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Early Permian Brachiopoda from Irian Jaya

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A new Early Permian (Aktastinian–early Baigendzhinian, early Artinskian) brachiopod fauna is described from the Aiduna Formation, which crops out in the upper reaches of the Mapia River, southern Irian Jaya. New taxa are *Neochonetes (Sommeriella) irianensis* sp. nov., *Chonetinella aidunaensis* sp. nov., *Sulcataria skwarkoi* sp. nov., and *Aulosteges tenuispinosus* sp. nov. Although material is fragmentary, the new fauna demonstrates significant links with Early Permian faunas of Western Australia and peninsula Thailand. The Carboniferous–Permian brachiopod biostratigraphy of Irian Jaya is reviewed, and known faunas are shown to range in age from probable Namurian to early Kungurian.

Introduction

The Irian Jaya Geological Mapping Project (IJGMP), for which fieldwork was carried out jointly by BMR and the Indonesian Geological Research and Development Centre between 1978 and 1981, yielded substantial new information on the late Palaeozoic geology of Irian Jaya. Work before the project started was summarised by Visser & Hermes (1962), who provided details of all previous palaeontological determinations from Palaeozoic rocks in Irian Jaya. Despite this earlier work, little precise information was available for the late Palaeozoic succession; ages assigned were invariably referred to the 'Permo-Carboniferous'.

New palaeontological data from the late Palaeozoic succession have been published for a number of groups: plants (Prasad, 1981), bivalves and gastropods (Dickins & Skwarko, 1981), brachiopods (Archbold, 1981a, 1981b, 1991; Archbold & others, 1982), a trilobite (Archbold, 1981c), cephalopods (Glenister & others, 1983), and bryozoans (Wass, 1989). Data on a new, moderately diverse Early Permian brachiopod fauna from the Aiduna Formation are presented herein.

Stratigraphy, locality, and preservation

The stratigraphy of western Irian Jaya is reviewed by Pieters & others (1983). In the northwest (Birds Head), a Late Carboniferous–Permian sequence constitutes the Aifam Group. This unit, from which previous brachiopod faunas have been described, is divided into three formations: Aimau Formation (oldest), Aifat Mudstone, and Ainim Formation.

Farther east, partly contemporaneous rocks make up the Aiduna Formation. Though Pieters & others (1983) included this unit in the Aifam Group, more recent work has suggested that it be excluded (Pigram & Panggabean, 1989). The Aiduna Formation consists of well bedded feldspathic and micaceous lithic sandstones interbedded with carbonaceous shale and siltstone.

The new material described herein is from a float boulder from locality 80D245, which is described as the upper reaches of the Mapia River on the southern flank of the Charles Louis Mountains of the western central ranges, north-central part of the Waghete 1:250 000 Sheet area (Fig. 1). This is the first assemblage to be described from the Aiduna Formation.

The fossils are preserved generally as natural internal and external moulds, although a few specimens have shell material remaining. These few specimens responded well to acid leaching, and very fine detail is preserved on the resultant moulds. Larger specimens are invariably incomplete, whereas smaller specimens are commonly complete.

Age of assemblage

Determination of the age of the assemblage must be regarded as provisional, because many of the species are inadequately known (and left in open nomenclature). Nevertheless in view of the remoteness of the source region, it is unlikely that further collections will be forthcoming in the forseeable future. As discussed in detail under the appropriate systematic descriptions, the assemblage demonstrates significant links with late Sakmarian (Sterlitamakian) and early Artinskian (Aktastinian to early Baigendzhinian) faunas of Western Australia and peninsula Thailand.

A maximum age for the fauna of Sterlitamakian can be assigned on the basis of links with Western Australian species of *Neochonetes (Sommeriella), Heteralosia*, and *Aulosteges*. However, these species also show links with younger faunas in Thailand and Western Australia respectively. *Echinalosia* is an early Baigendzhinian genus in Western Australia, whereas finely spinose *Stictozoster* may suggest a late Early Permian age. *Sulcataria* is a Late Carboniferous–Early Permian genus in North America, but appears to have a Late Permian distribution in the Himalayas. On balance, an Aktastinian–early Baigendzhinian (early Artinskian) age is favoured for the assemblage.

Biostratigraphy of the Aiduna Formation and Aifam Group

The new assemblage adds to the knowledge of the biostratigraphy of the late Palaeozoic of Irian Jaya by providing data on an early Artinskian fauna. As with other recent data on the late Palaeozoic succession, fossils come from isolated localities within broadly defined sections. Nevertheless, four brachiopod faunal horizons appear to be recognisable within these correlative sections to date, as briefly summarised below.

- ***Syringothyris irianensis* Zone**. This assemblage zone from float material, apparently from the Aimau Formation, represents the oldest yet discovered, and includes *Syringothyris irianensis* Archbold, *Derbyia*? sp., *Beecheria*? sp., and poorly known aulostegid and spiriferinid material. A Namurian age was favoured for the assemblage by Archbold (1991).

- ***Taeniothaerus aifamensis* Zone.** This poorly known assemblage from low in the Aifat Mudstone includes only the species *Taeniothaerus aifamensis* Archbold and undescribed

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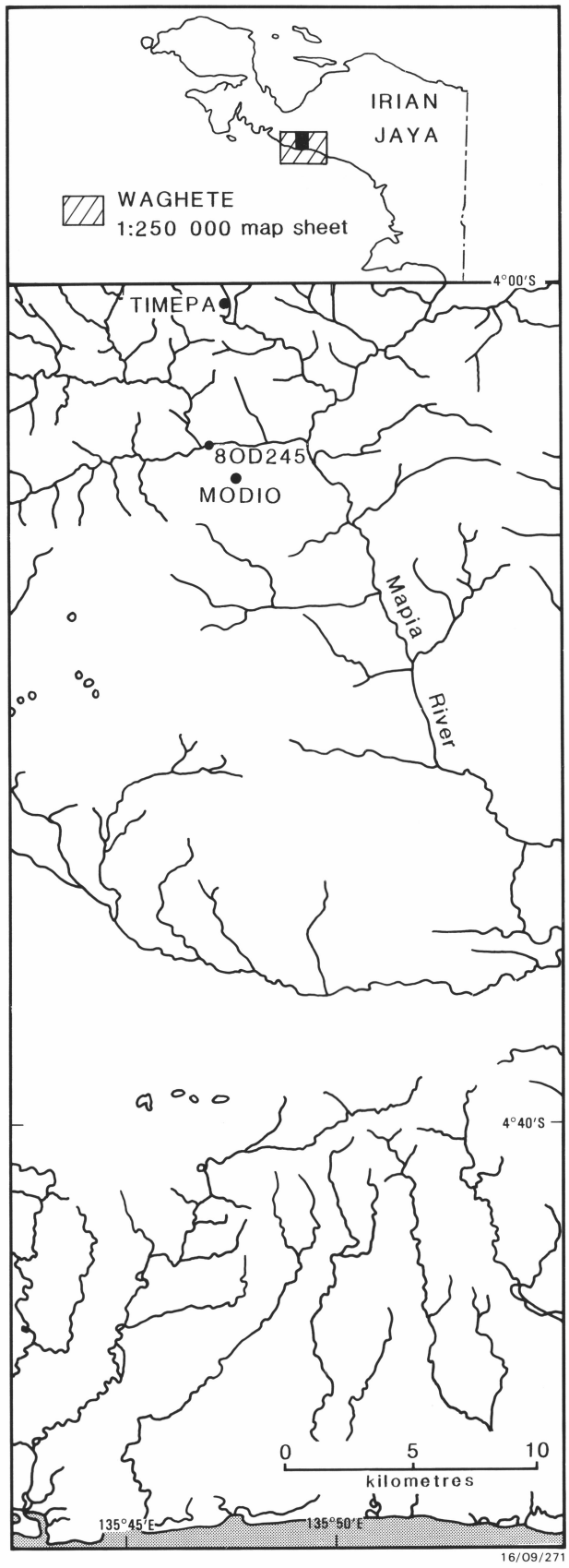

Figure 1. Locality map of fossil site 80D245.

pectinacean bivalves. The similarity of this species to forms in comparable faunas of Kashmir and the Pamirs suggested a Sterlitamakian age to Archbold (1991).

- ***Neochonetes (Sommeriella) irianensis* Zone.** This zone is represented by the assemblage described herein, for which an early Artinskian (Aktastinian–early Baigendzhinian) age is preferred.

- ***Stereochia irianensis* Zone.** This assemblage zone, also from the Aifat Mudstone but from a level higher than the *Taeniothaerus aifamensis* Zone, is represented by the youngest fauna described to date. The assemblage, described by Archbold (1981a, b), shows significant links with the brachiopod fauna from the Rat Buri Limestone, peninsula Thailand (Waterhouse & Piyasin, 1970; Grant, 1976). It includes *Streptorhynchus* sp., *Rhipidomella* sp., *Chonetinella? ainimi* Archbold, *Stictozoster* cf. *leptus* Grant, *Stereochia irianensis* Archbold, *Linoproductus pigrami* Archbold, *Cancrinella* sp., *Stenoscisma ratmani* Archbold, *Stenoscisma* cf. *tetricum* Grant, *Cruricella*? sp., *Callispirina* sp., *Spiriferellina* sp., *Hustedia* cf. *ratburiensis* Waterhouse & Piyasin, *Cleiothyridina* sp., and, at a different locality, *Quinquenella magnifica* Archbold. On the basis of similarities with Thai and Western Australian faunas, a late or latest Baigendzhinian–early Kungurian age was favoured for the assemblage (Archbold, 1981a).

Palaeogeographical importance of Permian faunas of Irian Jaya

The Permian faunas of Irian Jaya occupy a pivotal palaeogeographical position between the Gondwanan, intracratonic faunas of Western Australia and the Shan–Thai (or Sibumasu) terrane faunas of peninsula Thailand. The late Early Permian *Stereochia irianensis* assemblage was shown to possess strong links with Thai faunas (Archbold, 1981a; Archbold & others, 1982) and yet retain links with Western Australian faunas. The somewhat older *Neochonetes (Sommeriella) irianensis* assemblage, described herein, demonstrates a rather stronger Western Australian element, but still shows links with Thai faunas (and has distinctive components, such as *Sulcataria*, not known elsewhere in the Western Australian and Shan–Thai region).

Faunal relationships point to close palaeogeographical links between Western Australia, Irian Jaya, and peninsula Thailand during the Early Permian. The growing body of data on such links indicates that the concept of a Permian Tethys Ocean appears to be unrealistic, and that detailed continued unravelling of Asian geology is required in order to understand the timing of tectonic events in the region. Recent reviews of the role of palaeontological data for providing critical constraints on such tectonic models include those of Archbold (1987), Shi & Waterhouse (1990), and Bambach (1990).

Systematic palaeontology

All specimens are housed in the Indonesian Macropalaeontological Collections (IMC prefix), Geological Research and Development Centre, Bandung, Indonesia. All specimens were coated with ammonium chloride for the illustrations.

Order **Chonetida** Nalivkin, 1979
Suborder **Chonetidina** Muir–Wood, 1955
Superfamily **Chonetacea** Bronn, 1862
Family **Rugosochonetidae** Muir–Wood, 1962
Subfamily **Rugosochonetinae** Muir–Wood, 1962
Genus ***Neochonetes*** Muir–Wood, 1962

Type species. *Chonetes dominus* King, 1938.

Diagnosis. The diagnosis provided by Archbold (1981d, p. 113) is followed herein. Possible subgeneric groupings of species of *Neochonetes* are discussed in the same work, and the new species described here appears to fall within the subgenus *Sommeriella* Archbold (1982a; = *Sommeria* Archbold 1981d).

Subgenus ***Sommeriella*** Archbold, 1982a

Type species. *Chonetes prattii* Davidson, 1859.

Diagnosis. *Neochonetes* species, normally with distinct sulcus, often with gentle fold in dorsal valve, hinge spines at 40–45°, and maximum width of mature shells anterior of the hinge. Interior typical for genus.

Neochonetes (Sommeriella) irianensis sp. nov.
Fig. 2A–S

Holotype. IMF 101, a dorsal valve external mould.

Material. 1 dorsal valve external mould (IMF 101), 3 dorsal valve internal moulds (IMF 102–104), 6 ventral valve internal moulds (IMF 105–110), and 8 ventral valve external moulds (IMF 111–118).

Size ranges. Ventral valve maximum width, 6.2–18.5 mm; ventral valve height, 4.1–10.1 mm; dorsal valve maximum width, holotype only, 18.6 mm; dorsal valve height, holotype only, 9.3 mm.

Description. Ventral valve relatively weakly convex, sulcus distinct, of variable depth, broadens widely anteriorly, usually arises close to umbo. Dorsal valve gently concave with low median fold corresponding to ventral sulcus. Interareas very low. External ornament of both valves of fine capillae, which increase in number by bifurcation and intercalation. Growth lines at times distinct. Hinge spines distinct (4 per 5 mm on IMF 111).

Ventral median septum distinct, from less than 0.5 valve length up to 0.6 valve length, high posteriorly, arises close to umbo. Parallel vascular trunks distinct in mature specimens. Ventral muscle scars feebly impressed. Teeth small, sharp. Muscle field essentially smooth; remainder of shell interior papillose at submaturity.

Cardinal process poorly known, appears low. Dorsal median septum distinct, half of valve length, arises anteriorly of deep alveolus as do the short lateral septa. Sockets deep with distinct inner socket ridges and low outer socket ridges. Brachial ridges weakly developed. Interior of dorsal valve with papillae arranged in radial rows.

Discussion. The largest specimens of *N. (S.) irianensis* sp. nov. resemble some specimens of a suite of *N. (S.) prattii* from the Sterlitamakian Nura Nura Member of the Poole Sandstone in the Canning Basin, Western Australia (Archbold, 1981d, fig. 6A–T), in details of transverse shell shape, low convexity, and dorsal external appearance. The Nura Nura specimens are, however, larger than the new material, and possess deeply impressed internal features.

Despite its different generic assignment, some comparison of the new species is warranted with *Chonetinella andamanensis* Waterhouse (1981, pl. 2, figs. 18, 19; pl. 3, figs. 1–18) from the Aktastinian Kaeng Krachan Group of Thailand. *Neochonetes* and *Chonetinella* include species that approach each other in morphology, as discussed below. The Thai species is more alate than the new material, but external ornament and internal details are similar. *Chonetinella andamanensis* possesses a stronger development of the sulcus and fold and is more concavo-convex than the new species, but different generic names do imply greater differences than would be suggested by comparison of the two species.

Broili (1924, pl. 2, figs. 1–4) recorded a small *Neochonetes* from the Birds Head of Irian Jaya. This specimen is a distinct species with a gentle sulcus and distinctly concave dorsal valve.

Genus ***Chonetinella*** Ramsbottom, 1952

Type species. *Chonetes flemingii* Norwood & Pratten, 1855.

Diagnosis. Small, subquadrate rugosochonetinids with deep ventral sulcus and prominent dorsal fold. Costellae fine. Interior typical of subfamily.

Discussion. The limits of *Chonetinella* have been broadly interpreted by Grant (1976) and Waterhouse (1981), who included — within the genus — species that approach the morphology of *Neochonetes*. Both Archbold (1982b) and Afanasyeva (1988) stressed the rugosochonetinid affinities of the two genera, and permitted the Chonetinellinae of Muir–Wood (1962) to lapse. *Chonetinella* is interpreted herein, as in Archbold (1981a, 1981d), on the basis of the similarity of a species to the gross morphology and ornament of *Chonetinella flemingii* (Norwood & Pratten, 1855) as illustrated by Muir–Wood (1962, pl. 9, figs. 10–16).

Chonetinella aidunaensis sp. nov.
Fig. 3A–P

Holotype. A dorsal valve external mould (IMF 119).

Material. 2 dorsal valve external moulds (IMF 119–120), 6 dorsal valves internal moulds (IMF 121–126), 2 ventral valve external moulds (IMF 127–128), and 4 ventral valve internal moulds (IMF 129–132).

Size ranges. Ventral valve maximum width, 6.1–7.8 mm; ventral valve height, 4.3–6.1 mm; dorsal valve maximum width, 6.1–8.1 mm; dorsal valve height, 4.3–5.8 mm.

Description. Shell tending to subquadrate outline, maximum width at hinge line or mid-length of shell. Ventral valve strongly convex. Sulcus moderate to deep, broadens widely anteriorly. Dorsal valve strongly concave with prominent median fold corresponding to ventral sulcus. Interareas very low. Ornament of fine costellae, increasing in number by bifurcation. Growth lines indistinct. Hinge spines distinct, curved, emerge at high angle (50°+).

Ventral median septum short, posteriorly located, arises under umbo. Muscle scars indistinct, smooth; remainder of valve interior finely papillose. Teeth minute. Dorsal interior with short median septum, arises at variable distance anteriorly of prominent alveolus. Lateral septum poorly developed, short. Cardinal process poorly known but blunt. Sockets minute, inner socket ridges distinct. Brachial ridges moderately distinct at maturity. Valve interior papillose with papillae in radiating rows.

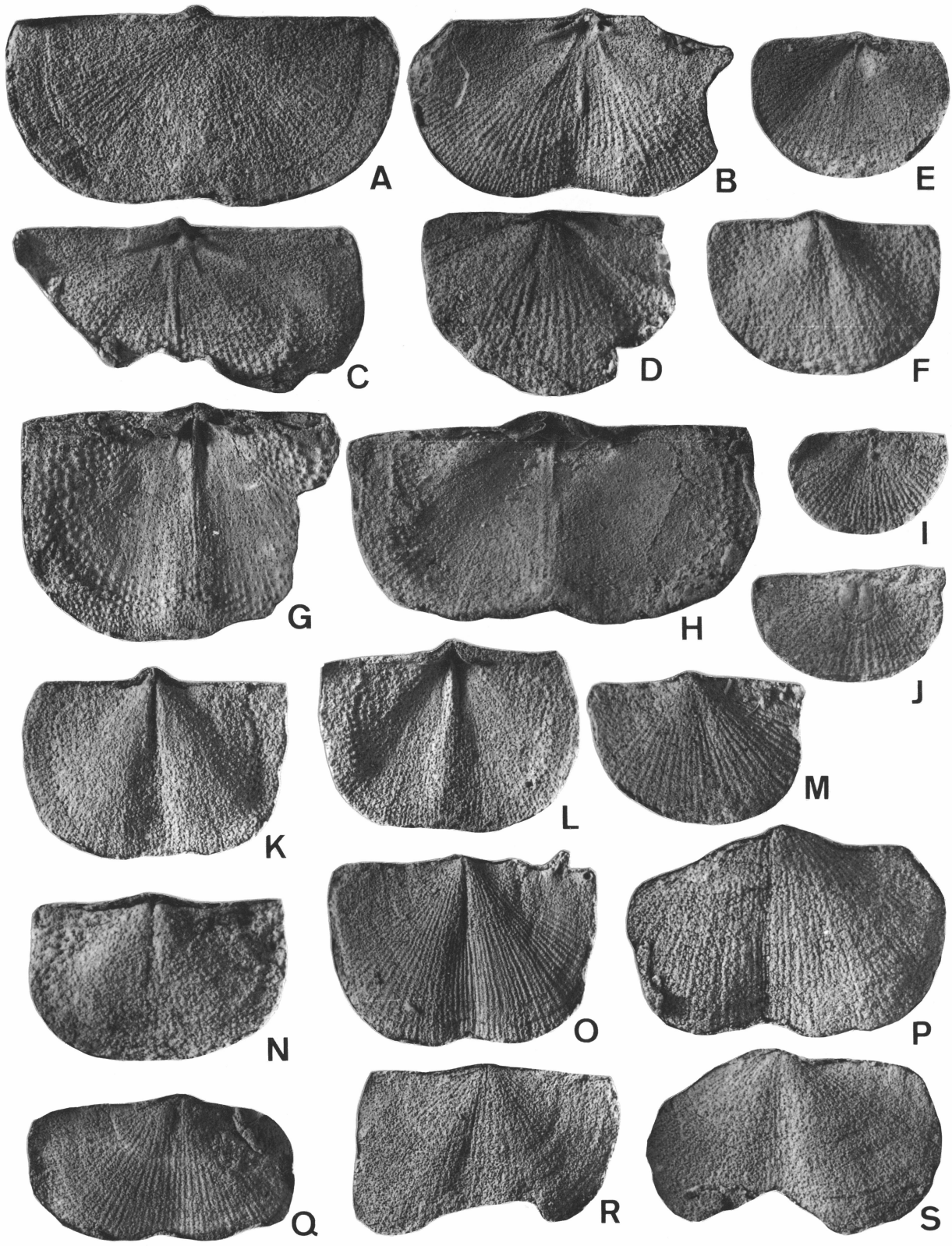

Figure 2. A—S, *Neochonetes (Sommeriella) irianensis* sp. nov.
A, holotype, IMF 101, latex cast of dorsal valve external mould, x 3.5. **B,** IMF 102, latex cast of dorsal valve internal mould, x 3.5. **C,** IMF 103, latex cast of dorsal valve internal mould, x 3.5. **D,** IMF 104, latex cast of dorsal valve internal mould, x 4. **E,** IMF 111, ventral valve external mould, x 4. **F,** IMF 105, ventral valve internal mould, x 4. **G,** IMF 106, latex cast of ventral valve internal mould, x 3.5. **H,** IMF 107, latex cast of ventral valve internal mould, x 3.5. **I,** IMF 112, ventral valve external mould, x 3.5. **J,** IMF 108, ventral valve internal mould, x 4.5. **K, L,** IMF 109, ventral valve internal mould and latex cast of mould, x 3.5. **M,** IMF 113, latex cast of ventral valve external mould, x 4.5. **N,** IMF 110, ventral valve internal mould, x 4.5. **O,** IMF 114, latex cast of ventral valve external mould, x 3.5. **P,** IMF 115, latex cast of ventral valve external mould, x 3.5. **Q,** IMF 116, latex cast of ventral valve external mould, x 3.5. **R,** IMF 117, latex cast of ventral valve external mould, x 3.5. **S,** IMF 118, latex cast of ventral valve external mould, x 3.5.

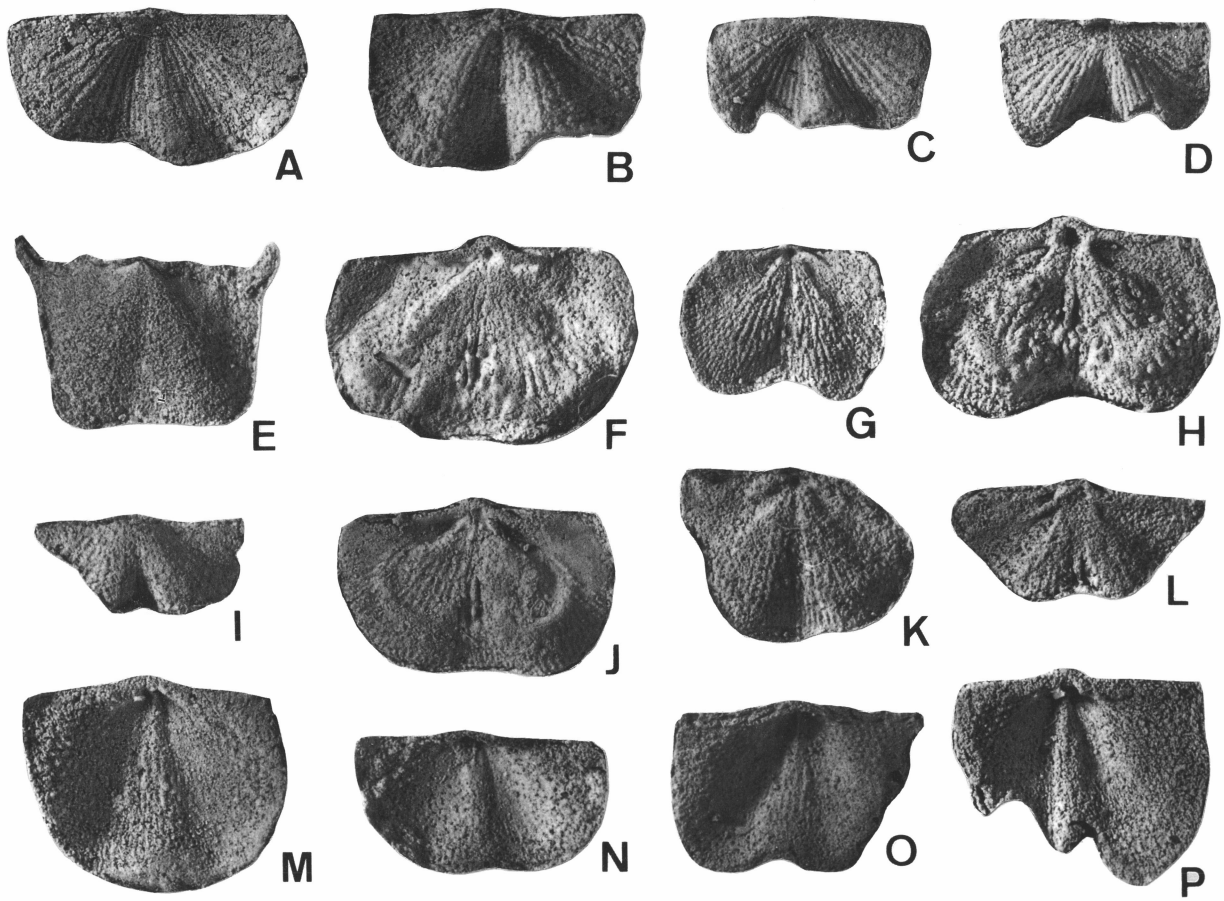

Figure 3. A–P, *Chonetinella aidunaensis* sp. nov.
A, B, holotype, IMF 119, latex cast of dorsal valve external mould and external mould, x 5. **C, D,** IMF 120, latex cast of dorsal valve external mould and external mould, x 5. **E,** IMF 127, latex cast of ventral valve external mould, x 5. **F,** IMF 121, latex cast of dorsal valve internal mould, x 5. **G,** IMF 122, latex cast of dorsal valve internal mould, x 4.5. **H,** IMF 123, latex cast of dorsal valve internal mould, x 4.5. **I,** IMF 128, latex cast of ventral valve external mould, x 5. **J,** IMF 124, latex cast of dorsal valve internal mould, x 4.5. **K,** IMF 125, latex cast of dorsal valve internal mould, x 5. **L,** IMF 126, latex cast of dorsal valve internal mould, x 5. **M,** IMF 129, latex cast of ventral valve internal mould, x 4.5. **N,** IMF 130, latex cast of ventral valve internal mould, x 4.5. **O,** IMF 131, latex cast of ventral valve internal mould, x 4.5. **P,** IMF 132, latex cast of ventral valve internal mould, x 4.5.

Discussion. The small size, subquadrate outline and pronounced concavo-convexity of the new species readily distinguish it from Early Permian species from Thailand described by Grant (1976) and Waterhouse (1981).

Chonetinella? ainimi Archbold (1981a, pl.1, figs. 5–9, 11–13) from the late Early Permian Aifat Mudstone, Irian Jaya, is a small species, less subquadrate and more deeply concavo-convex than the new species; perhaps the new species is ancestral.

The Kungurian *Chonetinella* sp. from the Coolkilya Sandstone, Carnarvon Basin, Western Australia (Archbold, 1981d, fig. 12D), has a similar outline to the new species, but is otherwise too poorly known for closer comparison.

Chonetinella aidunaensis sp. nov. has the general shell shape and internal details that resemble some species of the Late Permian genus *Waagenites* as described by Fang (1983) and Archbold (1988), but is distinguished from those species by its finer external ornament.

Subfamily **Svalbardiinae** Archbold, 1982b

Diagnosis. Externally smooth rugosochonetids. Small to medium size. Dorsal exterior pseudocapillate when worn. Hinge spines at low to moderate angle.

Discussion. The basis for the recognition of the Svalbardiinae was discussed by Archbold (1982b). Afanasyeva (1988), in a major review of the order Chonetida, suppressed the Svalbardiinae and included the name genus within her Chalimochonetinae. Even if her classification scheme is accepted, the Svalbardiinae has priority over the Chalimochonetinae.

Genus ***Sulcataria*** Cooper & Grant, 1969

Type species. *Chonetina? rostrata* Dunbar & Condra, 1932.

Diagnosis. Small, smooth rugosochonetid with ventral valve deeply sulcate, dorsal valve flatly concave with strong median fold. Deep antero-median trough in dorsal valve.

Discussion. The genus was fully discussed by Cooper & Grant (1969, p. 5; 1975, p. 1213). It resembles *Chonetinella* as defined herein, but is smooth. *Sulcataria* lacks the ears of *Dyoros* Stehli (1954), and is found in the Late Carboniferous and Early Permian of North America. The new species, *S. skwarkoi,* is referred to *Sulcataria*, even though — as presently understood — it lacks the well developed dorsal internal structures of the North American species of the genus.

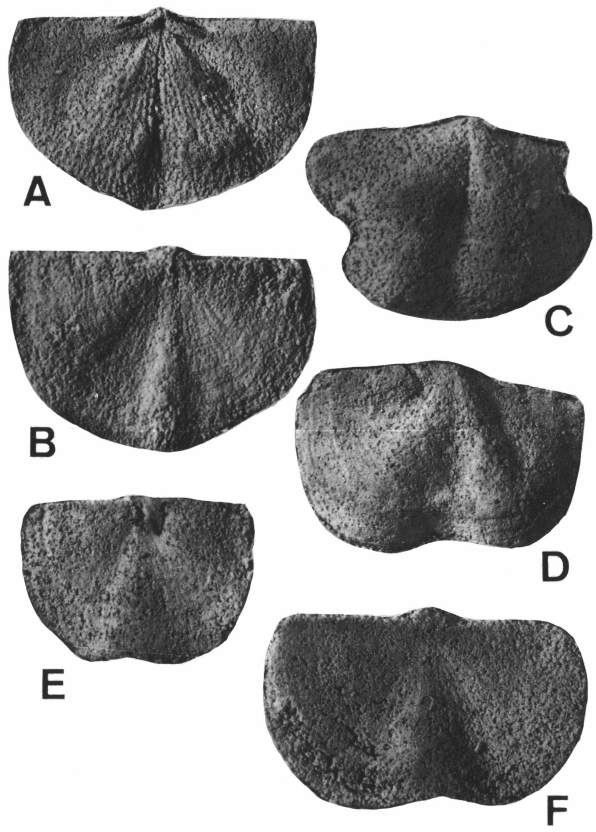

Figure 4. A–F, *Sulcataria skwarkoi* sp. nov.
A, B, holotype, IMF 133, latex cast of dorsal valve internal mould and dorsal valve exterior prior to acid leaching, x 5. **C,** IMF 134, latex cast of ventral valve external mould, x 5. **D,** IMF 135, latex cast of ventral valve external mould, x 5. **E,** IMF 136, latex cast of dorsal valve external mould, x 5. **F,** IMF 137, latex cast of dorsal valve external mould, x 5.

Sulcataria skwarkoi sp. nov.
Fig. 4A–F

Etymology. Named for Dr S.K. Skwarko, who collected many late Palaeozoic specimens of brachiopods during the IJGMP fieldwork.

Holotype. A dorsal valve internal mould, formed by leaching a preserved dorsal valve in rock (IMF 133).

Material. 2 ventral valve external moulds (IMF 134–135), 2 dorsal valve external moulds (IMF 136–137), and 1 dorsal valve internal mould, holotype (IMF 133).

Measurements. Holotype, IMF 133: maximum width, 8.4 mm; hinge width, 8.2 mm; height of valve, 5.5 mm. IMF 134 (ventral valve): maximum width, 8.5 mm; hinge width, 8.1 mm; height of valve, 5.7 mm.

Description. Shell outline subquadrate. Ventral valve strongly convex. Sulcus distinct, arises anteriorly of umbo and deepens markedly anteriorly of mid-length of valve. Dorsal valve flattish to gently concave with prominent dorsal fold. Interareas very low.

Exterior of valves smooth, traces of pseudocapillae on worn areas of dorsal valves adjacent to median fold. Growth lines visible on anterior of valve exteriors.

Ventral interior unknown. Dorsal interior with minute cardinal process. Dorsal median septum short, developed anteriorly of small deep alveolus, fills in the posterior section of the median trough of dorsal interior. Lateral septa short, low. Sockets distinct with pronounced inner socket ridges and small sharp outer socket ridges. Brachial ridges weakly developed, but on distinct raised region of valve interior. Papillae developed in radial rows on central anterior region of interior. Posterior lateral flanks of valve interior smooth. Pronounced, deep antero-median trough developed corresponding with dorsal fold anterior.

Discussion. Many of the small chonetid specimens within the new fauna are external or internal moulds of isolated valves. Hence it is by no means clear that all internal moulds of valves are correctly assigned between *Chonetinella* and *Sulcataria*. Nevertheless, the holotype dorsal valve possesses a distinctive interior when compared with those assigned to *Chonetinella*.

Sulcataria rostrata (Dunbar & Condra) as described by Cooper & Grant (1975, pl. 480, figs. 37–55) possesses a broader sulcus anteriorly than the new species, and a prominent dorsal median septum. *Sulcataria compacta* Cooper & Grant (1975) from the Neal Ranch Formation (Asselian) is closer to the new species; it has a similar shell outline, but a narrower dorsal fold and more strongly developed dorsal internal structures. *S. latisulcata* Cooper & Grant (1975) from the same formation and age has a much lower dorsal fold and weaker ventral sulcus than the new species.

Of considerable interest are the Late Permian records of *Sulcataria* from the Himalayas. *S. pentagonalis* from the Djulfian of Nepal (Waterhouse, 1978, pl. 1, figs. 13–16) is based on poorly preserved material, but possesses a broader fold than the new species. Specimens from the Djulfian of Kashmir (Waterhouse & Gupta, 1979, pl. 1, figs. 5, 7; pl. 2, figs. 1–8) are at times more alate with ears, but other specimens are subquadrate and hence comparable with the new species. Dorsal internal features are weakly developed as in *S. skwarkoi* sp. nov.

Order **Productida** Sarycheva & Sokolskaya, 1959
Suborder **Strophalosiidina** Waterhouse, 1975
Superfamily **Strophalosiacea** Schuchert, 1913
Family **Strophalosiidae** Schuchert, 1913
Subfamily **Strophalosiinae** Schuchert, 1913
Genus ***Heteralosia*** King, 1938

Type species. *Heteralosia slocomi* King, 1938.

Discussion. *Heteralosia* has been reviewed by Archbold (1986), who restricted the genus to small Strophalosiinae with no dorsal spines, while agreeing with Waterhouse (1959) that care was needed with ontogenetic studies in the group.

Heteralosia sp.
Fig. 5D, E

Material and measurements. 1 dorsal valve external mould (IMF 138): height of valve, 4.6 mm; estimated width of valve, 5.0 mm. 1 ventral valve internal mould (IMF 139): height of valve, 7.8 mm; width of valve, 7.2 mm.

Comments. The two specimens are referred to *Heteralosia* because of their small size and general similarities to species described from the Early Permian of Thailand (Grant, 1976), Texas (Cooper & Grant, 1975) and Western Australia (Archbold, 1986). Material is inadequate for detailed comparison with described species.

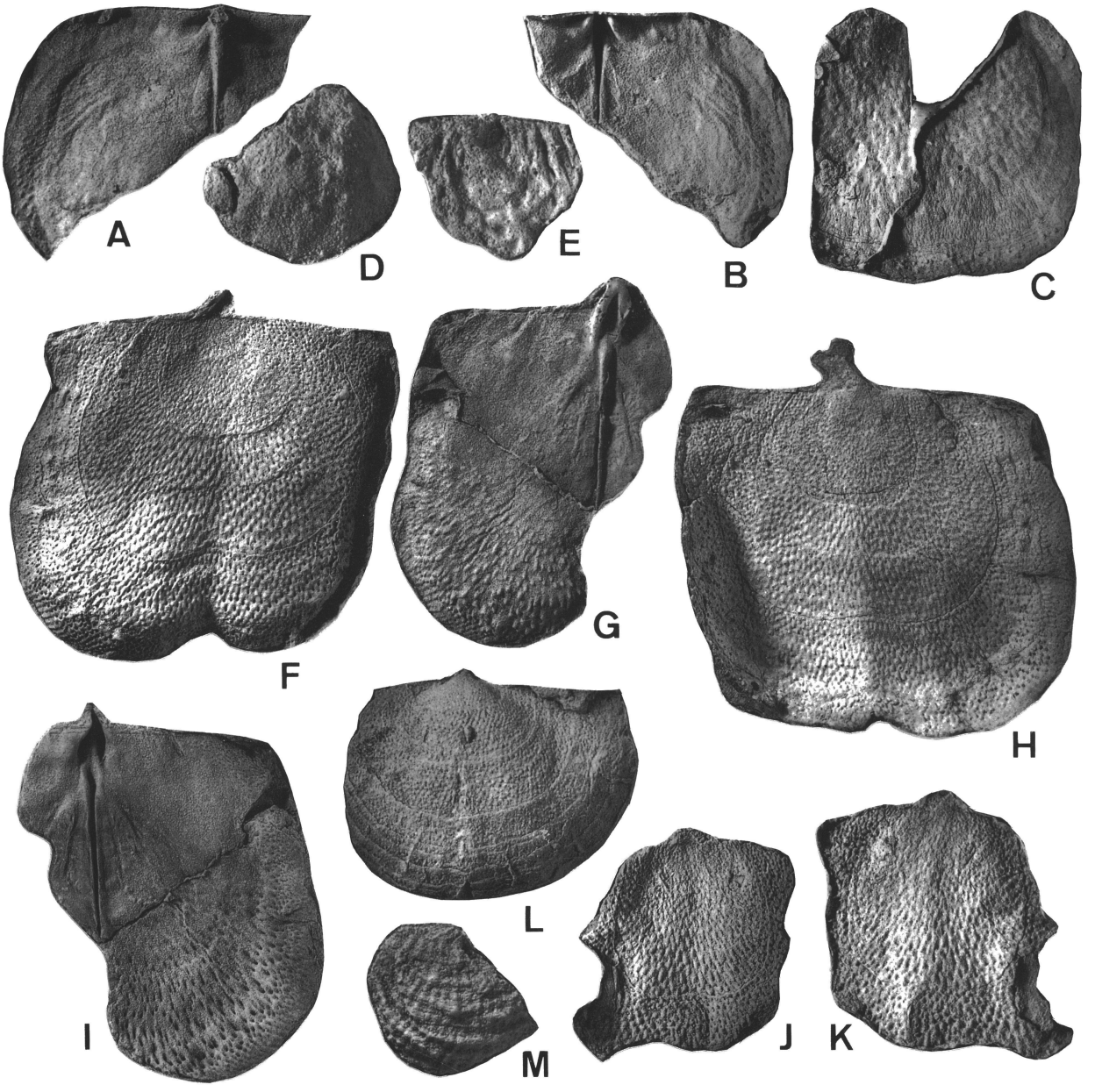

Figure 5. ***Echinalosia*** **sp.,** ***Heteralosia*** **sp.,** ***Aulosteges tenuispinosus*****,** ***Stictozoster*** **sp., and** ***Cancrinella*** **from the Aiduna Formation.** **A–C,** *Echinalosia* sp.: A, B, IMF 140a, latex cast of incomplete dorsal valve internal mould and internal mould, x 1.6; C, IMF 140b, latex cast of dorsal valve external mould, x 1.3. **D, E,** *Heteralosia* sp.: D, IMF 139, internal mould of ventral valve, x 4; E, IMF 138, latex cast of dorsal valve external mould, x 4.5. **F–K,** *Aulosteges tenuispinosus* sp. nov.: F, H, holotype, IMF 141a, dorsal valve external mould and latex cast of mould, x 1.3; G, I, holotype, IMF 141b, latex cast of dorsal valve internal mould and internal mould, x 1.3; J, K, IMF 142, dorsal valve external mould and latex cast of mould, x 1.3 and 1.5. **L,** *Stictozoster* sp., IMF 143, dorsal valve external mould, x 1.6. **M,** *Cancrinella* sp., IMF 144, portion of juvenile ventral valve, x 3.2.

Genus *Echinalosia* Waterhouse, 1967

Type species. *Strophalosia maxwelli* Waterhouse, 1964.

Diagnosis. Medium to large Strophalosiinae with circular to elongate shell outline. Dorsal valve with unthickened trail. Dorsal spines finer than ventral spines.

Discussion. Distinctions between *Echinalosia* and related genera with dorsal spines have been discussed by Archbold (1986) and Waterhouse (1986), and will not be repeated here.

Echinalosia sp.
Fig. 5A–C

Material and measurements. 1 incomplete dorsal valve internal mould (IMF 140a) and corresponding incomplete external mould (IMF 140b): estimated valve width, 38 mm; estimated valve length, 35 mm.

Comments. The material is provisionally referred to *Echinalosia* on the basis of its moderate size, presence of dorsal spines (although only preserved on the anterior margin of the external mould), and lack of valve thickening. A striking feature of the specimen is the cardinal process, which does not project above the hinge line unlike other species of the genus.

Superfamily **Aulostegacea** Muir–Wood & Cooper, 1960
Family **Aulostegidae** Muir–Wood & Cooper, 1960
Subfamily **Aulosteginae** Muir–Wood & Cooper, 1960
Genus ***Aulosteges*** von Helmersen, 1847

Type species. *Orthis wangenheimi* de Verneuil, 1845 (= *Aulosteges variabilis* von Helmersen, 1847).

Discussion. The type species was described from poor material by de Verneuil (1845, p. 194, pl. 11, fig. 5), and fully described, under a different name, by von Helmersen (1847; 1848, figs. 1–12). Von Helmersen (1853) subsequently clarified the confusion over the two specific names. More recent studies of the type species have included those by Likharev (1959, pl. 4, figs. 1–8; pl. 5, figs. 1–5), Muir–Wood & Cooper (1960, pl. 10, figs. 14–19), and Grigoryeva (1962, pl. 5, figs. 1–4).

Aulosteges tenuispinosus sp. nov.
Fig. 5F–K

Holotype. A complete dorsal valve external mould (IMF 141a) and incomplete corresponding dorsal valve internal mould (IMF 141b).

Additional material. 1 incomplete external mould of juvenile portion of dorsal valve (IMF 142).

Measurements of holotype. Valve width, 45.5 mm; valve length, 40 mm; length of dorsal septum, 21+ mm.

Description. Medium-size subquadrate dorsal valve. Widest anterior of mid-length. Thin-shelled. Ventral valve unknown. Dorsal valve gently convex at juvenile stage, becoming flattish and then markedly upturned. Narrow dorsal fold distinct, arises close to umbo. Valve exterior covered in small, elongate dimples and numerous closely scattered fine spine bases. Dorsal interior with pronounced blade-like median septum anterior of deep alveolus on either side of which are pronounced ridges. Interior face of cardinal process not preserved, but exterior face apparently massively trilobate judging from outline trace preserved on external mould. Anterior of dorsal interior strongly papillose. Adductor scars dendritic, not depressed.

Discussion. Despite the absence of ventral valve data and the limited nature of the material, the species is named because of the distinctive, well preserved material to hand. The species is only provisionally referred to *Aulosteges*, of which the type species lacks the distinct dimples on the dorsal valve exterior as indicated by Likharev (1959) and Grigoryeva (1962). *A. tenuispinosus* sp. nov. is close to Western Australian Early Permian species as described by Coleman (1957), such as the Sterlitamakian *A. baracoodensis* Etheridge (1903) and the Artinskian *A. ingens* Hosking (1931) and *A. lyndonensis* Coleman (1957). These species all appear to be closely related and, in turn, allied to *A. tenuispinosus* sp. nov., but possess less subquadrate dorsal valves than the new species.

Suborder **Productidina** Waagen, 1883
Superfamily **Productellacea** Schuchert & Le Vene, 1929
Family **Productellidae** Schuchert & Le Vene, 1929
Genus ***Stictozoster*** Grant, 1976

Type species. *Stictozoster leptus* Grant, 1976.

Diagnosis. The diagnosis provided by Grant (1976, p. 96) is accepted.

Discussion. *Stictozoster* has been reviewed by Waterhouse (1981) and Archbold (1981a, 1984). The genus has a late Sakmarian (Sterlitamakian) to Kungurian range in the south-east Asian–Western Australian region, and a Kungurian–Kazanian range in the Arctic. *Stictozoster* has previously been recorded from the late Early Permian of Irian Jaya (Archbold, 1981a).

Stictozoster sp.
Fig. 5L

Comments. A single dorsal valve external mould (IMF 143, with estimated width of 33.4 mm, and valve length of 21 mm) reveals the distinctive finely dimpled exterior with fine spines and lamellose growth lines of the genus. The specimen is large for the genus, but additional material is required for detailed comparison with described species.

Superfamily **Linoproductacea** Stehli, 1954
Family **Linoproductidae** Stehli, 1954
Subfamily **Linoproductinae** Stehli, 1954
Genus ***Cancrinella*** Fredericks, 1928

Type species. *Productus cancrini* de Verneuil, 1842 (*in* de Koninck, 1842).

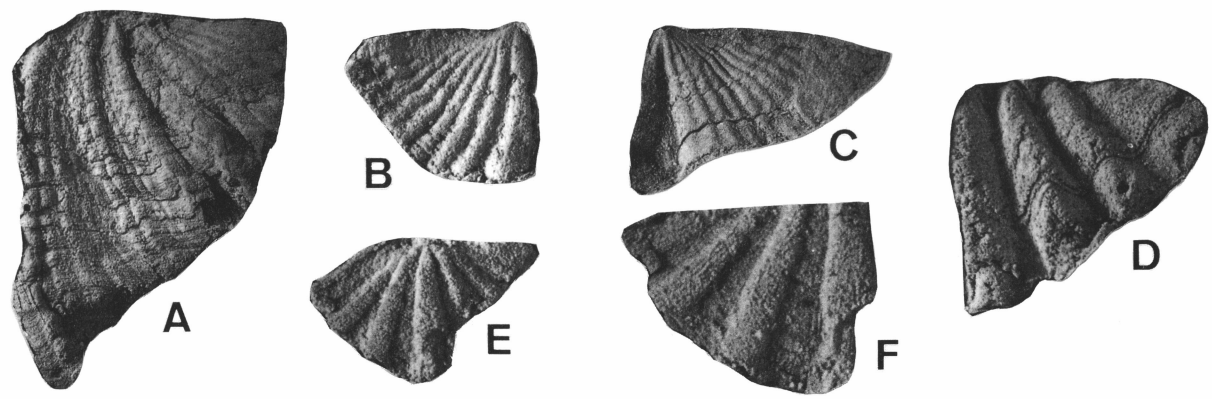

Figure 6. Spiriferids from the Aiduna Formation.
A, *Neospirifer* sp., IMC 145, latex cast of dorsal valve external mould, x 2.6. **B,** syringothyridacean no. 1, IMC 146, latex cast of dorsal valve external mould, x 3.2. **C,** syringothyridacean no. 2, IMC 147, latex cast of ventral valve external mould, x 2. **D,** *Spiriferellina?* sp., IMC 148, latex cast of portion of ventral? valve, x 3.5. **E, F,** spiriferinidinid indet., IMC 149, latex cast of dorsal valve and portion of cast enlarged, x 4 and x 8.

Cancrinella sp.
Fig. 5M

Comments. A single incomplete internal mould of a juvenile ventral valve (IMF 144, with valve length of 7.2 mm) indicates the presence of *Cancrinella*. The specimen is inadequate for detailed comparison with described species of the genus.

Order **Spiriferida** Waagen, 1883

Comments. The order Spiriferida is represented in the fauna by five incomplete specimens (Fig. 6). *Neospirifer* (IMF 145) is present, and two different syringothyridacean species are indicated (IMF 146–147). The punctate Spiriferinidina are represented by two forms: one has broad distinct, rounded lateral plications and a granulose exterior (a possible *Spiriferellina*, IMF 148); and the other has broad, widely spaced, flattish lateral plications and a capillate micro-ornament (IMF 149).

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