The Late Triassic molluscs, conodonts, and brachiopods of the Kuta Formation, Papua New Guinea

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The Kuta Formation is mainly a limestone deposit which crops out on the flanks of the Kubor Anticline in the Central Highlands of Papua New Guinea. It has been variously regarded as Cainozoic, Permian and Permo-Triassic in age, but is now positively dated as late Norian or Rhaetian (Late Triassic) on the basic of conodonts, molluscs and brachiopods. The Kuta Formation is thus the youngest known Triassic formation in Papua New Guinea. Interpretation of the local stratigraphy is simplified by this dating. It is now apparent that the marine Triassic sedimentation in Papua New Guinea commenced no later than the Anisian (Middle Triassic) and continued, probably uninterrupted, until Rhaetian time.

The fossils identified and described include the conodont *Misikella posthernsteini* Kozur & Mock, 1974, the ammonite *Arcestes (Arcestes)* cf. *sundaicus*, Welter, 1914, and some bivalves. The brachiopods *Clavigera*, *Zugmeyerella*, *Sinucosta*, *Robinsonella*, *?Hagabirhynchia* are equally important in dating the assemblage, but will be described in detail separately.

All the more closely identified fossils have a Tethyan Provincial aspect except *Clavigera* which was previously known only from New Zealand and New Caledonia.

Introduction

In the course of the regional mapping of the Kubor Anticline in the central highlands of New Guinea in 1968 and 1970 the Kuta Formation was sampled in a number of places with the hope of obtaining a more definite and accurate dating than had hitherto been possible. The preliminary palaeontological study of the collected fauna was not successful, as the contained corals proved to be too poorly preserved for identification, brachiopods seemed indicative of either Permian or Triassic age, the foraminifera were long ranging genera, and the bivalves were too few and fragmentary for identification and dating. The resulting general consensus was that the limestone straddled the Permo-Triassic boundary (Bain, Mackenzie & Ryburn, 1975).

In the present study the additional brachiopods and molluscs have been examined and 14 samples processed for conodonts in an attempt to establish the age of the formation more precisely. Nicoll is responsible for identification of the conodonts, Skwarko for the cephalopods and bivalves, and Campbell for the brachiopods. The stratigraphic section of the paper is the work of Skwarko and Nicoll.

Acknowledgements

Many of the samples were collected by J. H. C. Bain, D. E. Mackenzie, and R. J. Ryburn, of BMR; we wish to thank them for discussions concerning the field and stratigraphic relationships of rock units around the Kubor Anticline. J. D. Campbell (Univ. Otago, New Zealand) has been most helpful with comments on the *Clavigera* specimens. Sincere thanks are due to Dr. Y. Bando of Kagawa University, Japan, for his helpful comments on the identity of the ammonites; Professor J. A. Grant-Mackie of the University of Auckland, New Zealand, for the exhaustive discussion regarding the likely phylogeny of one of the more enigmatic bivalves; and Dr. K. Nakazawa, of Kyoto University, Japan, for his comments on the bivalves. The text-figures were drawn in the general draughting section of the geological drawing office, BMR.

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The Kuta Formation

The Kuta Formation consists of a suite of marine arkose, limestone, and shale outcropping in the central highlands of Papua New Guinea (Fig. 1). Its description below is largely based on Bain *et al.* (1970, unpublished; 1975).

The formation is 30 to 250 m thick and mainly consists of hard, buff to dark grey, massive, crystalline, coarse to fine-grained limestone. In places the limestone appears to grade laterally into calcareous breccia containing fragments of metamorphic rocks. The limestone rests on, and in places grades laterally into, a coarse, calcareous arkose, which in turn unconformably overlies the Kubor Granodiorite or the Omung Metamorphics. The formation is overlain by either the Late Jurassic Maril Shale or the Early Cretaceous Kondaku Tuff.

The presence in places of molluscs, brachiopods, corals, bryozoans, and crinoids, as well as the existence of the coarse basal arkose, points to a shallow-water environment of deposition, and Bain *et al.* (1975, p. 18-20) concluded that the limestone was deposited as fringing reefs on granitic wash and breccia derived from the adjacent Palaeozoic basement.

The Kuta Formation has been little disturbed since its deposition, and where observed is only slightly folded.

Age of the Kuta Formation

Bain *et al.* (1970, 1975), and Bain & Mackenzie (1974a, 1974b), have discussed in some detail earlier evidence pertaining to the age of the Kuta Formation, and this information is only briefly reviewed here.

The age has been the subject of much controversy. Limestone was first collected by N. H. Fisher, in 1937, from exposures overlying the Kubor Granodiorite near Kuta village, and a Miocene age was ascribed to these samples (Glaessner *et al.*, 1950). Glaessner identified foraminifera from new samples obtained from the Kuta area and dated the unit as Permian. These specimens and others identified later by Belford (Bain *et al.*, 1975) belong to long-ranging genera and do not necessarily indicate a Permian age for the Kuta Formation. Rickwood (1955, p. 69-70) used the name Kuta Group for limestone and calcareous arkose exposed east of Kuta Village, and identified several macrofossils, mostly brachiopods, from the unit. He thought the age to be Permian but noted that the macrofauna differed from described Permian faunas from either Australia or Timor. Rickwood's brachiopod identifications are discussed below.

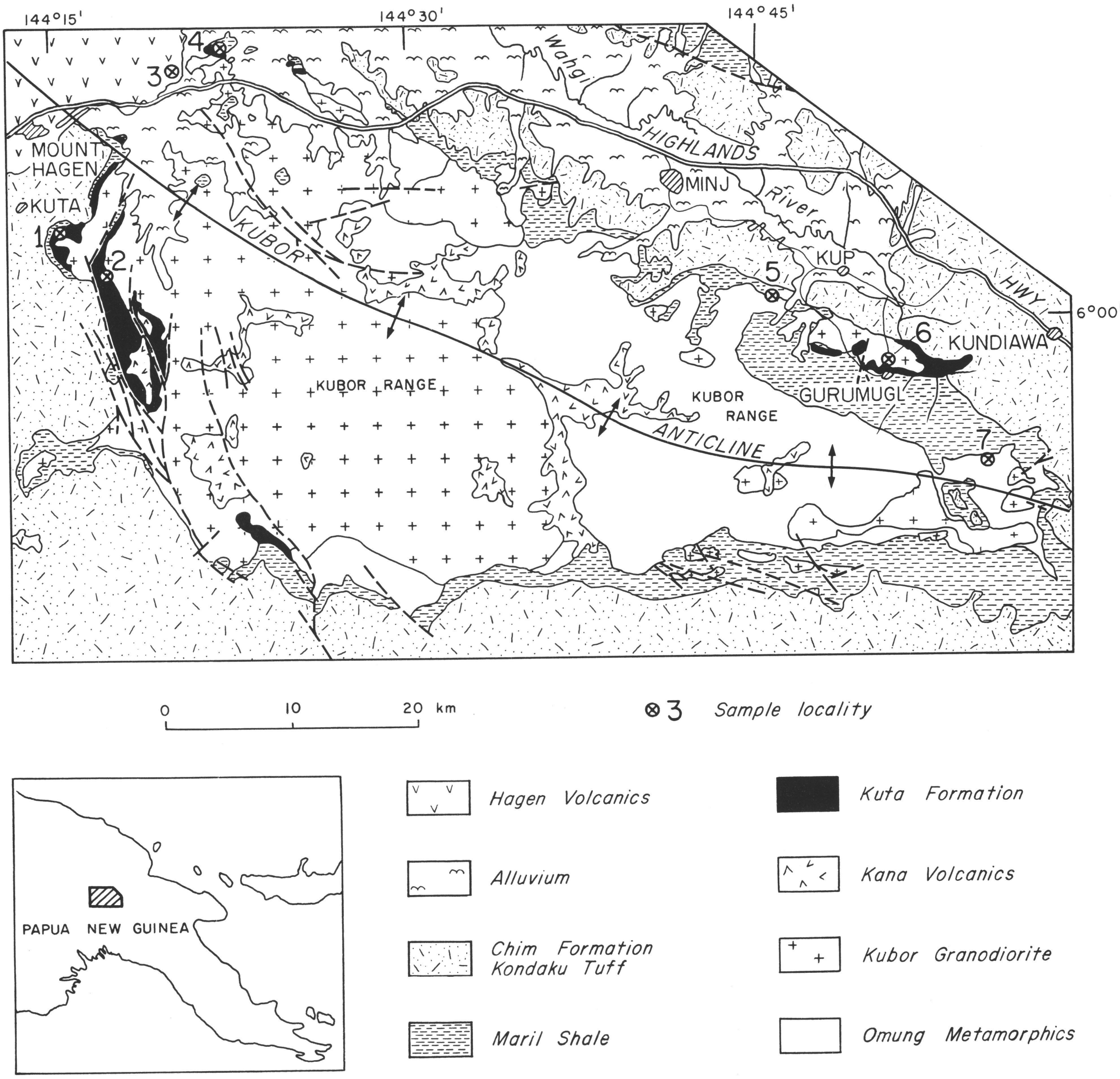

Figure 1. **Generalised geologic map of the Kubor Anticline, showing collecting localities. Simplified from Bain & MacKenzie (1974, 1975).**

Later collections of macrofossils from the Kuta were cursorily examined by workers at BMR and the Australian National University, who concluded that the fauna probably came from close to the Permian-Triassic boundary (Bain *et al.*, 1970, p. 15).

The recent discovery of the conodont *Misikella posthernsteini* (as *Neospathodus hernsteini* in Bain *et al.*, 1975) was the first indication of a late Norian or a Rhaetian age for at least part of the formation. This age was then confirmed by the recognition of *Arcestes* cf. *A. sundaicus*, a species originally described from Norian-Rhaetian strata of Timor. The athyroid brachiopod *Clavigera* represented by a species comparable with specimens from the late Norian-Rhaetian of New Zealand and New Caledonia offers further support. Finally the age is consistent with the occurrence of brachiopod genera known from farther afield, particularly *Zugmeyerella*, *Robinsonella*, *?Hagabirhynchia* and *Sinucosta*. *Canadospira* and *Stolzenburgiella* suggest slightly greater ages (Carnian and Anisian respectively) but these genera are known from a very limited number of occurrences elsewhere, and their ranges must be greater than previously realised.

Regional geology

The re-evaluation of the age of the Kuta Formation changes the previous interpretation of Permian and Triassic lithostratigraphic relationships in the Kubor Anticline. Figure 2 shows the revised stratigraphic column based on field observation (Bain *et al.*, 1975) and the present palaeontological determinations.

The Omung Metamorphics are regionally metamorphosed, non-calcareous sediments believed to have been deposited in a deep-water marine environment (Bain *et al.*, 1975, p. 16). The metamorphics were later intruded by the Kubor Granodiorite. Page (1971) dated the Kubor Granodiorite as either 244 (Rb-Sr) or 220 m.y. (K-Ar), that is either Late Permian or Early-Middle Triassic, the former being preferred.

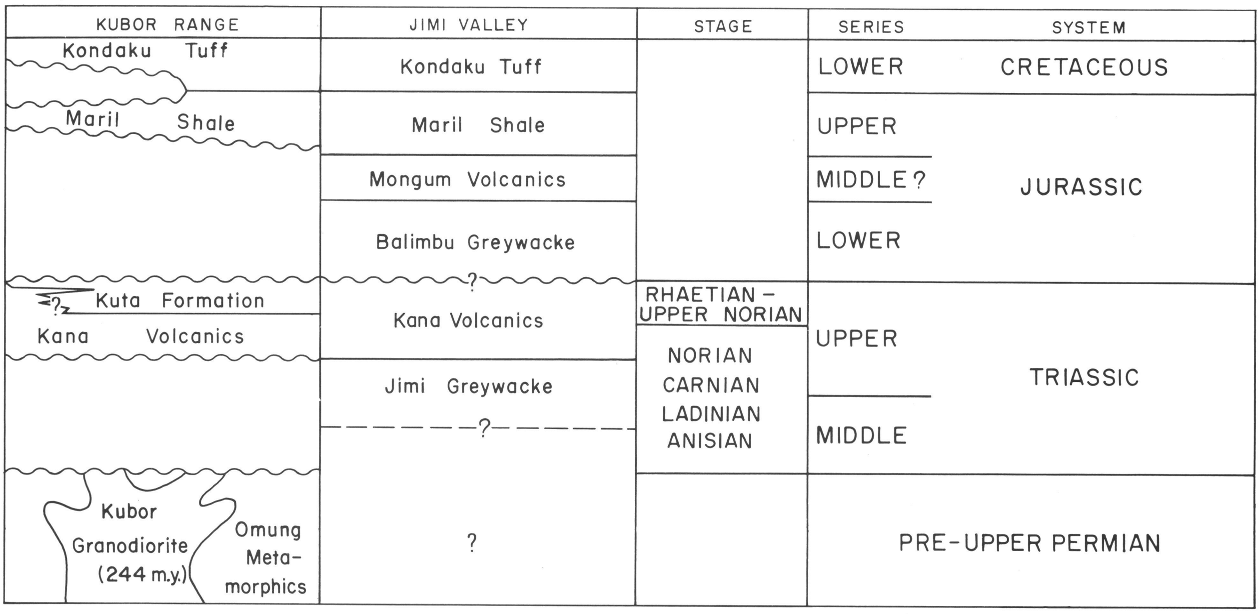

Figure 2. Stratigraphic correlation of Upper Palaeozoic and Lower Mesozoic units in the Kubor Range and Jimi Valley.

Following the intrusion of the Kubor Granodiorite the area was uplifted and subjected to erosion. By the Late Triassic, sedimentation had recommenced in the Jimi Valley area, to the north of the Kubor Anticline, with the deposition of the Jimi Greywacke, followed by the Kana Volcanics. These units were both considered by Skwarko (1967, p. 46) to be Late Triassic (Carnian-Norian) on the basis of macrofossils. The Jimi Greywacke is absent from the Kubor Range but there are remnants of the volcanic rock, up to 700 m thick, on the crest of the Kubor Anticline (Bain *et al.*, 1975). Lithologically these volcanics are similar to the Kana Volcanics but there has been no palaeontological age established for them in the Kubor Range.

On the palaeontological evidence the Kuta Formation is the youngest Triassic (Late Norian-Rhaetian) unit in the area. In the Kubor Range the Kuta Formation rests on a variety of stratigraphic and lithologic units, usually either the Kubor Granodiorite or the Omung Metamorphics. In a few areas it rests on a thin basalt which may be equivalent to the Kana Volcanics, but it has not been found overlying any of the thick volcanic sequences.

Previously the Kana Volcanics were thought to be younger than the Kuta Formation. However this was based on the presumed Permian age of the Kuta Formation. As it has been shown here that the Kuta Formation is, at least in part, younger than the Kana Volcanics, the relationship of these units in the Kubor Anticline is reversed.

In the Kubor Range the Kuta Formation and Kana Volcanics are both unconformably overlain by either Upper Jurassic or Cretaceous units. This depositional break, from latest Upper Triassic to Upper Jurassic probably represents a period of uplift and erosion in the Kubor Range area but Lower Jurassic units are present to the north. The erosion of both the Kuta Formation and Kana Volcanics during that period may help to explain their patchy distribution in the area.

Triassic palaeogeography

Until thirteen years ago no marine deposits of early Mesozoic age were known in Papua New Guinea. Today, following a series of discoveries of fossil assemblages, relatively extensive marine Triassic sedimentary rocks are known from the central part of the country.

There is still no evidence for inundation in the Early Triassic. The oldest known sediments are the Anisian (Middle Triassic) Yuat Formation, at least 600 m thick, on the Yuat River in the Central Highlands. The massive black shale contains some fine silty bands and rare beds of calcareous feldspathic sandstone. The presence of coaly fragments, carbonaceous lenses, small pieces of bone and a rich molluscan fauna (Skwarko, 1973a; Skwarko & Kummel, 1974) together with the absence of graded bedding, indicates a shallow-water environment of deposition (Dow *et al.*, 1972, p. 19).

The next youngest stratigraphic unit is the Carnian-Norian Jimi Greywacke; although probably present at the top of the Yuat River section it is more widespread in the Jimi River area, where it exceeds 800 m in thickness and from where it was first reported and its fauna described (Skwarko, 1963, 1967; Dow & Dekker, 1964, pp. 10-12). The Jimi Greywacke is an indurated fine to medium-grained greywacke and siltstone, commonly micaceous and calcareous, with coarse beds that are generally carbonaceous; there are minor beds of shale and feldspathic sandstone. Cross-bedding and ripple marks have been observed in places. The conformably overlying Kana Volcanics, of similar age, vary in thickness from 200 to 3000 m and consist mainly of interbedded feldspathic arenite and tuffaceous siltstone; massive dacite conglomerate and minor beds of quartz sandstone and calcarenite occur throughout (Dow & Dekker, 1964, pp. 10-12). The Kana Volcanics were deposited in shallow-water; and the Jimi Greywacke in somewhat deeper water.

The recent discovery of Ladinian or Ladino-Carnian Halobiidae in the general outcrop area of the Jimi Greywacke (Skwarko, 1973b) suggests uninterrupted sedimentation between the Anisian and Carnian-Norian. The Norian-Rhaetian age of the Kuta Formation further extends the duration of the Triassic seas in Papua New Guinea. Although the sediments, namely limestone and arkose, are quite different from the older Triassic sediments in the Central Highlands, they, together with their associated fossils, give evidence of shallow-water marine conditions (see Fig. 3).

Apart from the definitely Triassic units discussed above, there are others which may have been formed at least partly in the Triassic time. In this category are the '?Mesozoic-

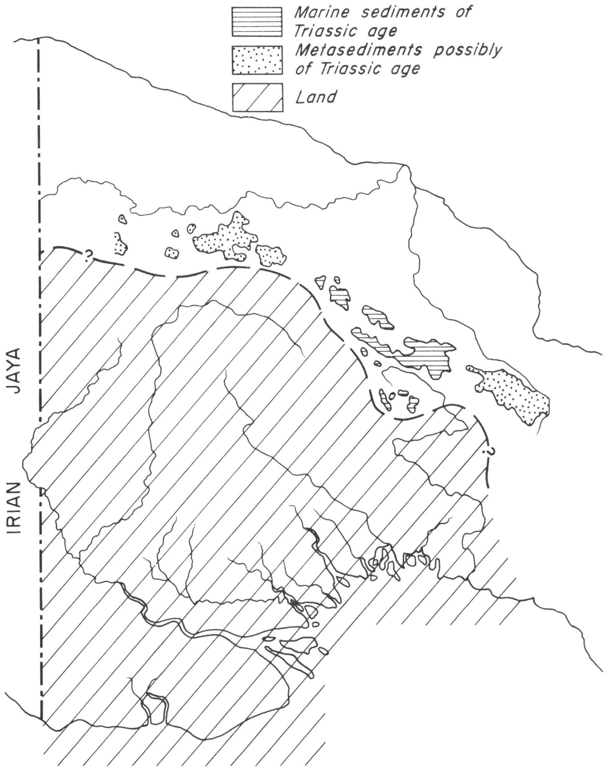

Figure 3. Distribution of Triassic sediments in Papua New Guinea and location of the Triassic shoreline.

Early Tertiary' Ambunti Metamorphics in the South Sepik region, the 'Mesozoic' Bena Bena Formation on the Markham and Karimui 1:250 000 Sheet areas, and the 'Mesozoic' Owen Stanley Metamorphics which extend through most of the length of peninsular Papua.

Figure 3 is an attempt to put the above data in the form of a palaeogeographic map. The coastline of the Triassic landmass is placed south of the Ambunti Metamorphics in the west, the known shallow-water marine sediments in the centre, and the Bena Bena and Goroka Formations as well as the Owen Stanley Metamorphics in the east. The generalizations and the assumptions of such a presentation are obvious, given the paucity of critical data.

Faunal analysis and systematic palaeontology

Details of the conodont, molluscan, and brachiopod elements of the Kuta Formation are given in the following section. All specimens are deposited in the Commonwealth Palaeontologic Collection (CPC) at the Bureau of Mineral Resources, Canberra. Sample locality information is given in Table 1.

Conodont fauna

Only two conodonts were recovered and both are assigned to *Misikella posthernsteini* Kozur & Mock. In Europe *M. posthernsteini* occurs in strata assigned to the *Rhabdoceras suessi* and *Choristoceras marshi* Ammonoid Zones (Kozur & Mock, 1974), which correspond to the Upper Norian Substage and the Rhaetian Stage of the Upper Triassic (Sweet *et al.*, 1971).

The references by McTavish (1975, p. 486) and Bain *et al* (1975, p. 20) to *Neospathodus hernsteini* from the Kuta Formation are to the specimens now assigned to *M. posthernsteini.*

The scarcity of conodonts in the Kuta Formation is probably a reflection of the reduced diversity, and probably also low abundance, of conodonts in the latest Triassic, just prior to their extinction. Rhaetian conodont faunas appear to be impoverished in Europe and absent in North America (Sweet *et al.*, 1971, p. 459). In the Gondwana Region the youngest previously recorded conodont faunas, from New Zealand and India (McTavish, 1975), are from the Upper Norian Substage. McTavish (1975, p. 486) believes the Indian fauna, originally considered Rhaetian by Sahni & Prakash (1973, p. 218) on the presence of *N. hernsteini,* is probably Late Norian. Neither the Indian nor New Zealand conodont faunas contain any elements in common with the Kuta fauna.

Systematics

Genus MISIKELLA Kozur & Mock, 1974

Type species: Spathognathodus hernsteini Mosher, 1967;
MISIKELLA POSTHERNSTEINI Kozur & Mock, 1974 Fig. 4 A-H.

1968 *Neospathodus lanceolatus* Mosher (part) p. 930, pl. 115, Fig. 7 only.

1974 *Misikella posthernsteini* Kozur & Mock, p. 247, Figs. 1-4.

Material studied: 2 specimens, CPC 16562 (locality 6, sample PNG-1), 16563 (loc. 6, PNG-0).

Description: A spathognathodoform element with laterally expanded basal cavity and reduced number of oral denticles. The element is slightly bowed laterally with left and right forms. The two specimens recovered have 4 and 3 denticles respectively. The denticles are laterally compressed with sharp margins that are fused to near their tips. The anterior denticles are posteriorly inclined and the upper part of the posterior-most denticle is bent sharply backward and away from the adjacent denticle. The anterior margin is sharp-edged rather than rounded.

The basal cavity is deeply excavated but it cannot be determined if the cavity extended into the denticles. The margin of the basal cavity of specimen CPC 16562 (Fig. 4, A-D) is flared outward near the base, except near the anterior end where the cavity margins narrow abruptly. The other specimen (CPC 16563, Fig. 4, E-H) is only slightly flared at the base. The posterior margin of the element is folded into the basal cavity and a prominent groove, very broad at the base, extends upward to the inflection point of the posterior denticle. The margins of this groove are rounded at the base but become sharp upward. The groove fades out as the posterior denticle becomes prominent.

Remarks: Misikella posthernsteini probably developed from *M. hernsteini* by a reduction in the number of denticles and the in-folding of the posterior margin. Mosher (1968, p. 930) mentions forms with flattened posterior margins and few denticles, which are probably transitional between *M. hernsteini* and *M. posthernsteini,* but gives no indication of their stratigraphic distribution.

The lack of other types of conodont element could indicate that the spathognathodoform morphology was the only surviving element in the conodont organism. However, the recovery of so few specimens more probably implies that conodonts were sparse in the study area and other elements were missed in sampling.

Map Locality	*Sample Number (a)*	*Locality data*	*Fossils studied (b)*	*Weight processed (c)*
	20 NG 2688A	Extensive outcrop, type area of the Kuta Fm, 10.4 km	Bi	12.3 kg
1	20 NG 2688B	SSE of Mount Hagen township, 3.5 km E of Kuta village	Bi	5.3 kg
	20 NG 2688C		Bi	12.9 kg
	20 NG 2688D	Grid ref. RAMU 1:250 000-196344; 5°55′S, 144°15′15″E	B	3.1 kg
2	116	Head of Pagum Ck, 12.5 km SSW of Korn. Sample 117 lies stratigraphically higher than 116 Collected by Rickwood	B	—
	117	Grid ref. RAMU 1:250 000-199341; 5°56′S, 144°17′E	B	—
3	20 NG 1319A	Small outcrop north of the Highlands Hwy, 12 km ENE of Mount Hagen township Grid ref. RAMU 1:250 000-205351; 5°49′25″S, 144°20′E		4.0 kg
4	20 NG 1377	Small outcrop north of the Highlands Hwy, 16 km ENE of Mount Hagen township	Bi	2.1 kg
	20 NG 1377A	Grid ref. RAMU 1:250 000-208357; 5°48′20″S, 144°22′E	B	2.0 kg
5	C 26/27	Rickwood sample, exact locality unknown, labelled NORMANZ LS, probably equates to BMR field locality 20 NG 0573; 10 km SE of MINJ township, vicinity of Dek village Grid ref. RAMU 1:250 000-251338; 5°58′40″S, 144°45′05″E	B	—
6	21 NG 0664	Samples from outcrop forming ridges north and northeast	B	2.0 kg
	21 NG 0665	of Gurumugl village, 13 km W of Kundiawa	B	—
	PNG-0	Samples PNG0 to 3 collected by Skwarko & Brown, 1972	B, Co	1.5 kg
	PNG-1		B, C, Co	4.8 kg
	PNG-2	Grid ref. KARIMUI 1:250 000-261332; 6°02′S, 144°50′25″E	C	6.7 kg
	PNG-3		C	4.0 kg
7	21 NG 0660	Sample may be either Kuta Fm or Maril Shale, from side of village road, 11 km SSW of Kundiawa Grid ref. KARIMUI 1:250 000-269325; 6°06′S, 144°54′50″E		2.0 kg
Not located	164	Rickwood locality 164, no data available	B	—
	None	Sample located only as 'Triassic Hills S of Mt Hagen', probably from the vicinity of locality 1 above		1.8 kg

Table 1. Collecting localities

(a) 20 NG and 21 NG samples were collected by BMR field parties during regional mapping.
(b) indicates fossil groups recovered and included in this paper. B—brachiopod, Bi—bivalve, C—cephalopod, Co—conodont.
(c) weight of samples processed for conodonts.

Molluscan fauna

Cephalopoda

Superfamily ARCESTACEAE Mojsisovics, 1875
Family ARCESTIDAE Mojsisovics, 1875

The available specimens, all incomplete, appear to belong to the Arcestidae, one of the six families of Middle and Late Triassic ammonites included in the Arcestaceae. Joannitidae can be distinguished by the overall curvature of the suture and its greater number of elements, as well as by the presence of bifurcating saddles; the Sphingitidae have a much wider umbilicus; the Cladiscitidae have more flattened whorl sides and venter; the Megaphyllitidae and generally larger Nathorstitidae both have ceratitic sutures with phylloid saddles—multisellate in the latter. In the context of this paper the relative size of the former is not significant, and the sharp venter of the Nathostitidae, although one more differentiating feature, can safely be omitted for ease of expression. The relationship of our specimens to the Arcestidae is clearly established through the presence of a modified peristome, and a straight ammonitic suture with both lobes and saddles triangular in shape, in combination with pronounced involution, considerable inflation, and a complexly subdivided ammonitic suture with a dividend ventral lobe and a series of lateral lobes decreasing in size towards the umbilicus. There is no specimen in the collection with a complete body chamber.

Genus ARCESTES Suess, 1865

Type species: Ammonites galeiformis Hauer, 1865 (pro *Am. glaeatus* Hauer, 1864; non von Buch); SD Mojsisovics, 1893.

There are six subgenera of *Arcestes,* a cosmopolitan genus of the Anisian-Rhaetian times. Our specimens lack the discoidal cross-section and rather complicated umbilicus cf. *Stenarcestes* Mojsisovics, 1895, the radial ribbing or ridging on the body chambers of both *Ptycharcestes* Mojsisovics, 1893, and *Anisarcestes* Kittl, 1908, and the constrictions and flared ribs on the phragmocone and body chamber of *Pararcestes* and *Proarcestes* Mojsisovics, 1893. They are consequently referred to the *Arcestes* s. str.

ARCESTES (ARCESTES) cf. SUNDAICUS Welter, 1914
Figs. 5, 6, 7, 8, G, H, L, 9A, E, G, H,

Material: Only five ammonites have been collected from the Kuta Formation. They are incompletely preserved, and from three geographically close sites. Diagnostic features which can be observed in one specimen generally cannot be observed in the others because of the unsatisfactory preservation. Four of the specimens are considered to represent the same species, but I have preferred to describe them individually, thereby showing clearly which specimen contributed which diagnostic features to the overall description.

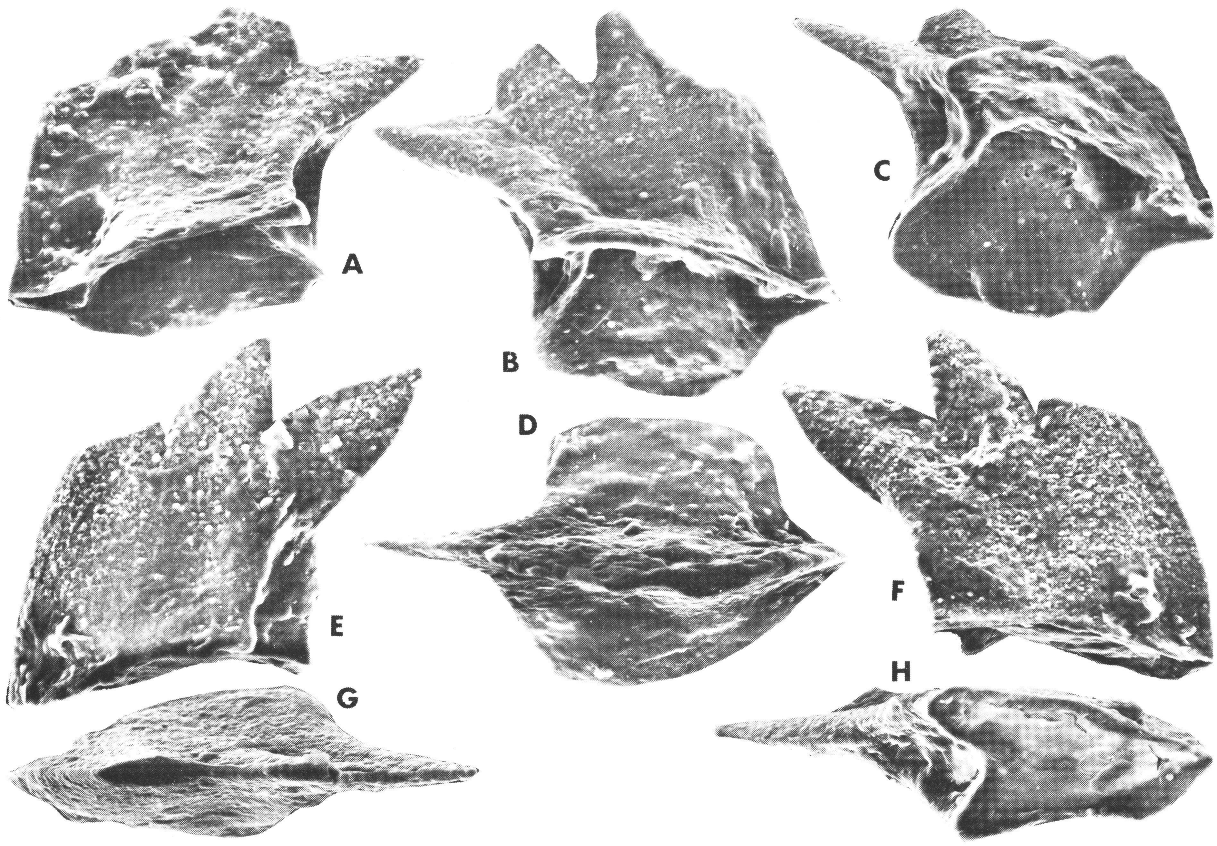

Figure 4. *Misikella posthernsteini* **Kozur & Mock. A-D left lateral, right lateral, aboral, and oral views of specimen CPC 16562; E-H, left lateral, right lateral, oral and aboral views of specimen CPC 16563. All specimens 200X**

Specimen CPC 15757 (loc. 6, PNG-2)—Figs. 9A, E, G

This, the most nearly complete specimen in the collection, is about 190 mm high and 110 mm across its widest part. It is involute with a completely smooth exterior. The body whorl is long and spindle-shaped in cross-section; the earlier whorls have a much more spheroidal cross-section. The shape of the peristome is unknown. the umbilicus is deep but with a narrow opening only about 18 mm across, its size reduced somewhat by a callus growing off at least a part of the umbilical shoulder. Inside the conch the umbilicus broadens somewhat before finally tapering off.

The sutures are complex ammonitic and closely spaced, and seem to be similar to that illustrated for CPC 15758 (Fig. 5).

Specimen CPC 15758 (loc. 6, PNG-2)—Figs 5, 8H, L

The presence of the suture pattern over the whole surface of this incomplete conch, together with the globose cross-sectional shape of the whorls, suggests that it is an internal whorl of a much larger shell. The surface is smooth.

Specimen CPC 15759 (loc. 6, PNG-1)—Figs 6, 8G

This is the only specimen in the collection with a complex mature suture pattern, some of which it is possible to reproduce (Fig. 6). In addition this is the only specimen which has constrictions, shallow though they may be: one of the phragmocone, and another on the body chamber not far from the line of the last suture.

When compared with CPC 15757 this specimen seems to be larger, with a larger umbilicus, and with possibly a more globose portion of the shell ventral to the umbilicus.

Figure 5. Suture line of specimen CPC 15758—*Arcestes (Arcestes)* cf. *sundaicus*.

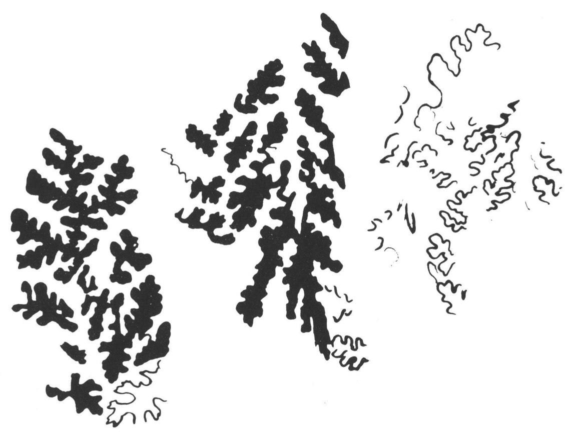

Figure 6. Suture line of specimen CPC 15759—*Arcestes (Arcestes)* cf. *sundaicus*

Specimen CPC 15760 (loc. 6, PNG-2)—Fig. 9H

This fragment of a large specimen comes from the distal-most portion of the body chamber and gives an insight into the shape of the aperture.

The margin of the aperture, i.e. the peristome, is complexly flexed (Fig. 7), but only portions of it are preserved and can be traced. As the chamber is followed toward the aperture, its dorsolateral wall maintains or even increases a little its inflation, before plunging steeply inwards while the ventrolateral part of the body wall becomes broadly but only slightly invaginated before swelling outward into two dome-like areas one on each side of the venter; a long, depressed strip with a fairly prominent linear median ridge precedes and parallels the peristome (Fig. 7).

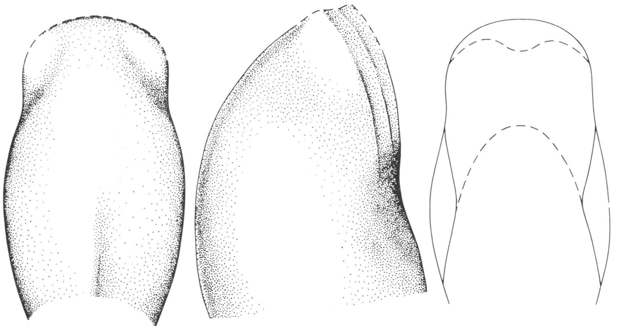

Figure 7. The body whorl and aperture shape of *A.* cf. *sundaicus* as reconstructed mainly from specimen CPC 15760. Because of the poor preservation of this specimen some structures may have been misrepresented. The sharpness of the keel shown on the left hand side figure may be a result of crushing

Discussion: Close similarity of the suture patterns and of the cross-sectional shape of the inner whorls leaves little doubt that specimens CPC 15757 and 15758 are conspecific. On comparison of these with CPC 15759 the similarity is, at first glance, not as obvious. This is because of the presence in CPC 15759 of constrictions on both phragmocone and body whorl, and because of the greater complexity of its suture pattern. However, the constrictions are extremely shallow and weakly defined, which implies that in this species the tendency towards formation of these structures is not very strong; from this it follows that within the range of intra-specific variation one could expect some specimens altogether free from constrictions. Regarding the differences in the suture patterns it is stressed that in both CPC 15757 and 15758 the sutures are on the immature part of the conch. In CPC 15759 on the other hand, it is the most mature set of sutures available for study and comparison, and these would be expected to be more complicated. All three specimens, CPC 15757-9, are thought to represent a single species.

Dr Y. Bando (pers. comm.), though agreeing with the identification of specimens CPC 15757 and CPC 15759 suggests that specimens CPC 15758 and CPC 15761 may in fact be a new species, the large size of their umbilicus making them comparable to the ammonite referred to by Welter (1914, pl. 29, fig. 20) as *Arcestes* sp. nov. ind. ex aff. *rothpletzi* Welter. Though Fig. G on Plate 9 of this paper shows that the umbilicus on the inner whorls of *A.* cf. *sundaicus*—and specimens CPC 15758 and CPC 15761 are such inner whorls—is in fact larger than on the last whorl where its size is reduced by a callus, Bando's valuable observation may indeed be correct.

CPC 15760, though a large specimen, represents in fact a small portion of the complete shell. It is a part of the most distal portion of the conch, and in our collection it shows the shape of the peristome. This specimen may well belong to the same species as those discussed above, but it is so incomplete that without additional material it will never be possible to verify its identification.

Comparison with other species: The great number of species of *Arcestes* s. str. already described, many of them in old literature, as well as the fragmentary nature of the available material seemingly makes identification not only difficult but also questionable. However,the large size of our mature specimens in itself eliminates most species from consideration, and the complex shape of the peristome also helps to narrow the field to but a few species of which *A.* (*A.*) *sundaicus,* described by Welter (1914) from undifferentiated Norian-Rhaetian strata of Timor, seems to be the most closely related. *A. sundaicus* is so far unknown beyond Timor, so its presence in the Kuta Formation cannot be used for dating more closely than 'Norian-Rhaetian'.

ARCESTES sp. indet.
(Fig. 8C, D)

Specimen CPC 15761: (loc. 6, PNG-3)

This small specimen almost certainly represents an inside portion of a larger shell. Its surface is covered by suture patterns of simple ammonitic type, having at least 8 elements and there is one moderately well preserved constriction. Its cross-section is compressed, and the inflation is much less than could be expected by comparison with the cross-section of the inner whorls of specimen CPC 15757. It is suggested that specimen CPC 15761 represents a species distinct from that represented by other specimens in the collection.

The evidence that CPC 15761 probably belongs to a different species from those above is fairly convincing and seen in the apparently greater involution of its whorls and their lesser inflation.

Bivalvia

In the Kuta Formation the bivalves are poorly represented. Specimens are few and fragmentary; their preservation allows only limited insight into external morphology, and no opportunity to study the hinge and other internal structures. The material illustrated and discussed here has been chosen mainly to complete the presentation of the fossil record. All identifications are tentative.

Family PECTINIDAE Rafinesque, 1815
CHLAMYS Group
Genus CHLAMYS Roding, 1798

Type species: Pecten islandicus Muller, 1776; SD Herrmannsen, 1847

CHLAMYS? sp. nov.
(Fig. 8A, B, E, F)

Material studied: At least five fragments. CPC 15764, 15766, 16909, 15765 (all loc. 1, 20NG2688C).

Description: Shell large, auriculate and orthocline, with unequally inflated valves, and with well defined and inflated umbo on convex valve bordered at least on one side with umbonal ridge. Both valves radially striated with regularly spaced primary riblets, their thickness increasing gradually and evenly distally; interspaces somewhat narrower than riblets. Secondary riblets, originating away from umbo are somewhat thinner than primary ones, few in number and irregularly arranged.

Remarks: In the course of discussions with Professor J. A. Grant-Mackie and Dr K. Nakazawa regarding the possible identity of this enigmatic bivalve a number of

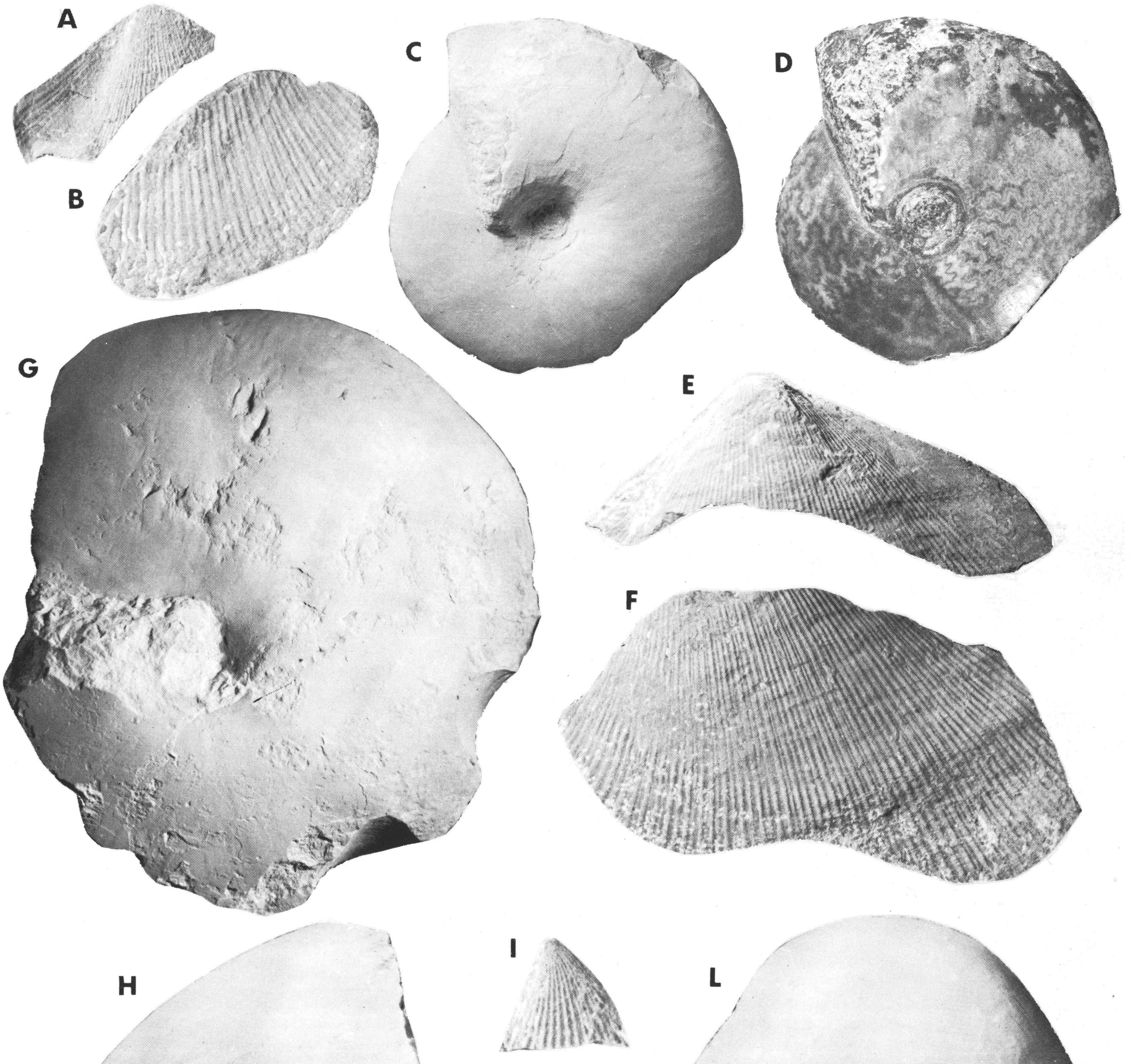

Figure 8. All specimens of natural size, coated with ammonium chloride and photographed in lateral view unless otherwise noted. A, B, E, F, *Chlamys?* sp. nov. A, fragment of proximal part of shell, external view, CPC 15764 (loc. 1, 20NG2688C); B, fragment of distal margin of shell, external view, CPC 15766 (loc. 1, 20NG2688C); E, incomplete proximal part of shell, external view, locality 20NG2688g. CPC 16909 (loc. 1, 20NG2688C); F, large fragment of medium part of inflated valve, external view, CPC 15765 (loc. 1, 20NG2688C). C, D, *Arcestes* sp. indet. Juvenile specimen in lateral view, coated with ammonium chloride, and bare showing suture pattern. CPC 15761 (loc. 6, PNG-3). G, H, L, *Arcestes (A.)* cf. *sundaicus* Welter, 1914. G, incomplete mature specimen, x 0.5, CPC 15759 (loc. 6, PNG-1); H, L, immature part of conch in lateral and ventral views, CPC 15758 (loc. 6 PNG-2); I, K, *Limea?* sp. Two fragments probably of same specimen, CPC 15763 (loc. 1, 20NG2688); J, *'Ostrea'* sp. Probably immature specimen, CPC 15762 (loc. 1, 20NG2688).

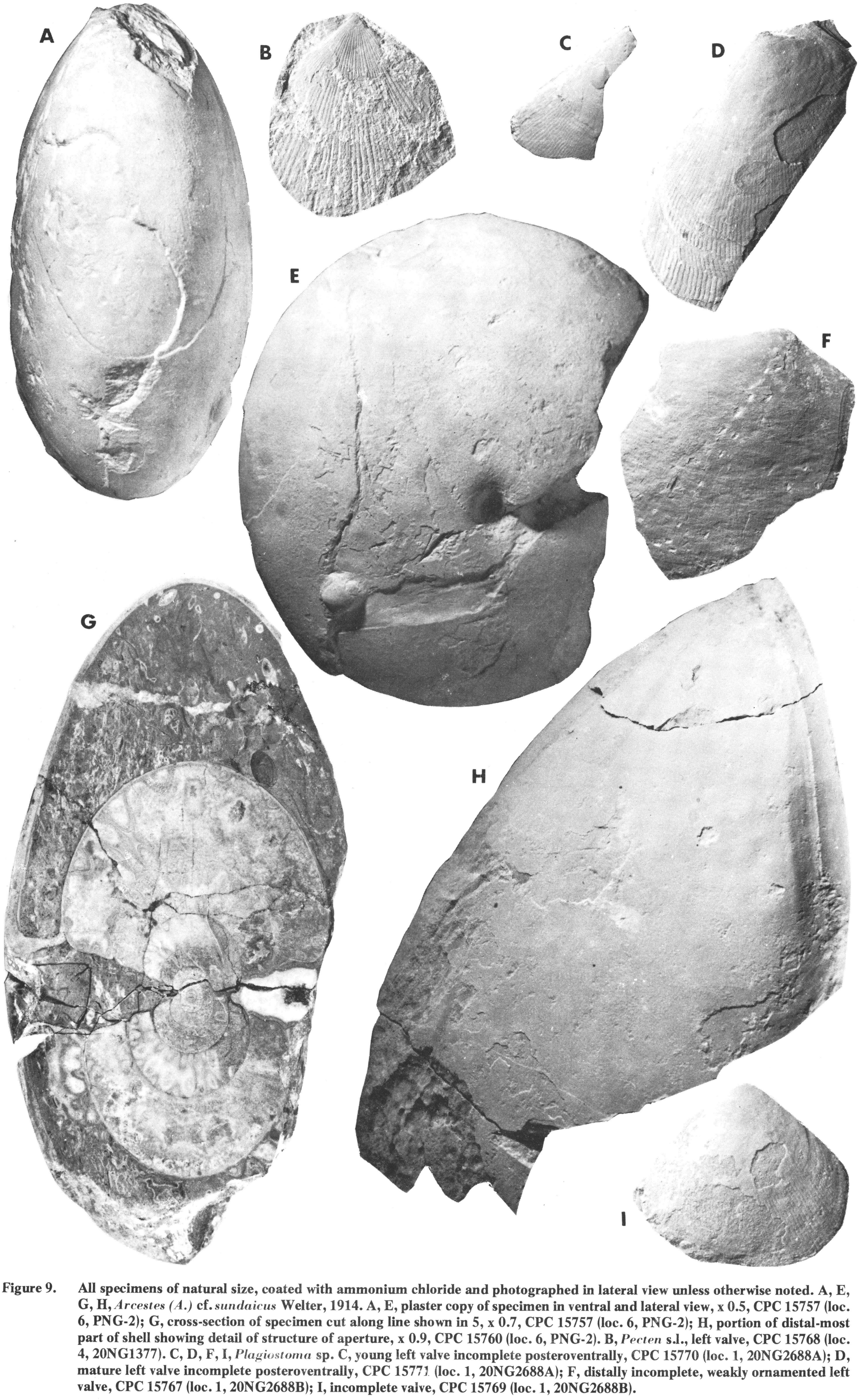

Figure 9. All specimens of natural size, coated with ammonium chloride and photographed in lateral view unless otherwise noted. A, E, G, H, *Arcestes (A.)* cf. *sundaicus* Welter, 1914. A, E, plaster copy of specimen in ventral and lateral view, x 0.5, CPC 15757 (loc. 6, PNG-2); G, cross-section of specimen cut along line shown in 5, x 0.7, CPC 15757 (loc. 6, PNG-2); H, portion of distal-most part of shell showing detail of structure of aperture, x 0.9, CPC 15760 (loc. 6, PNG-2). B, *Pecten* s.l., left valve, CPC 15768 (loc. 4, 20NG1377). C, D, F, I, *Plagiostoma* sp. C, young left valve incomplete posteroventrally, CPC 15770 (loc. 1, 20NG2688A); D, mature left valve incomplete posteroventrally, CPC 15771 (loc. 1, 20NG2688A); F, distally incomplete, weakly ornamented left valve, CPC 15767 (loc. 1, 20NG2688B); I, incomplete valve, CPC 15769 (loc. 1, 20NG2688B).

genera have been considered, including *Monotis, Limatula, Plagiostoma, Leptochondria, Eopecten, Eumorphotis* and *Chlamys*. In referring it to *Chlamys* I follow Nakazawa's suggestion, as its resemblance to the much smaller *C.* (*Praechlamys*) *inaequialternans* (Parona, 1889) from the middle Carnian of Southern Alps is indeed striking. In fact its similarity to the also smaller *C.* (*P.*) *inconspicua* (Bittner, 1901) seems to be hardly less striking, and I think that additional material, should it become available, will confirm the shell as a large new species of *Chlamys* (*Praechlamys*).

Family AVICULOPECTINIDAE Meek & Hayden, 1864
AVICULOPECTINIDAE? indet.
(Fig. 9B)

Material studied: one specimen—CPC 15768 (loc. 4, 20NG 1377)

There is only one incomplete valve in the collection. It is 40 mm high, with a pointed right-angle umbo, and is radially striated with low flat riblets which increase in breadth very gradually distally bifurcating in the process. The interspaces are linear and shallow. The auricle bears riblets similar to those on the main body of the valve.

Remarks: This specimen is either a right valve of an Aviculopectinid—as suggested by the bifurcating ribs and presence of radial riblets on the ear (Nakazawa, pers. comm.) or a left valve of a member of the *Pecten* group. The material in hand does not allow to establish the relationship between this specimen and the five specimens referred to *Chlamys* (*Praechlamys*)? sp. nov. above.

Family LIMIDAE Rafinesque, 1815
Genus PLAGIOSTOMA J. Sowerby, 1814

Type Species: Plagiostoma giganteum J. Sowerby, 1814

PLAGIOSTOMA sp.
(Fig. 9C, D, F, I)

Material studied: One ventrally and two posteriorly and ventrally incomplete left valves, one of them juvenile; one proximally incomplete right valve. CPC 15770 and 15771 (both loc. 1, 20NG2688A) and CPC 15767 and 15769 (both loc. 1, 20NG 2688B).

Description: Shell about 60 mm long and probably about 55 mm high, weakly to moderately inflated, with weak ornamentation over most of shell surface. Posterior auricle long, with shell margin beneath it initially flexed inwards then broadly convex. Anterior umbonal margin broadly and gently concave. Surface of valve—apart from beak area—ornamented with fine, shallow, somewhat sinuous flat riblets which increase in breadth very gradually distally; riblets separated by linear interspaces, and periodically somewhat offset by growth-rugae.

Genus LIMEA? Bronn, 1831

Type species: Ostrea strigilata Brocchi, 1814

LIMEA? sp.
(Fig. 7I, K)

Two fragments which probably belong to the one and the same valve (CPC 15763) are strongly ribbed with costae which radiate from a narrow and pointed umbo, gradually and evenly increasing in breadth distally. The ribs are robust and U-shaped (inversed) in cross-section; they are separated from each other by deep interspaces of about the same width as the ribs. Two interspaces have longitudinal threads in the middle along their length. In what appears to be the posterior part of the shell the ribs are reduced in size and relief, and seem to be more closely spaced.

Remarks: The preservation of the valve does not allow to determine whether it is an internal cast or an external mould; if an internal cast than the ribs are preserved less angular in cross-section than they should be, and the shell is probably *Pseudolimea*.

Family OSTREIDAE Rafinesque, 1815
'OSTREA' sp.
(Fig. 8J)

Material studied: One specimen—CPC 15762 (loc. 1, 20NG 2688).

The valve is probably that of a small oyster. It has a narrow sharp umbo and is concentrically ribbed with unevenly spaced growth-rugae. The strongly flexed surface reduces the likelihood of its being *Posidonia* or *Claraia*. A somewhat similar oyster has been described from the Triassic of Timor (Welter, 1914).

Brachiopod fauna

In the present study I have had access to the collection reported on by Rickwood (1955) and subsequent material collected by Bain *et al.* (1970) and by Brown and Skwarko in 1972. Much of the Rickwood material was calcined so that the specimens could be extracted with greater ease. Nevertheless it has still proved suitable for sectioning, and by further breaking up some of the blocks more genera have been obtained.

The Rickwood specimens are unnumbered, but some of them are in the original labelled boxes so that it is possible to refer to the individuals he used. The following notes are based on these specimens, supplemented where possible by others from the same collection and from the more recent collections.

Systematic notes

Terebratuloids. Several small terebratuloids are known from a number of localities. There are at least three different genera represented, one of which has dental lamellae and a short septalium supported on a septum that extends about one-third the length of the valve. It is this form that was referred to *Dielasma* cf. *elongatum* (Schlotheim) by Rickwood (1955). The calcite infilling has prevented preparation of the loop, and so generic identification is not yet possible. The form of the shell and the umbonal characteristics suggest that it is a species of *Zeilleria* Bayle.

Among the larger terebratuloids is the form referred to by Rickwood as *Dielasma* cf. *itaitubense* (Derby), a Brazilian Carboniferous species with strong dental lamellae and a long sessile septalium, whose loop is unknown. The New Guinea specimens also have dental lamellae but the inner hinge plates meet the floor of the valve separately at least towards the front of the narrow spetalium. The loop is short and lacks a median plate, and the crural points are high. The specimens probably belong to a new genus.

Spiriferoids.

Canadospira sp.

Several isolated pedicle and brachial valves are referred to this genus. They have the general form, smooth fold and sinus, simple sub-rounded lateral plicae, high cardinal area, dental lamellae, ventral median septum, dorsal median septum supporting the cardinal process, coarse punctation, and finely pustulose surface of the type species *C. canadensis* (Logan). It has not been possible to confirm the presence of denticle grooves on the ventral cardinal area. The form of the shell, the number and size of the plicae, and the orientation and height of the cardinal area are also variable, as in the type species (see Logan, 1967).

According to Dagis (1974) the genus is known only from the Carnian in far eastern USSR and Arctic Canada.

Specimens of this species were referred to *Spiriferina* sp. by Rickwood.

Spiriferinid *indet*

A smooth coarsely punctate brachial valve with a high smooth fold and a parasulcate commissure is included here. The length of the hinge is unknown, but it is probably brachythyrid. It has similar contours to *Laballa* Moisseiev, but without a pedicle valve definite identification is impossible.

Zugmayerella sp.

Two pedicle valves and at least one brachial valve are placed in this genus. The characteristic internal structures of the pedicle valve and the denticle grooves on the cardinal area have been observed. Pedicle and brachial valves are separated, and since *Canadospira* occurs at the same locality it is not possible to be sure of the assignment of all the broken brachial valves.

This genus is known from the Norian-Rhaetian of Tethys and far-eastern USSR.

Specimens were identified as *Spiriferina* by Rickwood.

Sinucosta sp.

Three isolated pedicle valves, a broken specimen with the two valves together, and about ten isolated brachial valves are assigned to this genus. They have the separated dental lamellae and medium septum in the pedicle valve, and the long and widely divergent crural plates characteristic of the genus. The ventral cardinal area is too high and the sinus a little too deep for them to be referred to *S. emmrichi* (Suess). The genus is widespread in the Middle-Late Triassic of Tethys and extends into the Lias in Europe. The greatest similarities are with Norian-Rhaetian species.

It was an isolated brachial valve of this species that was referred to *Streptorhynchus* cf. *pyramidalis* King by Rickwood.

Athyroids.

Clavigera sp.

Several specimens of isolated valves and three with valves together clearly belong to this genus. The identification has been confirmed by Dr J. D. Campbell of Otago University, who notes that they are similar to young specimens of *Clavigera* from the New Zealand Otamitan and Otapirian (late Norian-Rhaetian). The genus occurs in a similar stratigraphic position in New Caledonia.

Stolzenburgiella n. sp.

Two almost complete individuals and many broken isolated valves probably belong to this genus. The doubt in the identification comes from the lack of data on the internal structure of the type and only known species, *S. bukowskii* Bittner, from the Anisian of the Dinaride Alps.

Rhynchonelloids. There are at least four genera of rhynchonelloids in the faunas.

Costirhynchia sp.

This genus can be confidently identified. It is known from the Middle and Late Triassic of the Alps, Carpathians, Caucasus and China (Dagis, 1974).

Robinsonella sp.

Several specimens of this genus are present. It comes from the Norian and Rhaetian of the Alps, Balkans and Caucasus (Dagis, 1974).

Among the others is a representative of the Praecyclothyridinae Makridin, that is similar in many respects to *Hagabirhynchia* Jeffries. This whole subfamily is restricted to the Late Triassic, and *Hagabirhynchia* is from the Norian of Oman, the Himalaya and Indonesia.

Strophomenoids.

Thecidacean indet.

The single valve in the Rickwood collection that was referred to *Marginifera* is a wide straight-hinged form with a sharply reflexed margin. The shell structure is coarsely fibrous—definitely not pseudo-punctate. It cannot be a productacean. On the other hand, although the shell structure is compatible with a thecidacean assignment, the specimen is unusually large for a member of that group, and the shell form is different from any genus as presently assigned to it. Proper identification awaits the discovery of the other valve and the internal structure.

Age

There is no guarantee that the sampling localities are all on the same stratigraphic level. Consequently the faunas are listed separately.

Locality 2 (Fig. 1, table 1)—Rickwood's loc. 116.

Species represented:

?*Zeilleria* sp.
Large Terebratuloid ('*D. cf. itaitubense*')
Canadospira sp.
Zugmeyerella sp.
Sinucosta sp.

Age: Zugmeyerella indicates a Norian-Rhaetian age and the species of *Sinucosta* is similar to Norian-Rhaetian species in Tethys. *Canadospira,* on the other hand, is known only from the Carnian, though it is recorded from only a few localities. The age is clearly Late Triassic with a Norian-Rhaetian restriction preferred.

Locality 2 (Fig. 1, Table 1)—Rickwood's loc. 117

Species represented:

?*Zugmeyerella* sp.
Clavigera sp.
Thecidacean indet

Age: The significance of *Clavigera* is discussed below.

Rickwood's locality 164 (locality not located, Table 1):

Species represented:

Large Terebratuloid ('*D. cf. itaitubense*')
Stolzenburgiella sp.

Locality 5 (Fig. 1, Table 1)—Rickwood's loc. C26/7

Species represented:

Rhychonelloids indet.
Robinsonella sp.
Sinucosta sp.

Age: The *Robinsonella* and *Sinucosta* both indicate Norian-Rhaetian age.

Locality 6 (Fig. 1, Table 1)—samples PNG-0, PNG-1

Species represented:

Clavigera sp.
Spiriferinid indet.
Large Terebratuloid ('*D. cf. itaitubense*')
Costirhynchia sp.
?*Hagabirhynchia* sp.

Age: Clavigera sp. being closely comparable with late Norian-Rhaetian species in New Zealand and New Caledonia, is regarded as most significant. *Costirhynchia* is consistent with this age, and *Hagabirhynchia* supports a Norian assignment.

Locality 1 (Fig. 1, Table 1)—sample 20NG 2688D

Species represented:

Calvigera sp.

Age: Late Norian-Rhaetian

Localities 4, 6 (Fig. 1, Table 1)—samples 20NG 1377A, 21NG 0664, 21NG 0665

Species represented:
Stolzenburgiella sp.

Age: Middle-Late Triassic. Since this genus is known only from the Anisian overseas it is difficult to know how to date these occurrences. The only known species is *S. bukowskii,* so further discoveries are bound to extend the generic range. The fact that it occurs at Locality 164 with the same large terebratuloid as occurs with *Clavigera* elsewhere in the Kuta Limestone, suggests that a Norian-Rhaetian age is not impossible.

Apart from *Clavigera* which is only known from the Maorian Province, and *Canadospira* from the far eastern USSR and Canada, all the brachiopod genera identified are from the Tethyan Province. Most of them are from the European or Middle Eastern part of the province, but their apparent absence farther east is probably due to a lack of study of the faunas in south east Asia.

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