) re-interpreted some of the structures of *Rangea* and revised some of Gürich's descriptions. It is his conclusion (p. 285) that these fossils are thin membranaceous leaves and not remains of spherical bodies, and that therefore they are not Ctenophora. He had abundant material of *Pteridinium* but no new specimens of *Rangea* and his conclusion that both these fossils represented Gorgonaria was based mainly on *Pteridinium*.

The study of the new material of *Rangea* places it clearly in the vicinity of the Pennatulacea. This assignment explains (a) the peduncle, (b) the leaf-shaped main body, (c) the median field which represents the median "dorsal track" of the Pennatulacea, (d) the zig-zag junction of alternating branches which corresponds to the "ventral track", (e) the lateral branches which are comparable to the "leaves" of the Pennatulidae, and their secondary divisions which reflect the placing of the anthocodia on them, and (f) the spicular impressions in some of the fossils.

Some difficulties remain, but they are to be expected when an attempt is made to place a very ancient fossil in the system of recent forms. The difficulty which led Gürich summarily to reject relationships between *Rangea* and *Pennatula* still requires an explanation. In *Pennatula* the polyps sit on lateral extensions of the rhachis which are generally known as "leaves," while in *Rangea* the lateral branches appear to have been fused to form the single leaf-shaped main body which shows a well marked outer edge in a number of specimens. One exception from this was recognized by Richter who described the distal ends of *R. schneiderhöhni forma turgida* as freely projecting. Some specimens of *R. arborea* suggest a certain measure of separation and mobility of the lateral branches. Even a solid single leaf with a regular arrangement of polyps in lateral transverse rows would not be in conflict with the basic structure of the Pennatulacea, though this particular type of organization is not represented in the living fauna. In *Renilla* which is leaf-shaped with an undissected outline the polyps are irregularly distributed and occur on the "dorsal" side only, while in *Pennatula* they sit on separate lateral leaves on the "ventral" side. In *Rangea* the position of the polyps is not yet known but they must have occurred in transverse rows supported by

major spicular sclerites as in *Pennatula*, on a leaf-shaped expansion of the rhachis similar to that of *Renilla*.

The assignment of *Rangea* to the Pennatulacea supports the view that the different characters of some specimens are due to different types of preservation, though a later separation of additional species within the genus is not excluded. The preservation of the forms with "spicular" structure seems to have occurred after some maceration of the fleshy body had exposed the spicules which in living specimens are embedded in the flesh. It is further suggested that the ventral aspect of *Rangea* is represented by the forms with a median zig-zag groove (pl. xlv, fig. 1) where the lateral branches, comparable to the "leaves" in living Pennatulidae arise in close proximity to the middle portion of the rhachis, leaving between them a groove ("ventral track") instead of a median field ("dorsal track"). In other specimens the ventral and dorsal aspects are superimposed.

The relationship of *Pteridinium* and *Rangea* suggests that *Pteridinium* also belongs to the Pennatulacea rather than the Gorgonacea. This seems more satisfactory but a re-interpretation of *Pteridinium* will be possible only after re-examination of the South African material.

Rangea? sp.

Plate xlv, fig. 2

A very striking but unique specimen is here tentatively assigned to the genus *Rangea*. It is 70-75 mm. wide, with partially well marked lateral margins, but its distal and proximal portions are broken off. The fragment is 16 cm. long. It shows a median zig-zag line from which branches arise at angles of only 30-40°. These branches are separated by distinct sub-parallel furrows which are 16-20 mm. distant from each other. There are also secondary furrows about 5 mm. apart, diverging from the primary furrows at right angles and almost but not quite crossing from one to the next. A relationship with *Rangea* is suggested by its similarity with *R. arborea* in the presence of primary and secondary furrows on a leaf-shaped body and with its suggested ventral aspect in the development of a median zig-zag line. Differences are seen in the strong, widely spaced primary and secondary furrows and in the sharply defined straight outer margin. The secondary furrows do not seem to be confined to the proximal margins of the lateral branches if these are taken to diverge distally as in *R. arborea*. In the absence of the peduncle

the orientation of this unique fragment is still uncertain and the discovery of further specimens will have to be awaited before it is fully described. (See Addenda, pp. 396-397.)

Spriggia Southcott

Madigania Sprigg, 1949, Trans. Roy. Soc. S. Aust., 73, p. 93.
(*Madigania* nom. preocc., non *Madigania* Whitley 1945).

Madigania Harrington and Moore, 1956, Treatise Inv. Paleont., p. F154.

Spriggia Southcott, 1958, S. Aust. Naturalist, 32, p. 59.

This monotypic genus (type species *Madigania annulata* Sprigg, Holotype No. T 2031) differs from *Cyclomedusa* in the complete absence of radial ornamentation at least from the inner portions of the discs. More than 15 specimens are known at present. Harrington and Moore (1956) listed this fossil as "medusae incertae sedis".

Spriggina Glaessner

Spriggina Glaessner, 1958, Trans. Roy. Soc. S. Aust., 81, p. 158.

Spriggina, Glaessner, 1959, Geol. Rundschau, 47.

Since this fossil was first described, four additional specimens were found which do not contribute anything new to the knowledge of its characters. This is at present one of the rarest of the identifiable fossils from Ediacara. All specimens clearly belong to the type species, *S. floundersi* Glaessner (Holotype No. P 12771, pl. xlvii, fig. 1). One of the additional specimens is 24 mm. long and about 9 mm. wide, apparently complete with about 23 segments. The other (pl. xlvii, fig. 3) is 37 mm. long and about 11 mm. wide, incomplete, with about 29 segments preserved and the tail end broken off. The third specimen is 15 mm. long and 5.5 mm. wide. The fourth is very small and indistinct.

Tateana Sprigg

Tateana Sprigg, 1949, Trans. Roy. Soc. S. Aust., 73, p. 86.

Ediacaria (part) Harrington and Moore, 1956, Treatise Inv. Paleont., p. F74.

As stated above, this genus which was based on the type species *T. inflata* Sprigg (Holotype No. 2017, hypotype No. 2018) is not considered distinguishable from *Cyclomedusa*. It may be specifically identical with *C. radiata*.

Tibrachidium gen. nov.Type species: *T. heraldicum* sp. nov.

Characters as described for the type species.

Tibrachidium heraldicum sp. nov.

Plate xlvii, figs. 7, 8

Holotype No. P 12898.

Material: 23 specimens.

Description: All specimens are preserved as sub-circular impressions up to 26 mm. in diameter, with a sharply impressed outer rim and a distinctly sculptured surface. This sculpture consists of three hooked ridges of similar size and shape, radiating from the centre, and ending along the periphery in a fringe of tentacular projections. No such type of organisation has ever been observed in any known organism, and no specific descriptive terminology is available for it. Until more is known about this new organism, only general descriptive terms will be used, and they are not intended to carry any implications of homology. The basis of the following descriptions is not the fossil as it is observed but its artificially produced counterpart, all known specimens of the fossil being considered as external moulds. The reason for this interpretation is the observation that the marginal projections in the fossil merge with the matrix which rises steeply above them to the general level of the rock face, and that they end against a deeper depression away from the periphery. Reversal of the sculpture by casting shows the tentacular fringe arising from the outer slopes of three smoothly convex arms and ending as three-dimensional objects a little above the level of the surrounding rock. This seems a more likely interpretation of the original organic structure, and what follows is based upon it.

The centre of the structure is very slightly depressed but not sharply outlined, the inner ends of the three arms tapering slightly towards it. The arms then radiate, for a distance of about 5 mm. in the holotype, at equal angles. A convex, somewhat irregular area, here termed a *bullae*, is seen in each of the three interspaces, but these bullae do not rise to the level of the upper surface of the arms. The arms then turn at right angles, all in the same plane and in the same direction (dextrally in the artificial casts, sinistrally in all the natural specimens). Their distal portions are convexly curved so as to conform to the subcircular periphery of the structure. A peripheral tentacular fringe commences on the bend, extending to the tip of the

arm which is indistinct because of overlap by the beginning of the fringe of the next arm. The tentacles number about 18 on each arm; they extend from its flank to the periphery and their length decreases gradually towards the tip of the arm. They are generally slightly curved in the same direction as the arm and are not perfectly regularly arranged, some diverging more than others. They are not seen to branch or bifurcate. The coarse grain of the matrix obscures observation of their finer structure. In a few places suggestions of similar tentacular projections can be seen also on the inner sides of the arms, directed towards the bullae. These bullae lie within the curvature of the arms but each seems to be more closely joined to the radial portion of the arm next to that which curves around it. If that is correct then the bullae arise from the arms in a direction opposite to that of their hooked distal branches and about half-way between the centre and the angle. The periphery is sharp, surmounted by the blunt distal ends of the tentacles.

Remarks: This animal, though imperfectly known, is excluded from all known major groups by its three tentaculate arms. A superficial resemblance to certain echinoderms (Edrioasteroidea) which comes to mind must be discounted because of the complete absence of skeletal plates. That the body was soft and fleshy but tough can be concluded from the slight distortion of the outlines of the various specimens and of the tentacles in the fringes; but the arms must have been rigid lophophores as their position never varies. These fossils are sufficiently numerous to make it clear that the characters described above are of taxonomic value and not accidental features. The mouth was not in the centre, its position remains unknown. The organism could be considered an aberrant coelenterate, or else remotely related to one of the other groups of tentaculate invertebrates; but tri-radial symmetry of structures supporting tentacles which is obvious in the present fossil is otherwise unknown.

A number of undescribed fossils from Ediacara correspond in size and outline with this new form. They are flatly conical impressions, with indistinct, broad, radial ridges and furrows. About 8 of these impressions have been collected. The possibility of considering them as casts of the reverse side of *Tribrachidium* should be kept in mind though at present there is no evidence for such a supposition.

The specific name was chosen because of the striking similarity of the pattern of this fossil to the well-known heraldic design of three radially arranged arms or legs, as in the coat-of-arms of the Isle of Man.

Unidentified Fossils

In addition to the fossils listed or described in this catalogue there is a relatively small number of others. One group of these comprises bodily preserved animal remains which are represented by insufficient numbers of specimens. About 6 of them are similar in appearance and vaguely suggest affinities to Siphonophora (pl. xlvii, fig. 9). Being irregular in shape and different in details, probably as a result of compression in various directions, they cannot be satisfactorily described on the basis of the present material. Another group consists of traces of life activities such as tracks, trails or burrows. There are several types of casts which were probably produced by sediment-feeding worm-like organisms. They are remarkably rare in relation to the large number of other fossils in these beds. There are also problematical flat casts in the shape of what appears to be a flat spiral, vaguely resembling a distorted and flattened string of beads. There is no evidence of actual coiling and no proof of their organic origin (see p. 395).

2. CONDITIONS OF PRESERVATION

The study of the preservation of these remarkable fossils is essential, firstly, for the full understanding of their morphology and taxonomic characters, and secondly, for the reconstruction of the environment in which the animals lived and became entombed.

All fossils are seen as elevated or depressed areas on bedding planes of the quartzite. According to Sprigg (1949, p. 215) they occur "always on the upper surface of these slabs". Mincham (1958, p. 217) has observed that they "appear mostly, if not entirely, on the lower surface of each stratum". Some confusion is likely to have resulted from the fact that it is easier to find the fossils on loose blocks which cover the hillsides below the outcrops, than on outcropping rock slabs *in situ*, and that on loose blocks they are more easily seen on the rain-washed upturned than on the soil-covered lower surfaces. Thus it is easy for the collector to gain the impression conveyed by Sprigg, yet special studies in the field have shown that the fossils are almost, though not entirely, confined to the lower surfaces of the quartzite slabs. In fact, the favoured technique in recent collecting consists in the wholesale upturning of slabs jutting out of hillside outcrops in the hope that the rain (amounting only to a few inches a year) will wash away the soil and decomposed rock with which the lower surfaces are almost invariably clogged, and so expose the fossils.

A search was made for counterparts which should appear on the opposing upper surfaces. As a rule, upper surfaces show nothing at all. There is only one known exception. Dr. B. Daily has photographed a medusa-like fossil appearing as usual as a convexity on the lower surface of a large slab, together with its concave counterpart on the opposing upper surface of the bed below. He has also collected a sequence of three adjoining layers of quartzite (No. P 12900 A, B, C) from an outcrop. The bottom of the top layer (A) shows a *Dickinsonia* and medusae. The top of the middle layer (B) contains no counterparts. Its bottom shows a *Tribrachidium*. There is again no counterpart of this on the opposing top of the lower layer (C), while its bottom contains *Cyclomedusa*. Loose slabs cannot be reliably orientated as they represent usually single or incomplete sets of cross laminae. Yet for some specimens in the collection orientation is suggested by observed textural features and this makes it probable that at least one specimen of *Dickinsonia* (Adelaide University coll. No. T65-2024) is preserved on the strongly ripple-marked upper surface, while tubular worm casts project from and along what appears to be the lower surface. Three specimens collected by H. Mincham and B. Flounders are very unusual in appearance and seem to have come from the same bed. They are covered with long, narrow, leaf-like specimens of *Rangia*. One slab, No. P 12716, shows on the opposite face an impression of *Tribrachidium heraldicum* in the usual preservation. This appears to be the lower surface. These are the only specimens with fossils both on the upper and on the lower surface of a single slab. The extreme rarity of fossils on upper surfaces, and of counterparts, can be explained with a high degree of probability by the embedding of the organisms in thin layers and films of clay and the subsequent casting of either the organic bodies or their impressions by the overlying sand. The thin clay layers which are responsible for the flagginess are destroyed by the weathering which separates the flags or slabs from each other. Traces of very thin clay lenses are seen on fresh vertical fractures of some quartzite beds but the rock is so strongly welded around them by silicification that it has not yet been possible to obtain fossils by splitting along such lenses. Fossils can be found *in situ* by opening up flags in outcrop and removing the weathered material separating them, but some weathering has so far proved essential for the discovery of fossils. The same conditions were reported to exist in the fossiliferous Kuibis quartzite in Southwest Africa (Richter 1955).

The distribution of fossils throughout the thickness and outcrop area of the fossiliferous strata seems to be essentially random, and the more frequent species are found frequently associated on single slabs in considerable numbers. Parallel orientation, presumably by currents, has been found on one or two slabs containing elongate types of *Rangia*. Most other forms which are rounded in outline, do not show orientation or accumulation by transporting forces though some of them occur in groups. There is no evidence of fossils or bedding laminae being distorted by scavengers and nothing points to functional interrelations of the various types of organisms.

Sprigg has observed and discussed the important fact that all fossils represent soft-bodied organisms. This has been fully confirmed by later collecting. In addition to the evidence of the medusae, there is the distortion and folding over, before or during embedding, of specimens of *Parvancorina*, *Dickinsonia* and *Rangia*, proving that their tissues were soft. The outlines of the medusae and of *Tribrachidium* vary slightly and specimens of *Spriggina* show sigmoidal curvature. There is no evidence of hard parts other than impressions of spicules in *Rangia*.

The orientation of the organisms relative to the bedding planes during burial still presents difficulties of interpretation as they are practically all new so that their appearance and orientation in life are unknown. All *Parvancorina*, *Tribrachidium* and *Spriggina* (in this instance judging from the head which must have been convex) are preserved as impressions or "negatives". *Beltanella*, all or most *Cyclomedusa*, *Spriggia*, and "*Protolyella*" are preserved as flat or high (*Beltanella*) convexities on the lower surfaces of the beds. Cross sections through some medusoid fossils show evidence of considerable compaction and of even greater original convexity. This creates some difficulty in the comparison with recent medusae which are mostly found stranded in convex-upward position (Schäfer 1941). Further studies of these convex-downward genera and also of *Pseudorhizotomites* which differs from them in preservation are required. The genera preserved as "negatives" appear to be external moulds of actual individuals embedded in clay partings which have vanished, while *Rangia* seems to represent casts of impressions made by individuals in different positions.

The preservation of *Dickinsonia* has yet to be studied, but at least some specimens are clearly impressions on the lower surfaces of the beds and are therefore to be interpreted as external moulds.

3. CONCLUSIONS

a. Composition of the fauna

The Ediacara fauna can no longer be considered as consisting almost exclusively of medusa-like fossils, though these constitute the majority of specimens collected. The following seven genera can be recognized:—

Pseudorhizostomites Sprigg

Beltanella Sprigg

Ediacaria Sprigg

Protodipleurosoma Sprigg

Cyclomedusa Sprigg

?*Protolyella* Torrell

Spriggia Southcott

Much detailed and comparative work remains to be done on the hundreds of medusoid specimens which are available. The latest published taxonomic revision (Harrington and Moore, 1956) places the first of these genera in the Scyphomedusae, the second and third in the Trachymedusae (Trachylinida), the fourth in the Leptomedusae (Calypptoblastina), and lists the representatives of the remaining three as "Medusae incertae sedis". These assignments and the underlying morphological interpretations are subject to further revision in the light of the abundant new material.

The Phylum Coelenterata is represented in the fauna not only by possible Scyphozoa and Hydrozoa but also possibly by Siphonophora and by Anthozoa Octocorallia. The genera

Rangea Gürich and

Pteridinium Gürich

have been recognized and placed in the Order Pennatulacea. The first of these is a common element of the fauna.

The Phylum Annelida is represented by

Spriggina Glaessner

which resembles the living Tomopteridae. This Phylum could also include the common genus

Dickinsonia Sprigg,

of which abundant material has yet to be examined. Life activities of annelid (and possibly other) worms are represented by tracks and burrows which, however, are not very common.

Two entirely new types of invertebrates complete the fauna as it is known at present. They have been described as new genera

Parvancorina Glaessner and

Tribrachidium Glaessner,

each represented by a single new species.

b. Ecology

The fauna is marine and consists of pelagic and benthonic elements. Sprigg has discussed the fossils which were known to him with reference to living medusae and their pelagic mode of life. Little can be added to the discussion of this part of the fauna at the present stage of the investigations. We know now more about the conditions of embedding and preservation of soft-bodied animals (Schäfer 1941). The preferred orientation of the medusa-like fossils in a convex-downward position is puzzling and requires explanation. A prominent benthonic element in the fauna are the sessile Pennatulacea. Their living representatives occur in upright position in varying depths of water, with the peduncles buried in sandy sediment. They lived probably not far from their place of burial. There is evidence of worms burrowing in the sandy sediment. *Spriggina* could have lived either on the sea floor or in the water above it. The mode of life of *Parvancorina* and *Tribrachidium* is unknown. Representatives of these three genera were trapped on muddy ground, probably by receding water. That the sedimentary environment was a very unstable one is proved by the ubiquitous cross-bedding and ripple marking of the fossiliferous strata and by slump rolls and mud pellets. The nature and direction of the currents remains to be established by modern methods of analysis of cross-bedding. Sandstone casts of mud surfaces with drying cracks have been found and drying cracks on ripple-marked surfaces ("*Manchuriophycus*", see Häntzschel 1949) also occur. These occurrences prove that the water was shallow enough to make occasional emergence of newly deposited sediment possible. Some of the soft-bodied animals could have been preserved by desiccation, and in this sense Sprigg was justified in visualizing the area as one of "fossil beaches". If the problematic markings (pl. xlv, fig. 3) are in fact identical with the foam impressions described by Häntzschel and Richter (1954) which they resemble more than any known traces of organic activities, they would support the available evidence of emergence and drying of bedding planes.

c. Biostratigraphic relations

Sprigg (1947, 1949) had considered the age of the Ediacara fauna as Lower Cambrian, at a time when the place of the previously discovered Cambrian fossils in the general time-stratigraphy of that System was unknown and when the Pound Quartzite was thought to represent the Lower Cambrian. Daily (1956) has since placed the overlying *Archaeocyatha* limestones in the lower part of the Lower Cambrian. The occurrence of a rich new fauna without any known Lower Cambrian elements below these limestones is a valid reason for placing the Pound Quartzite at the top of the Precambrian and for considering its age as Late Proterozoic. Sedimentation was regionally continuous from Precambrian to Cambrian and has produced again and again through long spans of time similar rock types, so that there is little difference between the Marinoan and the Lower Cambrian dolomites, or the quartzites in the lower part of the Marinoan, the Pound and the Lower to Middle Cambrian. As in the time stratigraphy of later geological periods, only biostratigraphic observations can determine the position of the base of the Cambrian. Below that horizon only absolute measurements of geological time can be used, with the exception of the possible time significance of the Proterozoic ice ages—and of the Late Proterozoic fauna.

With the recognition of elements of the fauna of the Kuibis quartzite of the Nama System in the Ediacara fauna, this stands no longer alone and the way to its use in inter-regional correlation is opened. The occurrence of *Rangia* in the Ediacara fauna, together with *Pteridinium* and medusoid fossils which are at least similar to *Paramedusium africanum* Gürich is a strong argument in favour of placing the fossiliferous part of the Nama in the Late Precambrian. Medusoid fossils have been reported from the Late Proterozoic of other parts of Australia and from the Algonkian Nankowep Group of the Grand Canyon of Arizona. Detailed comparisons of these fossils and further collecting in Late Precambrian fossiliferous strata should be stimulated, because of not only their palaeozoological but also their biostratigraphic interest, by the discovery of a rich and varied Late Proterozoic fauna in South Australia.

ADDENDA

While this paper was in press, several publications were received to which reference should be made. Their titles have been incorporated in the list of references below but no alterations have been made in the text above.

Ford (1958) described Precambrian fossils from Charnwood Forest in Leicestershire, England, as *Charnia masoni* Ford and *Charniodiscus concentricus* Ford. The first name refers to frond-like bodies about 10-25 cm. long and up to 4.5 cm. wide, consisting of oblique lobes which meet alternately at a sinuous median groove. Each of these lobes is divided by secondary furrows, at right angles to the lateral furrows, into about 13 secondary "segments". The structure is almost identical with that described here (p. 387, pl. xlv, fig. 2) as *Rangia*? sp. This fossil which is about twice as large as the Charnian type specimen should now be known as *Charnia* sp., as it is closer in structure to this genus than to *Rangia*. Specific identification must await the discovery of other, more complete specimens at Ediacara.

The occurrence of *Charnia* among the Late Precambrian fossils of South Australia raises further points concerning the nature of these fossils, in addition to its obvious bio-stratigraphic interest. The English fossils end proximally in "blunt stalks" which are 2 cm. wide. This confirms the view that *Charnia* and *Rangia* represent similar organisms; what has been demonstrated concerning the Pennatulacean affinities of *Rangia* should apply to *Charnia*. Ford (1958, p. 214 f.) states that *Charnia* resembles *Rangia schneiderhöhni* Gürich and rightly rejects the view that these fossils are Ctenophora or Gorgonaria. His conclusion, however, is that "*Charnia masoni* may most rationally be interpreted as an algal frond". He suggests that *Charniodiscus concentricus* Ford ("a disc-like organism 5-30 cm. in diameter with a rough-surfaced central area surrounded by a smooth flange which may or may not bear concentric corrugations") may be the basal part of the same alga. "In one case only are frond and disc apparently associated". "If *Charniodiscus* were considered alone, it could be compared favourably with one or the other of the various forms of medusae such as those in the Lower Cambrian of Australia". This is of extraordinary interest, as the possibility of some medusoid fossils from Ediacara being the bases of the stalks of *Rangia* had been considered but put aside for lack of decisive evidence. Stalk-like projections from the centres of medusoid fossils have been observed but none of them shows a *Rangia* or *Charnia*-frond at the other end. A further search for such specimens will be made in the field. Ford's statement concerning the affinities of his fossils concludes: "The only likely alternative is that they represent a primitive coelenterate of unknown affinities". The new material of *Rangia* suggests that this alternative view is preferable, and that

these Precambrian Coelenterates were closely related to the Pennatulacea.

The stratigraphic range of this group seems to have been extended to the Lower Palaeozoic by the discovery of a *Pennatula*-like stalked frond about 12cm. long and less than 2 cm. wide, which was very briefly described by Tremblay (1941) from a coarse sandstone lithologically resembling the Upper Cambrian Potsdam sandstone, but found at a locality 90 miles down the St. Lawrence from Ottawa, where the geological map of Canada shows only Ordovician. Häntzschel (1958) has recently reviewed doubtful fossil Octocorallia and prefers to consider most of them as tracks of unknown animals. He admits, however, that Tremblay's fossil, though not definitely assignable, is comparable with Pennatulacea.

Finally, curious projections on lower surfaces of sandstone beds of Early Palaeozoic age have been described by Howell and Hutchinson (1958) from Washington and referred to *Bergaueria* Prantl, originally described from the Ordovician. Prantl thought them to be infillings of cavities occupied by Ceriantharia-like coelenterates and Howell and Hutchinson conclude that their fossils may have held the stalks of pennatulid-like animals.

EXPLANATION OF PLATES

PLATE XLII

- Fig. 1. View of Mount James. Looking north across the outcrop of massive quartzite and the underlying fossiliferous strata, from just below the base of the Cambrian, about one mile north of the Ediacara fossil reserve. Photo. M.F.G.
- Fig. 2. Outcrop of fossiliferous strata below top of Pound Quartzite, about one mile south of Gap Creek. Photo. B.D.
- Fig. 3. Outcrop of fossiliferous strata below top of Pound Quartzite, near locality of Fig. 2. Photo. M.F.G. Length of scale 9in.

PLATE XLIII

- Figs. 1-4. *Rangia arborea* nov. sp. Fig. 1. Holotype. Large specimen on weathered surface. Note distinct left lateral margin and secondary furrows mainly on right lateral branches. No. P 12891. Fig. 2 Specimen with distinct lateral margins, median field and lateral furrows. No. P 12890. Fig. 3 Specimen with zig-zag trace of median field, with "spicular" structure (compare with Pl. XLV, Fig. 2). No. P 12892. Fig. 4. Fragmentary specimen, with traces of secondary furrows on lower margins of lower left lateral branches. No. P 12896.
- Fig. 5. *Rangia schneiderhöhni* Gürich. Photograph of latex mould of holotype, forwarded by Dr. W. Häntzschel, Geol. Staatsinstitut, Hamburg, Germany.
Scale in centimetres.

PLATE XLIV

- Figs. 1-3. *Rangia arborea* nov. sp. Fig. 1. Specimen with long peduncle, on ripple-marked, eroded surface. The main body with its median field, lateral branches and secondary furrows is seen above a medusoid fossil, probably *Protolyella? mawsoni* (Sprigg). No.

P 12888. Fig. 2. Specimen showing "spicular" structure of median field, and lateral margins, partly folded over on left. Natural size. No. T 94-2015. Fig. 3. Specimen showing "spicular" structure of median field and lateral branches. $\times 0.9$. No. T 93-2016. Photographs 2 and 3 by Mr. K. P. Phillips.

PLATE XLV

- Figs. 1-2. *Rangia arborea* nov. sp. Fig. 1. Several individuals, partially overlapping, showing "dorsal" and "ventral" aspects, preserved on upper surface of bed. No. P 12716. Fig. 2. Fragmentary specimen (upper right), preservation intermediate between Pl. XLIII, figs. 2 and 3. Below are two unidentified medusoid fossils. No. P, 12895.
- Fig. 3. Unidentified casts. No. P 12893.

PLATE XLVI

- Fig. 1. *Rangia arborea* nov. sp. "Ventral" aspect. Compare with Pl. XLIII fig. 3. $4/3$ natural size (length of scale 1 cm.). No. P 12894.
- Fig. 2. *Rangia?* sp. Specimen with straight lateral margins and median zig-zag groove. Natural size. No. P 12897.
- Figs. 3-4. *Pteridium* sp. Two specimens from one slab, poorly preserved. Natural size. No. P 12744.

PLATE XLVII

- Figs. 1-4 *Spriggina floundersi* Glaessner. Fig. 1. Holotype, $5/4$ natural size. No. P 12771. Fig. 2. Paratype, $5/4$ natural size. No. P 12772. Fig. 3. Specimen No. P 12899, $4/3$ natural size. Fig. 4. Median portion of specimen No. 12772 enlarged to show acicular setae, attached to parapodia. $\times 2.4$.
- Figs. 5-6 *Parvancorina minchami* Glaessner. Two specimens showing oblique traces of possible appendages on the lateral areas. The apparent "tail" of fig. 6 appears to be due to fortuitous grooving of the bedding plane. Fig 5. $\times 1.2$, No. P 12901. Fig. 6 natural size, No. P 12887.
- Figs. 7-8. *Tribrachidium heraldicum* nov. gen., nov. sp. Fig. 7. Holotype, natural size, No. P 12898. Fig. 8. Paratype, natural size, No. P 12889.
- Fig. 9. Problematic fossil, possibly belonging to the Siphonophora. $4/3$ natural size, No. P 12734.

Specimens represented by figs. 1-8 are preserved as concave impressions but lighting chosen for clarity may give the appearance of reversed sculpture.

Photographs of figs. 4-7 and 9 by Mr. B. Flounders.

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