

JOURNAL OF

THE ROYAL SOCIETY

OF

WESTERN AUSTRALIA

VOLUME 48

PART 1

PUBLISHED 12TH MARCH, 1965

REGISTERED AT THE G.P.O., PERTH FOR TRANSMISSION BY POST AS A PERIODICAL

THE
ROYAL SOCIETY
OF
WESTERN AUSTRALIA

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**Journal
of the
Royal Society of Western Australia**

Vol. 48

Part 1

1.—The Physiography, Vegetation and Vertebrate Fauna of the Wallabi Group, Houtman Abrolhos

By G. M. Storr*

Manuscript Accepted—18th August, 1964.

The physiography and vegetation are described. All known vascular plants are listed (including those from North Island). Brief accounts are given of the reptiles, land-birds and mammals. The biogeography of the islands is discussed.

Introduction

In order to procure live wallabies (*Macropus eugenii*) for experiments and to observe them in the field, the Zoology Department organised three short trips to the Wallabi Islands in 1959 (April 16-22, June 21-25 and September 2-12) and one in 1960 (April 22-27). The writer had the good fortune of taking part in all of them and was able to make extensive collections of vascular plants and vertebrate animals.

The physiography of the Wallabi Group has been described by Dakin (1919) and still more fully by Teichert (1947). The following account is therefore brief—just enough for describing plant habitats and for a later discussion of the biogeography of the islands. The vegetation will be dealt with at greater length, for scarcely anything was previously known of it. In the accounts of the fauna, the writer has drawn freely on the observations of the naturalists who preceded him in these islands.

Physiography

The Houtman Abrolhos lie about 40 miles off the west coast of Western Australia between latitudes 28 and 29. The sea-bed west of the mainland descends in the first 5-10 miles to a depth of 20 fathoms, but one must go a further 40-45 miles before reaching the 40-fathom line, westwards from which the sea-bed dips steeply to the edge of the continental shelf. The Abrolhos are thus situated towards the western margin of a gently sloping platform. Each of the island clusters (Wallabi, Easter and Pelsart Groups) is located on a plateau-like hump on this platform. Although soundings are limited, it seems that North Island rises from the same submarine plateau as the Wallabi Group.

East and West Wallabi, with areas of 900 and 1,500 acres and dunes up to 50 feet high, are by far the largest and highest of the Abrolhos Islands. They and their nearest neighbours emerge from a broad rock-flat, composed mainly of old corals reefs which were planed in an earlier cycle of erosion to a level of 1-2 feet above present sea-level. Subsequent erosion has lowered much of the flat, though considerable areas in the lee of West Wallabi still lie above low water.

On much of West Wallabi and almost all of East Wallabi the old reefs are overlain by beds of younger limestone, 3-10 feet thick. Their composition varies: in some areas, shells or coral fragments predominate; in others, there is little or no macroscopic structure. But whatever their composition, the beds are remarkably uniform in appearance at the surface. Everywhere the fairly level exposures are cracked, so that the resultant slabs form, as it were, a gigantic crazy pavement. There is sufficient soil between the slabs to support a moderately varied assemblage of shrubs. Subterranean caverns are common, and several sink-holes have been enlarged or cleaned out to form wells that provide a modest supply of fresh water.

This pavement limestone occupies a large unbroken portion of the western half of East Wallabi. Its occurrence on West Wallabi is discontinuous. The largest area is in the central south of the island, extending from low cliffs in Rocky Bay to the inner foot of the west coast dunes. The next largest occurrence is on the ridge immediately inland from the north-east coast between Blowfish and Slaughter Points. Towards the northern end of this ridge the beds attain their highest elevation (c.10 feet). All the islets in the vicinity of the two main islands (Pigeon, Little Pigeon, Seagull, Tattler, Pelican, etc.) are composed entirely of this limestone. Uniformly about six feet high and surrounded by vertical or undercut cliffs, they are confusingly similar in appearance. In contrast, the low islets at the eastern margin of the Wallabi Group (Beacon, Long, Dick's, etc.) consist largely of coral boulders and

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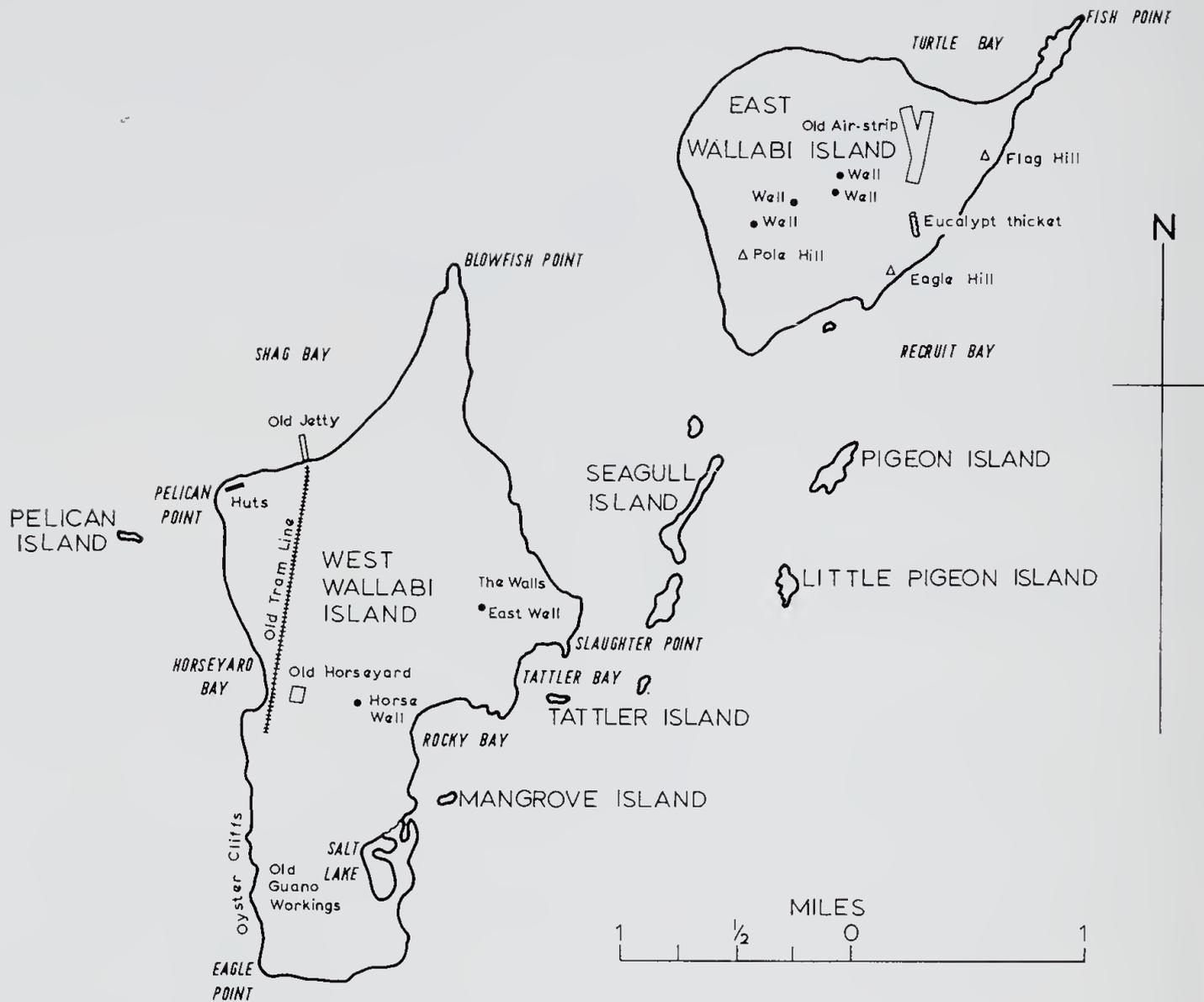


Fig. 1.—Wallabi Islands, Houtman Abrolhos, Western Australia.

shingle, much of it too recently thrown up from neighbouring lagoons to have become consolidated.

The only considerable part of the islands in which the old reef flat is not overlain by pavement limestone is the northern end of West Wallabi, west of the limestone ridge. Low-lying areas (less than two feet above sea-level), where the reef flat may appear at the surface, carry sheets of water after winter rains. Elsewhere the flat is covered with up to five feet of shell grit, interrupted here and there by narrow banks of guano-rich soil, usually striking N.E.-S.W. Evidently the whole of this area was a part of Shag Bay when sea-level was slightly higher than now. There is another and smaller break in the pavement limestone at the salt-lake, a little inland from the south-east coast of West Wallabi. At high tide the lake is connected with the sea by a small creek.

On East and West Wallabi (and North Island), alone of the Abrolhos, the pavement limestone may be overlain by dunes. Along the north and west coasts of East Wallabi and the central west coast of West Wallabi the dunes of calcareous sand are unconsolidated, and in

some places they are completely blown out. Between these dunes and the sea there are sandy beaches. In the eastern half of East Wallabi and the south-west corner of West Wallabi the dunes are consolidated, their orientation generally being N.N.W./S.S.E. and their bulk consisting of aeolianite, as can be seen in exposures at coastal cliffs. Where covered with sand the underlying presence of aeolianite is indicated by the greater density and variety of the vegetation compared to that on sandy dunes.

Vegetation

The dominant plant above beaches is the coarse tussocky grass, *Spinifex longifolius*. Other species are scarce and are represented by scattered individuals or an occasional stand of *Atriplex cinerea*, *Salsola kali*, *Senecio lautus* and *Poa caespitosa*. Shrubs are more common in the sandy dunes, e.g., *Olearia axillaris*, *Acanthocarpus preissii* and occasionally *Myoporum insulare*; but much of the ground is bare.

Seeing that the distinction between sand and shell grit is merely one of particle size, the vegetation of the two are surprisingly different. The plant cover is much more continuous on

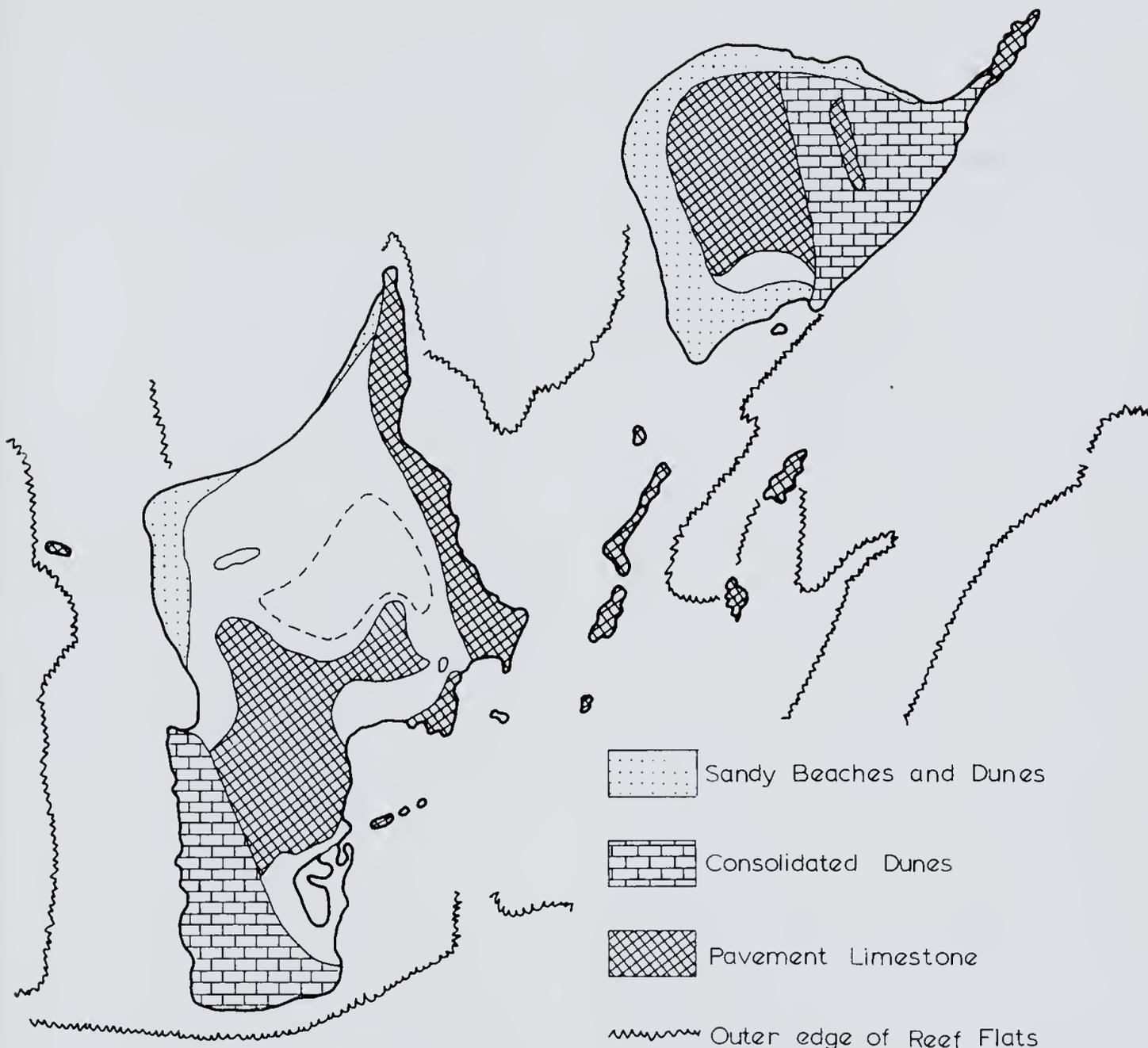


Fig. 2.—Wallabi Islands, showing physiographic divisions. The unshaded areas mainly consist of shell grit. The broken line in the middle of West Wallabi encloses land less than two feet above sea-level; it is an old rock-flat with little or no covering of shell grit; to its west is a small ridge of pavement limestone that was inadvertently left unhatched on this map.

the shell grit. A low saltbush is dominant, *Atriplex paludosa*, which tends to be replaced in low-lying areas by the shrubby samphire, *Arthrocnemum halocnemoides*. Other species include *Threlkeldia diffusa*, *Senecio lautus*, *Frankenia pauciflora* and stunted shrubs of *Olearia axillaris*. The whole of this country on West Wallabi is riddled with the burrows of mutton-birds (*Puffinus pacificus*). On East Wallabi, where beds of shell grit are much less extensive, the saltbush and samphire is replaced by thickets of *Diplolaena dampieri* and *Alyxia buxifolia*. In the narrow ecotone between the shell grit and pavement limestone the vegetation becomes sparse and virtually restricted to *Frankenia*.

Despite the scarcity of soil, the pavement limestone supports a fairly rich vegetation. The dominant species are shrubs from 3-8 feet tall:

Pittosporum phillyreoides, *Diplolaena dampieri*, *Grevillea argyrodendron*, *Spyridium globulosum*, *Exocarpus aphylla*, *Capparis spinosa*, *Pimelea microcephala*, *Sarcostemma australe*, *Olearia axillaris* and *Beyeria viscosa*. Also commonly present are *Dianella revoluta*, *Acanthocarpus preissii* and *Hibbertia subvaginata*.

All plants of the pavement limestone may be found on consolidated dunes; and on East Wallabi, where the aeolianite is usually close to the surface, several additional shrubs appear: *Dodonaea inaequifolia*, *Trichinium divaricatum*, *Lasiopetalum angustifolium*, *Leucopogon insularis*, *Acacia bivenosa*, *Mirbelia ramulosa* and *Bossiaea rufa*. In one valley there is a thicket of *Eucalyptus oraria*, about 6 chains long and 1-2 chains wide. Though their stems are up to six inches in diameter, they have been so bent over by the prevailing southerlies that the

tops of the trees are only 3-8 feet above the ground. Possibly some of the larger trees have been removed, for in 1843 Gilbert found a tree whose trunk was 18 inches through. Otherwise this thicket seems to be much as it was 120 years ago.

In contrast to East Wallabi, the flora of the consolidated dunes on West Wallabi is impoverished. Large areas are completely overrun by *Nitraria schoberi*; and the introduced succulent, *Cryophytum crystallinum*, monopolises otherwise bare ground.

Annual rainfall in the Abrolhos is probably about 12-15 inches, most of it falling from May to September. During my visit in April 1959, the condition of the vegetation was generally poor. The first substantial rain fell (in my absence) on May 29. Some showers were received on June 17, 2-3 inches on June 19, and a considerable amount on June 20 (the day before my second visit). By June 22 the vegetation had recovered: *Pimelea* was shooting profusely; *Carpobrotus* was clearly filling out; and *Diplolaena* had lost its grey half-dead appearance. Seedlings of annual species were abundant, but most of them were too young for identification. By early September the annuals had matured and were flowering. They were especially plentiful in mutton-bird rookeries and on offshore islets.

One of the anomalies of the vegetation of the islands is its greater richness on East Wallabi than on the considerably larger West Wallabi. The latter, though generally similar physiographically to East Wallabi, differs in certain other respects. First, West Wallabi has (or had) large deposits of guano. Second, it alone is colonised by burrowing petrels. Finally, but not so certainly, it has a denser population of wallabies.

It has already been mentioned that the consolidated dunes of West Wallabi are dominated by *Nitraria*, whereas those of East Wallabi support a good variety of shrubs and low trees, including several species unknown from West Wallabi. This difference can only be due to the ubiquitous presence of guano in the southwestern dunes of West Wallabi. As Gillham (1963) has shown, few species of plants tolerate a high concentration of guano.

Extraction of the guano between 1884 and World War I involved the vegetation in large-scale disturbances. Before removing the guano, which mostly lodges among boulders of limestone, all plants were stripped from an area, the stones laid to one side, and the soil shovelled with hoes and swept with heavy brooms into heaps (Helms 1902). Apart from the remains of a jetty, tramline and horseyard, and some obviously unnatural hollows and heaps of stones in the dunes, there was little evidence in 1959 of this once profitable industry. All the old excavations were completely revegetated but whether any plant species were permanently affected by this activity could not be ascertained. Likewise unknown is the effect of stock on the islands, e.g. the flock of goats formerly depastured on East Wallabi.

The presence of burrowing petrels on West Wallabi has had a twofold effect: (1) the suppression of sclerophyllous shrubs (with the

partial exception of *Frankenia* and *Olearia*) and their replacement by halophytic shrubs; (2) the encouragement of coprophilous annuals such as *Urtica urens*, *Chenopodium murale*, *Stellaria media* etc. The dominance of saltbush and samphire on the beds of shell grit inland from Shag Bay seemed at first sight to be due to soil salinity. But on East Wallabi similar beds between the limestone pavement and the beach at the southern tip of the island were found to carry a scrub of *Diplolaena* and *Alyxia*. The conclusion was inescapable that the petrels, whose burrows occurred throughout the West Wallabi shell grit, were in some way responsible for the dominance of the halophytes.

Apart from their 'hedging' of shrubs (details of which are given later) it is not easy to discern the effect of wallabies on the vegetation. If one compares the vegetation of the Wallabi Islands with that of North Island (on which wallabies no longer occur), the only obvious differences are the greater abundance of *Myoporum* on North Island, and the greater height and density of the annuals, especially grasses and composites, several species of which have not yet been recorded from the Wallabi Islands. As for differences between the two Wallabi Islands, the only one that seems attributable to wallabies is the relative abundance of *Eremophila glabra* in the eastern dunes of East Wallabi, where the animals are apparently not plentiful. This highly palatable under-shrub was found on West Wallabi only in a small area east of Horse Well. If a portion of the old air-strip on East Wallabi were fenced off, the effect of the numerous wallabies in that area would soon be revealed.

Annotated List of Plants

In a brief account of the vegetation of North Island (Storr 1960) only perennial plants were mentioned. The opportunity has been taken here to include all the species that were collected or observed on that island.

An asterisk before a specific name signifies that the plant has been introduced, and one after the name of an island signifies that the record is based on material identified by Mr. R. D. Royce. Many of the herbaceous species were only seen in winter and spring; though recorded herein as "annual", some of them could in fact be perennial in the strict sense of the word.

POTAMOGETONACEAE

Cymadocea antarctica (Labill.) Endl. and *Posidonia australis* Hook. f. Both these seaweeds were found cast up on the coast of West Wallabi*, and the first was also found on North I*.

SCHEUCHZERIAEAE

Triglochin mucronata R. Br. Small annual. North I.* (banks of salt-lake), West Wallabi* (damp flats).

T. trichophora Nees. Small annual. North I.*, East Wallabi*.

T. muelleri Buch. Small annual. East Wallabi*

GRAMINEAE

Setaria dielsii Herm. Annual. North I.*, West Wallabi*, Pigeon I.*.

Spinifex longifolius R. Br. Perennial. Coastal sand: North I.*, East Wallabi*, West Wallabi*.

**Phalaris minor* Retz. Annual. North I.* (near fishermen's camp), West Wallabi (mutton-bird rookeries).

Stipa elegantissima. Labill. Perennial. East Wallabi (consolidated dunes), West Wallabi*, Pigeon I.

S. variabilis Hughes. Perennial. North I., East Wallabi* (pavement), West Wallabi* (rare), Tattler I.

S. crinita Gaud. North I.*.

Sporobolus virginicus (L.) Kunth. Perennial. North I.* (damp soil south of salt-lake), West Wallabi* (shingly sea-sprayed beach on south coast).

Agrostis avenacea Gmel. East Wallabi*, West Wallabi*.

Polypogon monspeliensis (L.) Desf. Annual West Wallabi*.

P. tenellus R. Br. Annual. East Wallabi*, West Wallabi*.

**Avena fatua* L. Annual. North I.*.

Danthonia caespitosa Gaud. Perennial. North I.*, East Wallabi*.

**Koeleria phleoides* Pers. Annual. North I.*.

**Vulpia myuros* (L.) Gmel. Annual. North I.*, East Wallabi*, West Wallabi* (mutton-bird rookeries).

Eragrostis dielsii Pilger. North I.*.

Poa caespitosa Forst. Perennial. East Wallabi* (sand dunes).

**Bromus madritensis* L. Annual. North I.*.

B. arenarius. Labill. Annual. North I.*, East Wallabi* (pavement), West Wallabi* (north-east coast and mutton-bird rookeries).

**B. molliformis* Lloyd. Annual. North I.*.

**Cynodon dactylon* Rich. Perennial. North I.*, (around fishermen's huts).

**Hordeum leporinum* Link. Annual. North I.*.

CYPERACEAE

Scirpus antarcticus L. Small annual. East Wallabi*, West Wallabi*.

JUNCACEAE

Juncus bufonius L. Small annual. North I.*, East Wallabi (stony gully in eastern dunes).

LILIACEAE

Anguillaria dioica R. Br. Annual. North I.*, East Wallabi*, West Wallabi*.

Bulbine semibarbata (R. Br.) Haw. Annual. North I.* (shallow soil over limestone), East Wallabi* (consolidated dune), West Wallabi* (pavement and shell grit).

Thysanotus patersoni R. Br. Perennial twiner. North I.*, East Wallabi*, West Wallabi* (pavement), Pigeon I.

Dianella revoluta R. Br. Perennial. East Wallabi* (consolidated dune), West Wallabi and Pigeon I. (pavement).

Acanthocarpus preissii Lehm. Low sprawling shrub. Pavement, consolidated dune, shallow sand over limestone; North I.*, East Wallabi, West Wallabi, Pigeon I.

ORCHIDACEAE

Microtis unifolia (Forst.) Reichb. Annual. East Wallabi* (pavement).

URTICACEAE

**Urtica urens* L. Annual. West Wallabi* (mutton-bird rookeries).

Parietaria debilis G. Forst. Small annual. North I.*, East Wallabi* (consolidated dunes), West Wallabi* (mutton-bird rookeries).

PROTEACEAE

Grevillea argyrophylla Meissn. Shrub. East Wallabi* (consolidated dunes), West Wallabi* and Pigeon I. (pavement).

SANTALACEAE

Exocarpus spartea R. Br. Shrub. North I.* (sand dunes).

E. aphylla R. Br. Shrub. East Wallabi* (consolidated dunes), West Wallabi* and Tattler I. (pavement).

CHENOPODIACEAE

Rhagodia baccata (Labill.) Moq. Succulent shrub. Shell grit, consolidated dunes, pavement: North I.*, East Wallabi*, West Wallabi*, Tattler I., Pigeon I.

Chenopodium nitrariaceum (F. v. M.) Benth. Low succulent shrub. East Wallabi*.

Ch. carinatum R. Br. Annual. East Wallabi* (gull rookery at Fish Point).

**Ch. murale* L. Annual. North I.* (? sp.), West Wallabi* (mutton-bird rookeries and guano), Pelican I.

Ch. plantaginellum (F. v. M.) Aellen. Annual. East Wallabi* (gull rookery at Fish Point).

Atriplex paludosa R. Br. Low succulent shrub. Abundant on shell beds, shell grit, shingies: North I.*, West Wallabi*, Pelican I., Mangrove I., Tattler I., Pigeon I., Long I.

A. cinerea Poir. Low succulent shrub. North I.* and East Wallabi (fore-dune).

Enchylaena tomentosa R. Br. Low succulent shrub. North I.*, Pelican I., Mangrove I., Pigeon I.

Threlkeldia diffusa R. Br. Small ascending succulent shrub. Coastal sand, shingles and rock, and inland on shell grit: North I.*, East Wallabi*, West Wallabi*, Tattler I., Pigeon I.

Arthrocnemum arbuscula R. Br. Succulent shrub. North I.* (muddy floor of sink-hole, and banks of salt-lake), East Wallabi (coastal shell beds), West Wallabi* (shell grit and especially banks of guano), Pigeon I.

A. halocnemoides Nees. Succulent shrub. Shallow shell grit over limestone: North I.*, East Wallabi, West Wallabi*.

Salicornia australis Banks & Sol. Small flaccid succulent shrub. North I.* (damp mud in sink-hole, and low-lying flat south of salt-lake), West Wallabi (edge of tidal creek), Tattler I. (beneath mangroves).

Suaeda australis (R. Br.) Moq. Small flaccid succulent shrub. North I.* (with *Salicornia* and *Sporobolus* in damp soil south of salt-lake), Tattler I. (beneath mangroves).

Salsola kali L. Annual. North I.* (leeward slopes of east dunes), West Wallabi (beach).

AMARANTHACEAE

Trichinium obovatum Gaud. Small shrub. East Wallabi* (pavement).

T. divaricatum Gaud. Shrub. East Wallabi* (consolidated dunes).

T. eriотrichum (W. V. Fitzg.) C. A. Gardn. Climbing shrub. East Wallabi* (consolidated dunes), West Wallabi* (pavement).

Ptilotus villosiflorus F. v. M. Annual. West Wallabi*.

AIZOACEAE

**Cryophytum crystallinum* (L.) N. E. Br. Prostrate succulent annual. North I.* (banks of salt-lake), West Wallabi (guano workings), Pelican I. (abundant), Tattler I., Pigeon I.

Carpobrotus aequilaterus (Haw.) N. E. Br. Prostrate succulent perennial. North I.*, East Wallabi (consolidated dunes), West Wallabi (pavement, especially near coast), Tattler I., Pigeon I. White flowers as well as red on North and Tattler Islands.

PORTULACACEAE

Calandrinia calyptrata Hook. f. Small succulent annual. North I.*.

CARYOPHYLLACEAE

**Stellaria media* (L.) Vill. Small annual. West Wallabi* (mutton-bird rookeries).

**Sagina apetala* L. Small annual. East Wallabi*.

**Spergularia rubra* (L.) J. & C. Presl. Small annual. North I.*, East Wallabi*, West Wallabi*, Pigeon I.

RANUNCULACEAE

Ranunculus parviflorus L. Small annual. East Wallabi*.

CAPPARIDACEAE

Capparis spinosa L. Trailing shrub. Pavement and consolidated dune: East Wallabi*, West Wallabi*, Tattler I., Pigeon I.

CRUCIFERAE

Hymenolobus procumbens (L.) Nuttall. Small annual. North I.*, East Wallabi*, West Wallabi*.

Cakile maritima Scop. Annual. North I.* (beaches and blown-out dunes), East Wallabi.

CRASSULACEAE

Crassula colorata (Nees) Ostenf. Small annual. North I.*, East Wallabi* (sand dunes), West Wallabi*.

PITTOSPORACEAE

Pittosporum phillyreoides DC. Tall shrub. Pavement and consolidated dunes: East Wallabi*, West Wallabi*, Tattler I., Pigeon I.

CUNONIACEAE

Aphanopetalum clematideum (Drumm. & Harv.) C. A. Gardn. Shrub. East Wallabi*.

LEGUMINOSAE

Acacia bivenosa DC. Shrub. East Wallabi* (consolidated dunes).

Mirbelia ramulosa (Benth.) C. A. Gardn. Shrub. East Wallabi* (consolidated dunes).

Bossiaea rufa R. Br. var. *foliosa* Benth. Shrub. East Wallabi* (consolidated dunes).

GERANIACEAE

Erodium cygnorum Nees. Annual. North I.*, East Wallabi*, Pigeon I. (? sp.).

**E. cicutarium* (L.) L'Her. Annual. East Wallabi* (consolidated dunes), West Wallabi* (mutton-bird rookeries).

Pelargonium littorale Hugel. East Wallabi*.

OXALIDACEAE

Oxalis corniculata L. Small annual. East Wallabi* (consolidated dunes), West Wallabi*.

ZYGOPHYLLACEAE

Zygophyllum apiculatum F. v. M. Small annual. North I.*, East Wallabi*, West Wallabi*.

Nitraria schoberi L. Succulent shrub, sometimes tall. Coastal: North I.*, East Wallabi, West Wallabi, Pelican I., Mangrove I., Tattler I., Pigeon I., Long I., Beacon I.

RUTACEAE

Diplolaena dampieri Desf. Shrub. East Wallabi* (pavement, consolidated dunes, shell grit), West Wallabi* and Pigeon I. (pavement).

EUPHORBIACEAE

Phyllanthus calycinus Labill. Small shrub. East Wallabi* (consolidated dunes), West Wallabi.

Euphorbia drummondii Boiss. Small annual. East Wallabi*.

E. clutoides (Forst.) C. A. Gardn. Annual. North I.* (inner slope of western dunes).

Beyeria viscosa (Labill.) Miq. Shrub. East Wallabi* (pavement and consolidated dunes), West Wallabi* (pavement).

STACKHOUSIACEAE

Stackhousia viminea Sm. Perennial herb. North I.*, East Wallabi*, West Wallabi*.

SAPINDACEAE

Dodonaea aptera Miq. Shrub. North I.*, East Wallabi* (consolidated dunes and pavement), West Wallabi* (pavement).

D. inaequifolia Turcz. Shrub. East Wallabi* and West Wallabi* (pavement).

RHAMNACEAE

Spyridium globulosum (Labill.) Benth. Shrub, sometimes tall. Shallow sand over limestone, consolidated dunes and pavement: North I.*, East Wallabi, West Wallabi*.

MALVACEAE

Lavatera plebeja Sims. Tall perennial herb. Pelican I. (single plant).

**Malva parviflora* L. Annual. North I., East Wallabi*, Pigeon I.*.

STERCULIACEAE

Lasiopetalum angustifolium W. V. Fitzg. Shrub. East Wallabi* (consolidated dunes).

DILLENIACEAE

Hibbertia subvaginata Steud. Small shrub. East Wallabi*, West Wallabi* (pavement).

FRANKENIACEAE

Frankenia pauciflora DC. Small shrub. North I.* (shallow soil over limestone, especially at inner foot of western dunes), East Wallabi* (consolidated dunes), West Wallabi* (stony country near coast, and shell grit, especially where it contacts pavement), Tattler I., Pigeon I.

THYMELAEACEAE

Pimelea microcephala R. Br. Shrub. North I.* (shallow sand over limestone; rare), East Wallabi* (consolidated dunes), West Wallabi* (pavement), Tattler I., Pigeon I.

MYRTACEAE

Eucalyptus oraria L. A. S. Johnson. Small tree. East Wallabi* (consolidated dunes). Restricted to a single valley in the eastern dunes between Flag and Eagle Hills. A specimen collected by Dr. D. L. Serventy in 1945 was identified by Mr. C. A. Gardner (1949) as *E. gracilis*, a species otherwise known only from the semi-arid woodlands of the southern interior of the State. In *E. gracilis* the bark is deciduous, whereas all but the smallest branches of the East Wallabi trees are covered with rough grey bark. The trees were beginning to flower on April 20, 1959.

HALORAGACEAE

Haloragis trigonocarpa F. v. M. Perennial herb. East Wallabi*.

UMBELLIFERAE

Didiscus pilosus Benth. Annual. East Wallabi*.

Hydrocotyle diantha DC. Small annual. East Wallabi* (stony gully in eastern dunes), West Wallabi*.

Apium australe Pet.-Thou. Small annual. East Wallabi* (consolidated dunes), West Wallabi* (mutton-bird rookeries).

Daucus glochidiatus (Labill.) Fisch., Mey. & Ave-Lall. Small annual. North*, East Wallabi* (consolidated dunes), West Wallabi*.

EPACRIDACEAE

Leucopogon insularis A. Cunn. Shrub. East Wallabi* (pavement and consolidated dunes).

PRIMULACEAE

**Anagallis femina* Mill. Annual. West Wallabi*.

PLUMBAGINACEAE

Limonium salicorniaceum (F. v. M.) Low spreading shrub. North* (shallow soil over limestone), East Wallabi, (hollows in consolidated dunes) West Wallabi* (shell grit and guano banks), Tattler I., Pigeon I.

GENTIANACEAE

**Erythraea centaurium* Pers. Annual. North I.* (shallow soil over limestone), East Wallabi*, West Wallabi* (pavement).

APOCYNACEAE

Alyxia buxifolia R. Br. Shrub. East Wallabi* (shell grit, pavement, consolidated dune), West Wallabi (limestone near coast).

ASCLEPIADACEAE

Sarcostemma australe R. Br. Sprawling succulent shrub. East Wallabi* (consolidated dunes), West Wallabi and Pigeon I. (pavement).

BORRAGINACEAE

Cynoglossum australe R. Br. Annual. East Wallabi, West Wallabi*.

Trichodesma zeylanicum (L.) R. Br. Tall annual. North I.*.

VERBENACEAE

Avicennia marina (Forsk.) Vierh. Small tree (mangrove). West Wallabi* (a few in salt creek and at foot of nearby islet), Tattler I. (good clump on northern sheltered side of islet).

LABIATAE

Westringia dampieri R. Br. Shrub. East Wallabi* (pavement, consolidated dunes and, rarely, sand dunes), West Wallabi (limestone near coast).

SOLANACEAE

Solanum nigrum L. Herb. East Wallabi* (consolidated dunes and pavement, especially in and near wells), West Wallabi*.

Nicotiana rotundifolia Lindl. Annual. North I.*, East Wallabi*, Pigeon I.*.

SCROPHULARIACEAE

**Dischisma arenarium* E. Mey. Small annual. West Wallabi (shell grit).

MYOPORACEAE

Eremophila glabra (R. Br.) Ostenf. Low, somewhat flaccid shrub. East Wallabi* (consolidated dunes), West Wallabi (in a restricted area a little east of Horse Well).

Mycoporum insulare R. Br. Shrub, sometimes tall. North I.* (inner slope of eastern dunes), East Wallabi*, West Wallabi (pavement and sand near coast), Pigeon I., Long I.

PLANTAGINACEAE

Plantago varia R. Br. Annual. North I.* (shallow soil over limestone), East Wallabi*. West Wallabi*.

RUBIACEAE

Galium sp. Small annual. East Wallabi*.

GOODENIACEAE

Scaevola crassifolia Labill. Shrub. North I.* (dunes), East Wallabi (sandy and consolidated dunes).

COMPOSITAE

Brachycome iberidifolia Benth. Annual. East Wallabi*.

B. ciliaris (Labill.) Less. Annual. North I.*, East Wallabi*.

Vittadinia triloba (Gaud.) DC. Annual. East Wallabi*.

Olearia axillaris (DC) F. v. M. Shrub. North I.*, East Wallabi*, West Wallabi, Pigeon I.

Gnaphalium luteo-album. L. Annual. North I.* East Wallabi*.

Pcdosperma angustifolium Labill. Annual. North I.*, West Wallabi*.

Calocephalus aeruoides (F. v. M.) Benth. Annual. East Wallabi*, West Wallabi*.

Gnaphalodes uliginosus A. Gray. Annual. North I.*, East Wallabi*, West Wallabi*.

Senecio lautus Soland. Annual (or perennial in favourable situations). Mainly coastal. North I.*, East Wallabi*, West Wallabi, Pelican I., Pigeon I.

S. brachyglossus F. v. M. Annual. North I.*, East Wallabi*.

Picris hieracioides L. Annual. East Wallabi*.

**Sonchus oleraceus* L. Annual. North I.*, East Wallabi, West Wallabi*, Pelican I., Tattler I., Pigeon I.

Reptiles

The Wallabi Islands have a surprisingly rich reptile fauna. Of the 18 species* definitely recorded from the group, all occur on West Wallabi which has an area of only 2.3 square miles. Moreover, several species are represented by abnormally dense populations, viz. *Egernia stokesi*, *Amphibolurus barbatus*, *Phyllurus milii* and *Python spilotos*. On the other hand, certain species (notably the geckoes *Gehyra variegata* and *Heteronota bynoei*) are rare by mainland standards. Nevertheless, reptiles are clearly the dominant vertebrates in the group, and they have evidently profited from the scarcity of land birds (5 resident species).

Apart from their ecological interest, Abrolhos reptiles are important taxonomically, for the types of seven species came from these islands. Knowledge of this fauna began in 1840 with the collections of HMS Beagle, two of whose officers are commemorated in *Egernia stokesi* and *Heteronota bynoei*. Two years later John Gilbert visited the Abrolhos, but unfortunately, as with the 'Beagle' collections, no record was kept of the islands on which his numerous specimens were obtained. Gilbert (1843) does mention a lizard on Pelsart Island that is undoubtedly *Egernia kingi*. He also saw a Green Turtle in the Wallabi Group, and on most islands he found the remains of "Hawksbill Turtles."

The ornithologist A. J. Campbell visited the Abrolhos in December 1889 and recorded five species, only one of which (*Python spilotos*) explicitly came from the Wallabi Group (Campbell 1890). During a long visit in 1894-5, Otto Lipfert (a former preparator in the W.A. Museum) seems only to have collected *Rhynchoelaps bertholdi*, a single specimen from West Wallabi.

The naturalists of the Percy Sladen Trust Expedition to the Abrolhos in 1913 and 1915 were the first generally to record the precise locality of their specimens. They obtained ten species on the Wallabi Islands, eight of them constituting the first definite record for the group (Alexander 1922).

An expedition from Harvard University spent a fortnight on the Wallabi Islands in October 1931. Their large collection of reptiles included six species that were new for the group (Loveridge 1934).

During four visits in 1959-60, my colleagues and I were only able to add another two species. It would seem, then, that the fauna was almost completely known. Yet in the British Museum (according to its catalogues) there are six more species from the Abrolhos: *Diplodactylus vittatus* Gray, *Egernia whitei* Lacépède, *Tiliqua rugosa* (Gray), *Sphenomorphus richardsoni* (Gray), *Hemiergis quadrilineatus* (Gray), and *Denisonia coronata* (Schlegel), as well as two species of frog: *Limnodynastes dorsalis* (Gray) and *Myobatrachus gouldi* (Gray). The specimen of *Sphenomorphus richardsoni*, collected by Bynoe, remains unique. All the others were collected by Gilbert. Perhaps most if not all of them actually came from the mainland; though it is possible that they were collected

in the imperfectly explored Pelsart and Easter Groups, from which only two species are certainly known: *Egernia kingi* (Pelsart Island) and *E. stokesi* (Rat Island). However, more field work must be carried out on the islands before these problematical species are disposed of. As none of them are localised, they are excluded from the following list.

GEKKONIDAE

Phyllurus milii Bory. East Wallabi, West Wallabi, Pigeon I. Abundant; especially under slabs of limestone. Commonly seen at night when out feeding on bare ground.

Diplodactylus spinigerus Gray. West Wallabi. Moderately plentiful. Several were found walking on the ground in daylight. Gilbert collected the two syntypes in the Abrolhos.

Phyllodactylus ocellatus (Gray). West Wallabi. Uncommon. The two syntypes of *Diplodactylus bilineatus* Gray (currently regarded as synonymous with *ocellatus*) were obtained by Gilbert in the Abrolhos.

Phyllodactylus marmoratus (Gray). East Wallabi, West Wallabi, Pelican I., Tattler I. Not common on the larger islands, but abundant under slabs of limestone on offshore islets, where it is the only gecko. My specimen from East Wallabi came from a hollow eucalypt log. Four of the five syntypes were collected by Gilbert in the Abrolhos.

Heteronota bynoei Gray. West Wallabi. In contrast to their abundance on the mainland of Western Australia this and the following species are the rarest geckoes in the group. The Harvard Expedition collected one, and I got two under driftwood on a shingly beach. The type was obtained by Gilbert in the Abrolhos.

Gehyra variegata (Duméril & Bibron). West Wallabi. The two I collected are the only specimens from the Abrolhos apart from one in the British Museum whose collector is unknown.

PYGOPODIDAE

Lialis burtoni Gray. East Wallabi, West Wallabi. Uncommon. This may be the 'small grey snake' seen by Alexander on East Wallabi and tentatively referred to *Denisonia coronata*.

Delma fraseri Gray. West Wallabi. Alexander's two specimens are the only record for the Abrolhos.

AGAMIDAE

Amphibolurus barbatus (Cuvier). East Wallabi, West Wallabi. Abundant, especially in sandy country among clumps of *Spinifex longifolius*. These lizards differ considerably from those on the mainland of Western Australia and were described by Loveridge as a distinct race, *minimus*. They are mainly distinguished on their smaller size, narrower head, and longer tail and hind-legs.

SCINCIDAE

Egernia stokesi (Gray). East Wallabi, West Wallabi, Tattler I., Pigeon I. Abundant, especially under slabs of limestone. Two of my East Wallabi series were taken from the hollow stems of dead shrubs. The 12 syntypes were collected in the Abrolhos, four of them by Gil-

*Recently an additional species was collected by the Aquinas College Expedition, viz. the skink, *Rhodona nigriceps* (Glauert).

bert, the others presumably by the 'Beagle'. Abrolhos specimens never attain the size of mainland animals.

E. kingi (Gray). East Wallabi, West Wallabi, Pigeon I. Moderately plentiful, favouring *Spinifex longifolius* and other coastal habitats. Also seen, but not captured, on Tattler Island, a $\frac{3}{4}$ acre islet off the east coast of West Wallabi. The Abrolhos population probably merits sub-specific rank.

Ctenotus lesueuri (Duméril & Bibron). East Wallabi, West Wallabi. Plentiful in all habitats. The 14 specimens obtained by the Harvard Expedition were misidentified by Loveridge as *Egernia formosa* Fry, a species that is restricted to the Kalgoolie-Laverton region.

Rhodona praepedita (Boulenger). East Wallabi, West Wallabi. Uncommon. My East Wallabi specimen was collected under leaf litter in the eucalypt thicket. Two specimens obtained a few days earlier on North Island were listed in Storr (1960) under *Lygosoma praepeditum* Boulenger, a commonly used synonym of *lineata*.

Ablepharus boutoni (Desjardin). East Wallabi, West Wallabi. My specimens came from low cliffs of limestone, into the crevices of which they dart when disturbed. They belong to the race *plagiocephalus* Cocteau. A small skink seen on Tattler Island was possibly of this species.

Ablepharus lineocellatus Duméril & Bibron. East Wallabi, West Wallabi. Moderately plentiful in sandy country. This is the species referred to by Alexander as a *Lygosoma* with an 'orange head and pink throat'.

Ablepharus elegans (Gray). West Wallabi. The three specimens of the Harvard Expedition are the only record for the Abrolhos.

BOIDAE

Python spilotus Lacépède. East Wallabi, West Wallabi. Common in all habitats. During the day they are usually found coiled up beneath a bush, though an occasional one may be seen moving around. At night they are more active. They probably hibernate in winter; at any rate none was seen during my visit in late June 1959. One of the specimens collected by the Harvard Expedition had just swallowed a young *Egernia stokesi*. J. Akerstrom, a fisherman living on West Wallabi, has seen young wallabies inside Carpet Snakes.

ELAPIDAE

Rhynchoelaps bertholdi (Jan). East Wallabi, West Wallabi. Uncommon. Usually found under slabs of limestone.

Land Birds

In contrast to the diversity of the herpetofauna, only five species of bird are certainly resident in the Wallabi Group. Two more species, the kestrel and cuckooshrike, are possibly resident, and the cuckoo could be a regular visitor in spring.

Little has been learnt of the land birds since Gilbert's visit in 1843. Later workers have paid much more attention to the sea birds, which nest in great numbers on these islands. A paper devoted to marine and littoral species has been prepared for publication in the *Emu*.

TURNICIDAE

Turnix varia (Latham). The Painted Quail is common on East and West Wallabi. Also occurred on one of the Pigeon Islands (Alexander 1922).

Most of the West Wallabi population occurs in low dunes covered with *Spinifex* and in the more open parts of the saltbush and samphire flats. They are even found in the dense tangles of *Nitraria* covering the old guano workings north of Eagle Point; but they shun the large areas of pavement limestone. Much of their food is obtained by scratching in the surface soil, the resultant scrapes being very characteristic of the areas they are abundant in. On loose sand, e.g., just above high-water mark, the scrapes tend to be circular depressions about 5 inches in diameter and 1-2 inches deep. Further inland they are less deep and usually crescentic in shape and thus remarkably like the hoof-marks of horses. They are excavated by scratching 2-3 times with one foot, then half-rotating the body and scratching with the other foot. They also visit the fishermen's camp at Pelican Point to feed on scraps.

At night they sleep on the ground, usually in pairs side by side at the foot of a bush. Their eyes shine red in torch-light, and they can often be picked up by hand. The weight of six birds was, 61, 65, 65, 66, 67 and 70 g. The colour of the upper bill was dark bluish grey, the iris vermilion, and the legs deep chrome-yellow.

On April 26, 1960, one was flushed from a nest south-east of the 'Walls'. It was located among shrubs of *Frankenia pauciflora*, which on West Wallabi dominates the narrow zone between shelly flats and limestone ridges (this ecotone constitutes a favourite feeding area). The nest was a saucer shaped depression nearly 4 inches across and $\frac{3}{4}$ inch deep, lined with fine twigs, and sheltered from above by a *Frankenia*. The three white eggs were finely dotted with brown and had underlying grey spots. Further south (and a little inland from Rocky Bay) a nest was found that was protected from above by a sparse dead bush and a few wind-blown inflorescences of *Spinifex*. The three eggs were somewhat different in colour to the first clutch; they were pale brown, finely flecked with reddish and dark brown. That evening two chicks were found among *Spinifex* behind the fishermen's huts at Pelican Point. Hall (1902) found eggs on October 20, which indicates a long breeding season.

The Abrolhos populations constitute an endemic race, *scintillans* Gould. The differences between it and the mainland race, *stirlingi* Mathews, are discussed by Alexander (1922).

COLUMBIDAE

Phaps elegans (Temminck). The Brush Bronzewing is common on East and West Wallabi and Pigeon Island.

On West Wallabi they occur in all kinds of vegetation, including (unlike the quail) the scrub growing on limestone. On April 21, 1959, an empty nest was found on top of a *Spinifex* tussock. The saucer-shaped platform of *Spinifex* roots was 5 inches in diameter and sheltered from above by a few blades of the grass. On

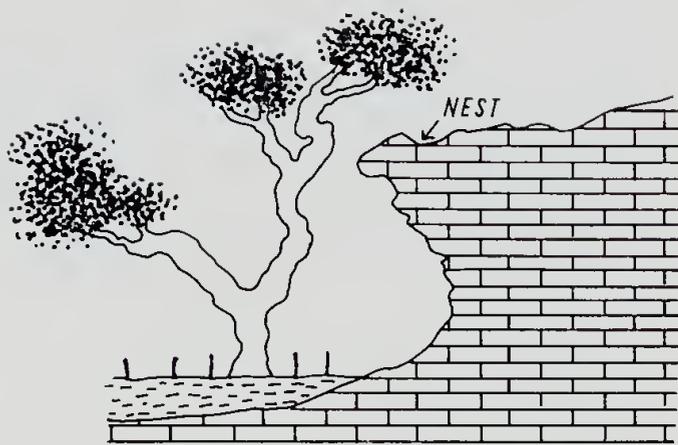


Fig. 3.—Location of Brush Bronzewing nest on Tattler Island. Height of cliff about five feet.

April 26 of the following year a pigeon was flushed from two eggs in a relatively substantial nest in a dense bush of *Myoporum insulare* near East Well. On the same day a remarkable nest was found on Tattler Island; the two eggs had been laid on a few fine twigs placed in a slight depression in the limestone at the edge of a low cliff, the nest being sheltered from above by the dense foliage of a mangrove (see sketch, Figure 3). Since Alexander found a nest with a fresh egg as late as November, the breeding season must be spread over many months.

Four birds (the first three female) shot on West Wallabi on April 22, 1959, had the following data: weight, 185, 157, 169, 173 g; wing, 155, 157, 156, 154 mm; total length in the flesh, 284, 278, 274, 280. The bill was black; the legs red, becoming black towards ends of toes; and the iris very dark brown (almost black).

A ringed Domestic Pigeon was caught at the fishermen's camp on West Wallabi in April 1958 (H. Akerstrom).

FALCONIDAE

Falco cenchroides Vigors & Horsfield. Status uncertain. Nankeen Kestrels were occasionally seen singly above the dunes along the south-west and south coasts of West Wallabi and the south-west coast of East Wallabi. They favour blown-out or sparsely vegetated sections of the dunes. In view of the great number of lizards on the Wallabi Islands, it is surprising that this species is not more plentiful.

PSITTACIDAE

Cacatua roseicapilla Vieillot. Vagrant. A small flock of Galahs flew south over the fishermen's camp on West Wallabi in June 1957 after a long period of strong E.N.E. winds (H. Akerstrom, pers. comm. 19/iv/59).

CUCULIDAE

Chalcites basalis Horsfield. Status uncertain. A Horsfield Bronze-Cuckoo was heard in the centre of West Wallabi on September 10, 1959.

HIRUNDINIDAE

Hirundo neoxena Gould. The Welcome Swallow is resident in small numbers on East and West Wallabi and Pigeon Island. On September 9, 1959, a nest with three eggs was found in a hut on West Wallabi.

CAMPEPHAGIDAE

Coracina novaehollandiae (Gmelin). Status uncertain. On April 17, 1959, a Black-faced Cuckoo-Shrike was observed on West Wallabi in limestone scrub near Horse Well. On June 23 there was one at almost the same place, and on the following day two were seen about a mile further north. On September 8 one was observed at the eucalypt thicket on East Wallabi.

MALURIDAE

Sericornis maculatus Gould. The Spotted Scrub-Wren is moderately common on East and West Wallabi. On September 9 a juvenile was seen on West Wallabi, just able to fly. At that season the singing was especially vigorous.

Mayr and Wolk (1953) recognised the sub-specific distinctness of the Wallabi Islands population, for which the name *houtmanensis* Zietz has priority (by one year) over *fuscipes* Alexander (1922).

ZOSTEROPIDAE

Zosterops lateralis (Latham). The Grey-breasted Silvereye is moderately common on East and West Wallabi (including Tattler Island) and Pigeon Island. During the crayfishing season on West Wallabi they concentrated (in flocks of up to 40) at the fishermen's camp, where they fed on scraps, the most favoured item being the discarded halves of rock-melons whose remaining flesh was cleanly stripped. They were very bold and entered huts as soon as their occupants left them.

Mammals

A wallaby and a rat are the only land-mammals in the Wallabi Group. The wallaby, described by Pelsart in 1629, was probably the first Australian mammal to be observed by Europeans, whereas the rat was not discovered till nearly 300 years later. A species of seal has been included in the following list, but the Cetacea have been omitted (although two species of dolphin are common in these waters, their identity remains uncertain).

MACROPODIDAE

Macropus eugenii (Desmarest). Formerly occurring on North Island (Storr 1960), the Tammars is now confined in the Abrolhos to East and West Wallabi. The population on West Wallabi amounts to some hundreds, the animals being most numerous on the flats of shell grit, where they hide during the day in tunnels through the densest clumps of salt-bush and samphire. They also occur on the limestone pavement where thickets of *Pittosporum phillyreoides* and other tall shrubs provide them with daytime shelter. The population on East Wallabi seems to be much smaller. Here the wallabies are most numerous in the low scrub round the old airstrip.

Most of the sink-holes containing water have been covered up on both islands; of the remainder it is doubtful whether any constitute a water supply for the Tammars. Certainly some animals have attempted to reach the water but, as their skeletons testify, have failed to climb out. Their principal source of water would be the juices of the plants they feed on.

Like the Quokkas on Rottnest, the Tammars prefer the more succulent species of plants, e.g. *Rhagodia baccata*, *Sarcostemma australe* and *Arthrocnemum halocnemoides*. The most heavily browsed of the non-succulent shrubs are such relatively soft-leaved species as *Pimelea microcephala*, *Eremophila glabra* and *Hibbertia subvaginata*. Most of the remaining species of shrubs are browsed at some time or other, and individuals of the following were noted as 'hedged': *Diplolaena dampieri*, *Spyridium globulosum*, *Exocarpus aphylla*, *Pittosporum phillyreoides*, *Capparis spinosa*, *Mirbelia ramulosa*, *Myoporum insulare*, *Westringia dampieri*, and occasionally *Grevillea argyrodendron*. The bark of *Dodonaea aptera*, *Lasiopetalum angustifolium*, *Eremophila glabra* and *Acacia bivenosa* is more sought after than the foliage. The tough leaves of the liliaceous herb *Dianella revoluta*, are evidently eaten only when young. In winter and spring the annual herbage must comprise a large part of the diet. At any rate these plants never grew so tall or dense on the main islands as on offshore islets. The most favoured species are the grasses, *Bromus arenarius*, *Agrostis avenacea* and *Setaria dielsii*.

So as to gain some idea of the nutritive value of the vegetation, terminal foliage was collected on each trip in 1959, brought to Perth wrapped in plastic, and weighed before and after oven-drying. Water content of the plants are set out in Table 1, including, where available, estimates for the same species on Rottnest at the same dates (the latter were interpolated from water-content graphs, plotted from data obtained over several years).

The samples of April 22 were also tested for content of crude protein. The following values (% dry weight) were kindly supplied by the Government Chemical Laboratories, and for comparison Rottnest estimates for that date are again given in brackets where available.

<i>Nitraria schoberi</i>	19.2 (13.5)
<i>Capparis spinosa</i>	18.8
<i>Arthrocnemum halocnemoides</i> ..	13.9 (6.0)
<i>Pimelea microcephala</i>	11.2
<i>Arthrocnemum arbuscula</i>	11.0 (9.0)
<i>Atriplex paludosa</i> ..	10.3 (9.7)
<i>Myoporum insulare</i>	8.3 (7.4)
<i>Diplolaena dampieri</i>	8.1 (5.8)
<i>Beyeria viscosa</i>	6.7
<i>Olearia axillaris</i>	6.3 (6.7)
<i>Sarcostemma australe</i>	5.6
<i>Pittosporum phillyreoides</i>	4.2 (5.0)
<i>Grevillea argyrodendron</i> ..	3.8

Although practically nothing is known of the relative amount of the various plants eaten by the Tammars, some inferences on their diet can be made from the above data. The water content of the vegetation, presumably, as on Rottnest, is lowest in late summer and highest in late winter. The disparity in this respect between summer and winter diets will be even greater than is apparent from Table 1, when it is recalled that annual herbage is available in winter and spring. Generally the water content averages somewhat lower than on Rottnest. This is especially so in the succulent species, and is a consequence of the fact that the Abrolhos only receive half as much rain at Rottnest.

Table 1

Water content (% wet weight) of West Wallabi plants. Estimates for Rottnest in brackets

	April 22	June 25	Sept. 11
<i>Arthrocnemum arbuscula</i>	69	76	79
<i>Arthrocnemum halocnemoides</i> ..	77 (79)	— (83)	— (90)
<i>Atriplex paludosa</i>	56 (75)	77 (78)	79 (85)
<i>Beyeria viscosa</i>	38		
<i>Capparis spinosa</i> ..	75	76	78
<i>Diplolaena dampieri</i>	47 (56)	67 (68)	67 (68)
<i>Grevillea argyrodendron</i>	49	43	58
<i>Myoporum insulare</i>	69 (68)	79 (75)	81 (78)
<i>Nitraria schoberi</i> ..	81 (83)	84 (91)	82 (90)
<i>Olearia axillaris</i> ..	45 (41)	61 (58)	62 (53)
<i>Pimelea microcephala</i>	62	78	71
<i>Pittosporum phillyreoides</i>	59 (57)	60 (58)	60 (61)
<i>Rhagodia baccata</i>	— (75)	— (81)	78 (88)
<i>Sarcostemma australe</i>	77	88	87
<i>Threlkeldia diffusa</i>	69 (81)	— (91)	83 (89)

With minor exceptions, protein levels are considerably higher on West Wallabi than Rottnest, due no doubt to the abundance of nitrogen in the guano-rich soil. Probably as on Rottnest, protein levels are at their lowest in April, rising like the water content to maxima in late winter. And as for Rottnest Quokkas, the few weeks before the break of season would be most critical for the Tammars. The relatively high level of protein in the vegetation should help tide them over this period. The average excess of protein in West Wallabi plants over Rottnest plants of the same species was 27% on April 22, at a time when the protein content of the diet of Rottnest Quokkas varies locally between 6 and 9% (Storr, 1964).

The breeding season seems to be much the same as in Rottnest Quokkas, which is understandable in view of the similar distribution of rainfall. All of four females examined in late April 1959 had a naked joey in the pouch. The largest of these was 23 cm long; two of the others were almost as large, but the smallest was only 2 cm long. In the following September many young were seen at heel.

According to the fisherman on West Wallabi, the juveniles are preyed on by Carpet Snakes (*Python spilotos*) and Sea-Eagles (*Haliaeetus leucogaster*). This predation does not seem to be sufficiently intense to affect their numbers. In the past, human predation was at times much heavier. For example, Stokes and two companions shot 76 on West Wallabi in four hours (after which he aptly named the easternmost extremity of the island Slaughter Point). His colleague Surgeon Bynoe, in a curious account of marsupial reproduction, mentions examining the uteri of "between two and three hundred" wallabies (Stokes 1846, p. 156). It is little wonder that Gilbert (1843) found the animals more abundant on East than West Wallabi two years after the visit of the 'Beagle'.

In a recent unpublished study, J. Kelsall (pers. comm.) found the Abrolhos wallabies to differ in several characters from mainland animals. The name, *houtmanni* Gould, is available for the Abrolhos race.

MURIDAE

Rattus glauerti Thomas. In November 1907, C. P. Conigrave collected a young adult male rat in the sand dunes of East Wallabi. It was later

sent to the British Museum, where Oldfield Thomas (1926) made it the type of a new species. Thomas believed it was related to *R. fuscipes* Waterhouse of the south-western mainland, as did Iredale and Troughton (1934), who regarded it as a subspecies of *fuscipes*. Tate (1951) dissociated *glauerti* from *fuscipes*, suggesting rather that it was a recent introduction of a rat of the Malayo-Polynesian *concolor-exulans* group.

In April 1959 the writer collected three adult rats on West Wallabi, one of which was a female with 10 nipples (4 pectoral, 6 abdominal). As the mammary formula in the *concolor-exulans* group is consistently 4 + 4 (Tate 1936 and 1951), the Abrolhos rat clearly does not belong there. Despite its belated discovery (compared to that of the Tammar), there is no reason for doubting that *glauerti* is truly indigenous, and that it is an insular race of one or another of the southern Australian species of rats. As the following description shows, *glauerti* is most like *R. greyi* Gray.

The external measurements of the rats (Nos. 1-3) are given in Table 2. All three had similar pelage: long soft hair with dark bluish grey bases, tipped on the back with reddish brown and below with whitish. The short hair of the hands, feet and muzzle was whitish. The tail was uniformly dark and had 13 or 14 scales per cm. The caudal hairs were black and twice as long as the scales.

The skull prepared from specimen No. 1 measured as follows: total length 36.2, zygomatic breadth 17.1, inter-orbital breadth 5.3, cranial breadth 15.8, interparietal 10.2, nasals 11.0 × 3.6, zygomatic plate 3.2, palatal foramina 6.2 × 1.7, bulla 6.8, molar crowns 5.8, m² 2.9 × 1.8. The rostrum was broad and flat, the braincase rounded and unridged, and the bullae were rounded.

On the following June 22 another five adults were caught on West Wallabi: No. 4 (♂, weighing 79.5 g), No. 5 (♀, 99), No. 6 (♂, 105), No. 7 (♀, 82.5, and No. 8 (♂, 81). On the evening of September 8, 1959, two adults were taken in break-back traps in the sand dunes behind Turtle Bay, East Wallabi: No. 9 (♂, 82), and No. 10 (♀, 67—it had lost all but the tip of its tail). Few rats were seen on West Wallabi in September, and the only ones caught were two juvenile females early in the morning of the 12th: No. 11 (45) and No. 12 (47). On April 23-25, 1960, three adult males were caught on West Wallabi: No. 13 (not weighed), No. 14 (70) and No. 15 (81); the testes of the last two were greatly enlarged.

Specimens No. 1-12 have been lodged in the Western Australian Museum. As specimens No. 13-15 are no longer available in Western Australia, their measurements are given in Table 2 (I measured No. 13 and J. Kelsall measured No. 14 and 15). Immediately after capture, the pelage of No. 14 was described as follows: dorsal and lateral hairs greyish brown, tipped reddish brown; guard hairs blackish; hands and feet whitish; underneath white.

Most of the rats were caught in sandy country well vegetated with *Spinifex longifolius*, a few were among saltbush on the flats of shell

Table 2
External measurements (mm) of six *Rattus glauerti* from West Wallabi

Field Number	Sex	Head + Body	Tail	Pes	Ear
1	♂	127	120	26.5	17
2	♂	129	113	27	18
3	♀	131	123	26	18
13	♂	104	117	26	18
14	♂	134	104	26	20
15	♂	141	107	27	19.5

grit, and only one was collected on pavement limestone (it was disturbed in the daytime from a heap of stones beside East Well). Though an occasional rat may be seen in the daytime, they are really active only at night. With a head-torch their red eyes can be picked up whenever they come out to feed on the bare ground between patches of vegetation. Bewildered by the light, they are easily run down and captured. They readily bite if given the opportunity. Apparently they spend the day hidden in the bases of shrubs and tussock grasses. They certainly do not burrow.

The rats were so numerous on both islands in 1959-60 that I cannot understand why the species was not discovered before 1907. Perhaps their numbers undergo large fluctuations and my visits happened to coincide with a population peak. With so many fishermen resident in the Wallabi Group during the crayfishing season, the future of this beautiful little rat is very insecure. A few feral cats could soon exterminate it.

OTARIIDAE

Neophoca cinerea (Péron & Lesueur). The Hair Seal was formerly abundant, even though the Abrolhos are towards the northern limit of its Western Australian range. In his account of the Wallabi Islands, Gilbert (1843) wrote, "all the islands in this group are thickly inhabited by the seal; we would frequently come upon groups of 7, 8, and 9, lying asleep on the sandy beach; they are very easily captured, by walking steadily up to them with a club, when a single blow on the nose brings them down." In 1889 Campbell observed that they were "principally found in the Easter and Pelsart groups but now getting scarce."

I saw none during my four visits, though one was missed by only three days; it followed fisherman G. Klee in his boat for a short distance past Pelican Point on April 16, 1959. In the following September I found the remains of an adult male among the mangroves off the south-east coast of West Wallabi. It had evidently been dead for a month or more. Its skull was brought back and later lodged in the Western Australian Museum.

This magnificent seal shows little fear of man, which has resulted in its decimation throughout the greater part of its range.

Discussion

In his summary of the vertebrate fauna of the Abrolhos, Alexander (1922) contrasted the wealth of the Wallabi Islands with the poverty

of the Easter and Pelsart Groups. He concluded that the land fauna of the Abrolhos had been derived from the mainland via the Wallabi Islands by transmarine dispersal. He also concluded that when the islands were populated with this fauna the opposite mainland must have been more like the extreme South-west than it is today. Neither of these hypotheses is tenable now.

Alexander was evidently unaware of the general post-Pleistocene rise in sea-level, and that islands as distant from the mainland as the Abrolhos could nevertheless be only a few millennia in age. The separation of the Wallabi Islands from the mainland was dated by Main (1961) at 11,500 years ago. While some doubt may attach to the precise date of their separation, other evidence confirms that the Wallabi Islands were formerly part of the mainland.

Although the rocks underlying them are of marine origin, the dunes of the Wallabi Islands (and North Island) could only have formed when the area was continental. Admittedly, calcareous sand is produced on islands by the weathering of limestone; production, however, is generally outpaced by removal when sea-level is rising or stationary. Even on an island as large as Rottnest, dune and beach sand is continually being lost to the sea (Storr 1963).

Moreover the fauna and flora of the Wallabi Islands are distinctly continental in their richness and balance. It is too much to suppose that two species of mammal, two snakes, 16 lizards (in 12 genera and four families) and 114 vascular plants (in 94 genera and 50 families) have crossed Geelvink Channel in sufficient numbers to become established on these small islands.

That many of these animals occur on other west coast islands is a reflection of their ability to survive on shrinking land masses rather than ability to cross the sea. A few species, e.g. *Delma fraseri*, *Egernia stokesi* and *Rattus glauerti* have not, to the writer's knowledge, been found on other islands. Similarly with the flora, while there are many species common to a number of west coast islands, there are some that are not otherwise insular. In the latter category are the orchid *Microtis unifolia* and the shrubs *Grevillea argyrophylla*, *Trichinium eriотrichum*, *T. divaricatum*, *Aphanopetalum clematideum*, *Bossiaea rufa*, *Hibbertia subvaginata* and *Sarcostemma australe*. The greater part of the fauna and flora is widespread in coastal situations, especially those with calcareous rocks and soils. But none of the animals and few of the plants seem especially adapted for transmarine dispersal.

Alexander's second hypothesis was based on the belief that certain vertebrate animals occurred considerably further north on the Abrolhos than on the west coast mainland. Alexander was not explicit as to the nature of the change on the mainland; it has been interpreted as one of "climatic deterioration" (Serventy and Whittell 1948, p.50).

In the last few years naturalists have paid increasing attention to the mainland north of Perth, and the known range of most of the species cited by Alexander has been advanced,

one by one, to the latitude of the Abrolhos and even beyond. Since Alexander's time the known northern limit of the Brush Bronzewing has been extended from the Moore River successively to the Hill River (Storr and Ford 1959) and Freshwater Point, 25 miles south of Dongara (Ford 1960); the Painted Quail from the Moore River to the lower Murchison (Sedgwick and Morrison 1949) and to Peron Peninsula (Bathgate, pers. comm.); the Spotless Crake from Perth successively to Yanchep (Serventy and Whittell 1948) and Hutt Lagoon (Ford 1962); and *Egernia whitei* (*sensu lato*) from 30 miles north of Perth to Eneabba (on the mainland) and to Bernier Island in Shark Bay (Douglas and Ride 1962).

There only remain *Denisonia coronata*, *Rattus fuscipes* and *Macropus eugenii*. The known range of *Denisonia coronata* on the mainland has only been extended north from Perth to Gingin (Glauert 1957); but the supposed occurrence of this species in the Abrolhos has never been confirmed. It is also irrelevant that *Rattus fuscipes* is still known only from the south coast, for the Abrolhos rat has been shown since Alexander's time to belong to a different species (*R. glauerti*).

The Tammar has not been collected on the mainland any further north than in Alexander's time. There is, however, some evidence that it exists on the mainland opposite the Abrolhos. In October 1962, I had a fleeting glimpse of a small macropod in *Acacia rostellifera* scrub, 12 miles north of Balline; it did not appear to be a young Grey Kangaroo, the common species in that area. A few months later, Mr. Tom Pepper, of Tamala Station, told me that a "grey wallaby" lived in York Gum and other thickets on Lynton Station (especially the Port Arthur thicket), but he had not heard of them for twenty years. Recently Dr. W. D. L. Ride (pers. comm.) examined a rough skin of a wallaby that was shot five miles inland from Port Gregory; he believes that it was almost certainly from a Tammar.

Alexander did not consider the flora of the Abrolhos. Had he done so, he might just as easily have arrived at the opposite conclusion, that the climate of Geraldton was formerly drier and warmer. Most Abrolhos plants extend well to the north and south of the islands. I know of none that has its northern limit in the islands; whereas at least two species (*Capparis spinosa* and *Sarcostemma australe*) are not known from so far south on the mainland coast.

The fate of Alexander's hypothesis is a sobering reminder that while it is fairly easy to discover what is present on an island, it is much more difficult to ascertain what is absent from the mainland.

Churchill (1960) and various members of the A.N.Z.A.A.S. Quaternary Shoreline Committee have cited evidence, from Australia and New Zealand, that 4-5000 years ago sea-level was 9-10 feet higher than now. At first sight the small islands immediately east of the Wallabi Islands fit in well with the concept of a previous 9-10 foot higher sea-level. Their flat tops, 5-8 feet above present sea-level, are consistent with submarine planing. The richness

of their fauna and flora, however, is quite inconsistent with any hypothesis that demands their submergence since they were initially severed from the main islands.

Pigeon Island, for example, is only 400 yards long and 100 wide and is separated from East Wallabi by half a mile of sea. Yet its vegetation is not noticeably less diversified than any similar area of pavement limestone on East or West Wallabi. Its flora comprises 30 species, most of which are woody plants. It is inconceivable that so many shrubs like *Capparis*, *Sarcostemma* and *Grevillea* could have become established on this island in 2-3000 years.

It is possible that these islands were at least 7 feet higher 4,000 years ago and that falling sea-level has kept pace with their loss of elevation. If the islands have been lowered by surface erosion, the pavement limestone on the Wallabi Islands should attain elevations of up to 15 feet where it is protected by overlying dunes. No such elevations have been observed, but then exposures are very limited in which the contact can be seen between pavement and dune limestone. At any rate surface erosion is probably a less potent force here than subterranean solution and the subsequent collapse of the caverns so produced. Alternatively the islands may have lost elevation through general subsidence of the continental shelf (in which case the age of the islands would be over-estimated).

Whereas a 9-10 foot rise in sea-level would drastically reduce the area of East and West Wallabi and completely obliterate all the smaller islands, a two-foot rise would hardly effect the latter, margined as they are with vertical cliffs. It has already been conjectured that Shag Bay must formerly have penetrated deeply into the north-western part of West Wallabi. West of East Well the pavement limestone terminates abruptly in low cliffs that have every appearance of having formed under coastal conditions. Such a transgression of the sea would have required a rise in sea-level of no more than two feet.

Acknowledgments

My visits to the Abrolhos were primarily for marsupial studies and were financed by a grant from the C.S.I.R.O. to the Zoology Department of the University of Western Australia. Transport to the islands was generously provided by the Golden Gleam Fish Processing Co. and Mr. A. J. Fraser (Director of Fisheries). I am grateful to Mr. R. D. Royce (Chief Botanist, Government Herbarium) for the identification of plant specimens and to the fishermen on West Wallabi and Pigeon Island whose hospitality we enjoyed.

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2.—The Ocypode Ghost Crabs of Western Australia (Crustacea, Brachyura)

By R. W. George and Mary E. Knott*

Manuscript Accepted—18th August, 1964.

Four species of *Ocypode* are recorded in Western Australia. Two, *O. ceratophthalma* and *O. cordimana* are widespread Indo-west Pacific species occurring along the northern coasts of Australia; the other two are probably Australian endemics, *O. convexa* occurring on the west coast and *O. fabricii* on the northern and upper west coasts of Australia.

The first male pleopod is figured and described for each species. A key and short descriptions are provided to enable adults and most subadults to be identified. Notes on the behaviour of the two probably endemic species are recorded.

Introduction

In recent years, active collecting has produced much crustacean material from Western Australia; perusal of the previous literature reveals inadequate comparisons of local and circum-Indian Ocean material in many instances.

This report deals with the genus *Ocypode*, pointing out several previous misidentifications in the literature. Full bibliographic treatment has been attempted for *O. fabricii* and *O. convexa* but not for *O. cordimana* and *O. ceratophthalma*. Catalogued specimens now housed in the Western Australian Museum are indicated by the abbreviation WAM preceding the catalogue number and the measurements given in the text are those of the length of the carapace.

Acknowledgments

We wish to record our appreciation to Dr. Isabella Gordon of the British Museum (Natural History), who kindly examined specimens of *Ocypode* identified as *O. kuhlii* in the collection of that Museum; to Dr. L. Bott of the Senckenberg Museum and Dr. Danièle Guinot of the Muséum National D'Histoire Naturelle who kindly made comparisons of our material with the holotypes of *O. nobilii* and *O. fabricii* respectively; to Dr. L. B. Holthuis of the Leiden Museum and Dr. J. Yaldwyn of the Australian Museum for photocopies of original descriptions; to Dr. F. H. Talbot of the South African Museum for the loan of specimens identified as *O. kuhlii* from East Africa; to Dr. A. Crosnier of the Centre D'Océanographie de Pointe-Noire for his advice; and to the many collectors of material dealt with in this paper, particularly those who made special efforts to secure crabs for us.

Mrs. Marina Tyndale-Biscoe and Miss Sue Woods gave valuable technical assistance in the initial and final stages of the work. Mrs. A. Neumann's assistance in translating certain French and German texts is gratefully acknowledged.

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First Male Pleopods

The general shapes of the first male pleopods of the four species of *Ocypode* examined are similar, consisting of a straight or slightly curved main shaft closely applied to the convex thorax *in vivo*. The term "upper surface" referred to in the text is that side of the pleopod exposed when the abdomen is pulled back. Descriptions were facilitated by removal of the entire pleopod followed by low power microscopic examination.

When viewed directly above the upper surface, the pleopod of some species, e.g. *O. ceratophthalma* (fig. 1A), can be easily subdivided into main shaft, constricted "neck" and expanded "head". The head when viewed obliquely or laterally is expanded for all species examined. The head of each pleopod curves outward to terminate in a hard chitinous tip. The main shaft of all species is covered with sparse pubescence.

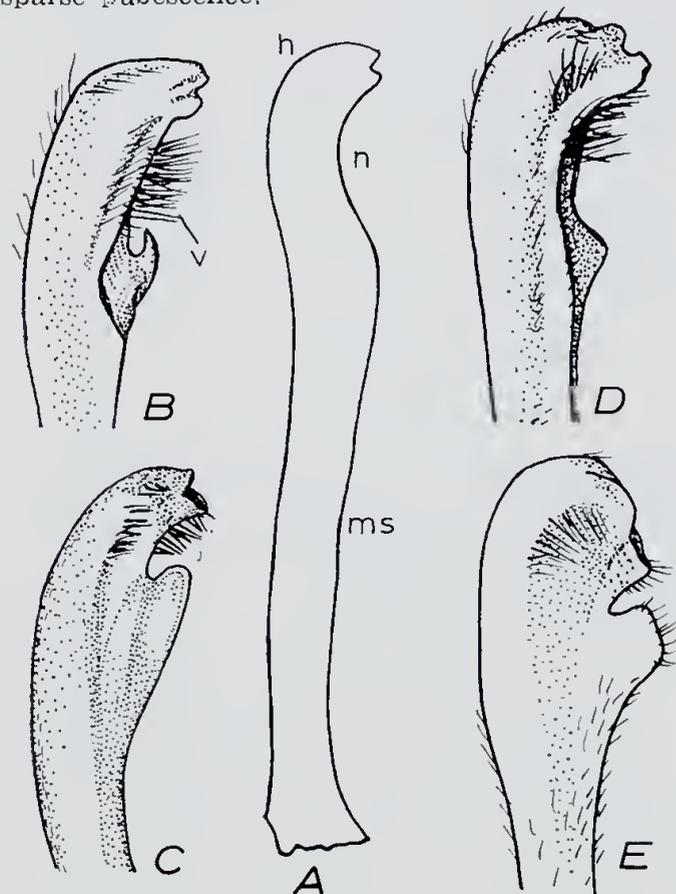


Fig. 1.—First male pleopods of *Ocypode*. Actual pleopod lengths given: A, B, *O. ceratophthalma* (18.1 mm); C, *O. cordimana* (14.9 mm); D, *O. fabricii* (15.8 mm); E, *O. convexa* (16.9 mm). A, viewed directly above upper surface, pubescence omitted; B, C, D, E, head viewed obliquely from upper outer aspect. m.s. = main shaft, n. = neck, h. = head, v. = vibrissae. Drawn by Miss R. Hunt.

The diagnostic features are: the shape of the distal expansion of the lower surface ridge, the arrangement of the vibrissae on the head, and the form and position of the chitinous tip surrounding the distal aperture.

The figures are of the head of the left pleopod viewed obliquely from the upper, outer aspect. Measurements of total pleopod lengths are given in the figure legends.

Ocypode Weber 1795

Type species.—*Cancer ceratophthalmus* Pallas, 1772.

The diagnostic features of the genus are fully described by Alcock (1900, p. 344). The spellings *Ocypode* and *Ocypoda* have both been used by previous workers for this genus and here the spelling *Ocypode* is adopted in view of the recommendations made to the International Commission on Zoological Nomenclature by Holthuis (1962, pp. 237, 244 and 245).

Representatives of this genus occur on the Tropic and Subtropic coasts of all the major oceans of the world and the largest number of species have evolved in the Indo-west Pacific region. Although we have not attempted a complete review of the genus, it would appear that there are 14 species in the Indo-west Pacific, three in the Atlantic and two in the East Pacific regions. Current research on this genus by the French workers, Drs. Guinot and Crosnier, will no doubt help to clarify the taxonomy of the group.

Major revisions of this genus have previously been given by such workers as Kingsley (1880), Miers (1882) and Ortmann (1894 and 1897); and valuable contributions to the Indo-pacific *Ocypode* species have been published by Alcock (1900) and Tesch (1918). Most of these workers recorded variations in some characters (particularly length of ocular stylet and shape of outer orbital angle) yet these variable characters have sometimes been used in the construction of their identification keys. This has led to some misidentifications, particularly of sub-adult and juvenile specimens.

The diagnoses and the key given here are designed to facilitate the identification of adult and most subadult specimens of the four Western Australian species of *Ocypode*; only tentative identifications are possible for extremely juvenile specimens.

Close microscopic examination of these juveniles revealed certain adult characters which could be relied upon, and some which could not.

When examined microscopically (particularly if dry), the stridulating organ is possibly the best character on which to base an identification. Although it may be extremely difficult to accurately count the components of the juvenile stridulating organ, it is easy to see the actual type of structures of which it is composed. For example, the stridulating organ of juvenile *O. ceratophthalma* is obviously composed of two different types of structures, whereas in *O. fabricii*, the stridulating organ is composed of only one type of structure, transverse ridges; and these are obviously different from the arrangement of separate tubercles that forms the stridulating organ of *O. convexa*.

In the juveniles, the leg hairbrushes are represented by sparse lines of hair compared with the dense brushes developed in the adult. In the species from Western Australia, the general shape of the orbit and outer orbital angle vary little from juvenile to adult. In other species from other areas, e.g. *O. saratan* these vary with size, as discussed later.

Key to the Western Australian species of *Ocypode*

- | | | |
|--|---|--------------------------|
| 1. Palm of large cheliped with stridulating organ | 2 | |
| Palm of large cheliped without stridulating organ | | <i>O. cordimana</i> |
| 2. (1) Stridulating organ solely or partly composed of transverse ridges | 3 | |
| Stridulating organ solely composed of roundish tubercles (10-25); lower orbital edge with a deep lateral and a deep median notch | | <i>O. convexa</i> |
| 3. (2) Stridulating organ composed of round and/or elongated tubercles in the upper part and transverse ridges in the lower; lower orbital edge with no lateral notch | | <i>O. ceratophthalma</i> |
| Stridulating organ composed solely of fine transverse ridges (108-141); lower orbital edge with a broad, U-shaped lateral notch | | <i>O. fabricii</i> |

Ocypode cordimana Desmarest

(Fig. 2A)

Ocypode cordimana; Desmarest 1825, p. 121; Stimpson 1907, p. 110; Boone 1934, p. 191.

Ocypode cordimana; Kingsley 1880, p. 185; Haswell 1882, p. 95; Miers 1882, p. 387; Alcock 1900, p. 349; Tesch 1918, p. 35; Sakai 1939, p. 613.

Ocypode cordimanus; Barnard 1950, p. 84.

Diagnostic features.—No stridulating organ on palm of large cheliped. Lower orbital edge with a broad key-hole shaped lateral notch and a very slight median notch. Eyes without stylets. Outer orbital corners acute, directed forwards. Anterior upper border of propodus of second and third pereopod in male with single hairbrush; in female, single hairbrush on second pereopod only. Inner dorsal margin of merus of large cheliped with curved, toothed flange. Inner margin of carpus of large cheliped with single main tooth and very small subsidiary teeth; outer distal margin of carpus granulate, without distinct teeth.

Description of male pleopod (Fig. 1. C, WAM 27-63).—Viewed directly above upper surface, main shaft not expanded to form distinct head. Lower surface of shaft with ridge terminating in an expanded, smooth, oval lobe proximal to head. Tip bilobed, straight-edged, obliquely-directed. Upper and lower margins of outer surface of head each with a fringe of short vibrissae.

Material examined

Western Australia.—One male (28.3 mm) and one female (25.5 mm) East Montalivet Is. (west of Darwin), A. Whitworth on "DOROTHEA", 21.x.1962, WAM 27-63 and 140-63.

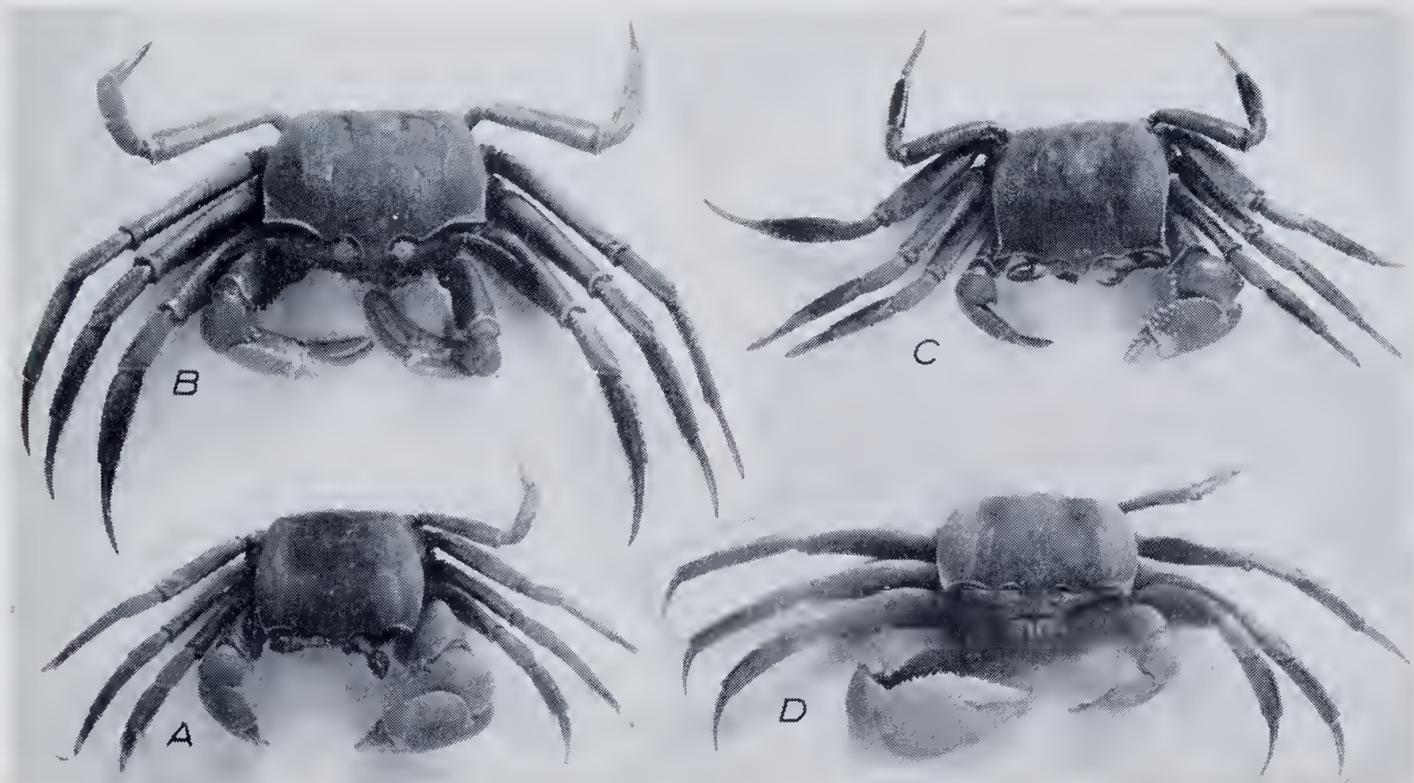


Fig. 2.—Male *Ocypode* from Western Australia. A. *O. cordimana* WAM 27-63; B. *O. ceratophthalma* WAM 20-64; C. *O. fabricii* WAM 4-64; D. *O. convexa* WAM 24-63.

Other localities.—Two immature males (10.2 and 11.6 mm) Ashmore Reef, Timor Sea, J. McIntyre, C.S.I.R.O.. August 1961, W.A.M. 28-63; four juveniles (4.0 to 8.2 mm) Marion Reef, Paget Island, Coral Sea, G. F. Mees, 25.xi. 1961, WAM 76-63; two males (16.5 and 13.8 mm) south end Heron Island, Queensland, R. W. George, 23.v.1961, WAM 74-63; one male (14.1 mm) Urunga, near Coff's Harbour, New South Wales, Mrs. R. W. George, 1.x.1959, WAM 75-63.

Distribution.—"Mauritius, east coast of Africa to Red Sea, Indo-pacific to Japan" (Barnard), East Australia (Haswell); now recorded from Western Australia. The type locality is Ile de France (Mauritius)—see Boone 1934, p. 191.

Ocypode ceratophthalma (Pallas)

(Fig. 2B).

Cancer ceratophthalmus Pallas 1772, p. 83, pl. 5, figs. 7 and 8.

Ocypoda ceratophthalma; Miers 1882, p. 379; Miers 1886, p. 238; Alcock 1900, p. 345; Tesch 1918, p. 36; Balss 1935, p. 140; Sakai 1939, p. 614; Gillett and McNeill 1962, pl. 118.

Ocypode ceratophthalma; Edmondson 1946, p. 310; Tweedie 1950, p. 321. (feeding behaviour).

Ocypode ceratophthalmus; Barnard 1950, p. 86.

Ocypode kuhlii; Miers 1882, p. 384 (part) and 1884, p. 237 (part).

Diagnostic features.—Stridulating organ on palm of large cheliped consists of round and/or elongated granules in the upper part and fine transverse ridges in the lower, margined distally by sparse pubescence in females and a dense hairbrush in males. Lower orbital margin without median or lateral notches. In our series, specimens over 24 mm with distinct ocular stylets, length of the stylet usually in proportion with length of carapace; specimens less than

24 mm with rudimentary or no ocular stylet. At equivalent size, males have longer ocular stylets. Outer orbital corners right-angled and outwardly directed. Anterior surface of propodus of second and third pereopods of male with triple hairbrush; females with single hairbrush and few scattered hairs. Inner dorsal margin of merus of large cheliped almost straight, toothed; without flange. Inner margin of carpus of large cheliped with single main tooth (a number of subsidiary teeth develop in large specimens); outer distal margin of carpus denticulate.

Description of male pleopod (Fig. 1. A, B, WAM 20-64).—Viewed directly above upper surface, main shaft constricted to form neck and expanded distally to form head. Lower surface of shaft with ridge terminating in small, smooth, acute projection proximal to head. Tip bilobed, almost straight-edged, longitudinally-directed. Outer margin of head with double fringe of long vibrissae.

Material examined

Western Australia.—Ten males (26.1-38.4 mm), thirteen females (24.3-36.5 mm) and six juveniles (6.7-19.0 mm) from fifteen separate localities between East Montalivet Is. and Dorre I., Shark Bay. WAM 66-55, 69-55, 33-63, 34-63, 78-63, 79-63, 81-63, 83-63, 85-63, 86-63, 88-63, 90-63, 91-63, 93-63, 94-63, 95-63, 98-63, 136-63, 143-63, 19-64, 20-64.

Other localities.—Five males (26.9-35.2 mm), three females (29.8-33.0 mm) and two juveniles (8.2 and 12.8 mm) from the following localities: Penang; Christmas I. and Cocos Is., Indian Ocean; Heron I., Queensland; Port Macquarie and Forster, New South Wales. WAM 80-63, 82-63, 84-63, 87-63, 89-63, 92-63, 96-63.

Comments.—Miers (1882, p. 385) recorded "a series of rather smaller specimens" of *O. kuhlii* from Thursday Island. However, re-examination of three of his specimens by Dr. Gordon at the British Museum and of another small specimen by us from the Australian Museum, showed that they were all juvenile *O. ceratophthalma*. Further, Dr. Gordon examined the remaining material, recorded by Miers (1882, p. 385) as *O. kuhlii* (except the female from Japan which could not be located), and states (pers. comm.) "Although Miers seems to have adopted de Man's characters for *O. kuhlii*" in his paper, the fact remains that not one of his specimens of supposed "kuhlii" agrees with de Man's description of the two specimens in the Leiden Museum. Until someone re-examines and figures *O. kuhlii* holotype from Java, I cannot be sure that any material so-called in our collection belongs to that species." The Shark Bay record of *O. kuhlii* by Miers 1882 is in fact *O. convexa* (discussed later).

Distribution.—"Mauritius, east coast of Africa to Red Sea, Indo-pacific" (Barnard). The type locality is India.

Ocypode fabricii Milne Edwards

(Fig. 2C)

Ocypoda fabricii Milne-Edwards 1837, p. 47 and 1852, p. 142.

Ocypoda aegyptiaca; Balss 1935, p. 140.

Non *O. fabricii*, Kingsley 1880, p. 182.

Diagnostic features.—Stridulating organ on palm of large cheliped composed of 108-141 extremely fine transverse ridges, accompanied distally by a dense patch of pubescence in males and scattered hairs in females. Lower orbital edge with a broad median notch and a U-shaped lateral notch. Stylets on eyes very short. Outer orbital corners very acute, usually directed outwards. Anterior surface of propodus of second pereopod with triple hairbrush (largest male 37.9 mm), double hairbrush (other males) or single hairbrush (females). Distal half of anterior surface of propodus of third pereopod with single hairbrush (largest male) or sparse or absent (remainder of material). Inner dorsal margin of merus of large cheliped straight with regular denticles along proximal half, distal half with clusters of irregular teeth. Inner margin of carpus of large cheliped irregularly toothed with two (subadult) to nine teeth (female 29.8 mm).

Description of male pleopod (Fig. 1. D, WAM 4-64).—Viewed directly above upper surface, main shaft expanded to form head but not markedly constricted to form neck. Lower surface with ridge terminating in a very low, smooth, bulbous expansion proximal to head. Tip trilobed, spooned, longitudinally-directed; distal aperture opens between the two proximal lobes. Outer margin of upper surface of head with two tufts of long vibrissae.

Material examined.—One male (17.6 mm) East Montalivet Is., A. Whitworth on "DOROTHEA", 21.x.1962, WAM 102-63; one female (16.6 mm) Derby, Driver Stuart, March 1945, WAM 277-45; two males (19.4 and 19.8 mm) Yampi Sound, G. A. Robinson, March 1959,

WAM 103-63; two juveniles (9.8 and 11.2 mm) Yampi Sound, G. A. Robinson, July/August 1960, WAM 105-63; one female (30.3 mm) Adele I., W. Goode on "DOROTHEA", 19.x.1962, WAM 100-63; one female (recently moulted) (32.2mm) Crab Creek, Broome, M. C. MacDonald, 12.i.1962, WAM 138-63; one female (29.8 mm) probably Broome, E. J. Stuart, 1917, WAM 9391; one juvenile (11.0 mm) Legendre I., Dampier Archipelago, H. Williams and M. C. MacDonald, 10.vi.1962, WAM 97-63; two males (13.9 mm) three females (16.5 to 18.5 mm) one juvenile (8.5 mm) Dolphin I., Dampier Archipelago, R. D. Royce on "DAVENA", 29.v.1960, WAM 30-63; one female (18.4 mm) four males (12.7 to 24.5) and one (abdomen damaged) (11.7 mm) between east and west Lewis Is., Dampier Archipelago, B. R. Wilson on "DAVENA", 12.vi.1960, WAM 104-63; one female (23.5 mm) Shark Bay, Mrs. J. Watson, May 1961, WAM 101-63; one male (29.4 mm) and one female (31.3 mm) Denham, Shark Bay, B. R. Wilson, 29.xii.1959, WAM 145-63 (donated to Paris Museum); one male (37.9 mm) Denham's Hummock east side of Shark Bay, R. Slack-Smith, 9.i.1963, WAM 144-63; two males (32.8, 34.7 mm) and one female (33.1 mm) Little Lagoon, 1½ mile N. Denham, Shark Bay, D. Bathgate, 12.iii.1964, WAM 4-64, 18-64; one male (21.4 mm) unknown locality 9390; one ovigerous female (30.8 mm) unknown locality WAM 99-63 donated to Senckenberg Museum.

Comments.—Milne Edwards (1837) gave only a very general description of this species, unaccompanied by illustrations; and this species has remained in relative obscurity after Miers (1882) and Ortmann (1897) included *O. fabricii* with *O. ceratophthalma*. Their reasons for this procedure were based on an erroneous description given by Kingsley (1880) whose specimens from Australia and Natal are not *O. fabricii* since they had tubercles in place of fine striae on the stridulating ridge.

In view of the previous obscurity of *O. fabricii*, we initially believed that our material belonged to an unknown species so we are indebted to Dr. Crosnier for suggesting correctly, that our Western Australian material of this species might be *O. fabricii*. He has recently been studying *Ocypode* and other genera from Madagascar for which he examined closely the type of *O. fabricii*. On his suggestion, we sent several of our specimens to Dr. Danièle Guinot, Museum National D'Histoire Naturelle, Paris, for direct comparison with the holotype of *O. fabricii* and she reports that our specimens agree with the holotype from "Océanie". The precise locality of the holotype is not known but since our material and two specimens of this species which Dr. Guinot has seen from "west of Darwin", are all Australian in origin, it is likely that the holotype was collected in the western part of Oceania, if not Australia.

No specimens of this species were found in the collections of the British Museum or the Zoological Survey of India when one of us (R.W.G.) examined them in 1963; there were however some specimens from Northern Australia incorrectly identified as *O. kuhlii* in the Singapore Museum.

On the basis of the number of striae in the stridulating organ *O. fabricii* closely resembles *O. nobilii* de Man, 1902. The stridulating ridge of the *O. nobilii* male holotype (18 mm c.l.) is formed of approximately 115 transverse striae. A personal report by Nobili to de Man (1902, p. 481) records a large male (21 mm) with 120 transverse striae. An adult female (WAM 99-63) and small males and females (WAM 30-63) of *O. fabricii* were sent to Dr. Bott of the Senckenberg Museum for comparison with the holotype of *O. nobilii*. He regarded the holotype male of *O. nobilii* as an adult which clearly differed from the specimens of *O. fabricii* sent for comparison. He pointed out that the most striking difference between the species, apart from the much greater size of *O. fabricii*, was the shape of the merus of the walking legs. The ratio of the length to breadth of the merus of pereopod 4 in *O. nobilii* is 2.6 whereas in *O. fabricii* this ratio is 3.25. Another distinguishing feature is the shape of the lateral notch on the lower margin of the orbit; in *O. nobilii* it is shallow and obtuse but in *O. fabricii* it is deep and U-shaped.

Balss (1935, p. 140) identified an adult specimen from Shark Bay as *O. aegyptiaca* Gerstaecker 1856 and he probably used Ortmann's (1897) key for his identification. Indeed all our specimens of *O. fabricii* key out closest to that species using Ortmann's key. In addition, Balss regarded his Shark Bay specimen as conspecific with *O. aegyptiaca* specimens from the Red Sea; in our opinion, his Red Sea specimens were not adult, but subadult animals. Miers (1882, p. 382) noted that the shape of the orbital corners and the length of the ocular stylet of *O. aegyptiaca* vary with size and this observation was confirmed when one of us (R.W.G.) collected a series of the common Red Sea ghost crab from East Aden Protectorate in March 1963. This collection was made during a short term crayfish assignment with the F.A.O. United Nations (FAO/UN 1963).

Holthuis (1958) pointed out that Forskål's (1775) name of *O. saratan* for the Red Sea ghost crab is valid and antedates *O. aegyptiaca* Gerstaecker (1856). The comparison of our East Aden series of *O. saratan* with local material is represented diagrammatically in Figure 3; there is little obvious difference between the subadult *O. saratan* (fig. 3. B, C) and adult *O. fabricii* from Shark Bay (fig. 3. D, E). The two species can be readily distinguished at most stages of growth by the 100 or more fine striae in the stridulating ridge of *O. fabricii* compared with 60-100 striae on the stridulating organ of *O. saratan*. The notched form of the outer orbital angles of *O. saratan* as figured by Laurie (1915, p. 467) is represented in four of our nine adults from East Aden and all our adults have the stylet recurved posteriorly, not anteriorly as shown by Laurie.

It is also noteworthy that the juveniles of *O. saratan* from East Aden would be identified as *O. kuhlii* using the key produced by Miers (1882). It is not unlikely that juveniles of this species and other species (see comments on *O. ceratophthalma*) have in the past been designated *O. kuhlii*.

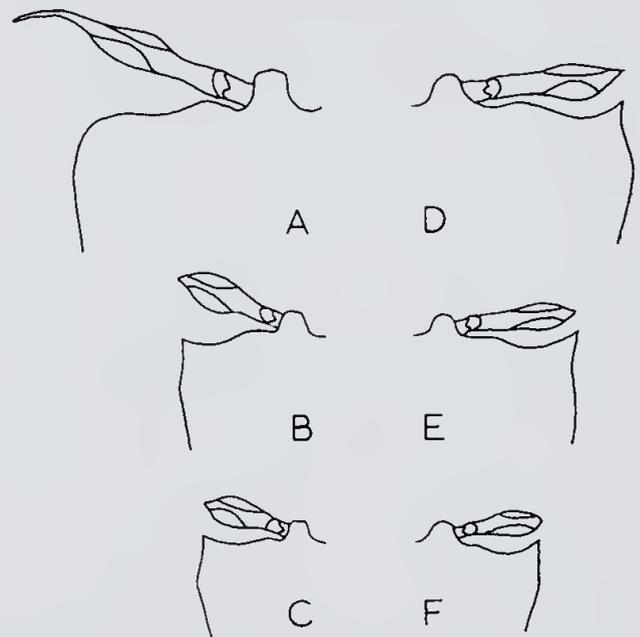


Fig. 3.—Growth Changes of *Ocypode*. A-C; *O. saratan*, East Aden Protectorate WAM 142-63. A male 42.2 mm, B female 22.5 mm, C female 18.6 mm; D-F: *O. fabricii*, Western Australia. D WAM 144-63 male 37.9 mm, E WAM 145-63 female 31.3 mm, F WAM 104-63 male 18.3 mm. Measurements are those of the carapace length.

Distribution.—North and west coasts of Australia from East Montalivet Is. (west of Darwin) to Shark Bay. The type locality is "Oceania".

Ocypode convexa Quoy and Gaimard

(Fig. 2D)

- Ocypode convexus* Quoy and Gaimard 1824, p. 525.
Ocypoda convexus; Kingsley 1880, p. 185.
Ocypoda kuhlii; Miers 1882, p. 384 (part).
Ocypode pygoides Ortmann 1894, p. 766 and 1897, p. 362; Montgomery 1931, p. 451 (sic *pygoides*); Ride 1962, p. 17.
Ocypoda pygoides; Balss 1935, p. 140.
non *O. convexa*; Stimpson 1858, p. 100 and 1907, p. 109 = *O. stimpsoni* Ortmann 1897, p. 364.
non *O. convexa* Nobili 1900, p. 518 = *O. nobilii* de Man 1902, p. 478.

Diagnostic features.—Stridulating organ of 10 to 25 roundish tubercles. Lower orbital edge with two deep notches, one central and one lateral. Eyes without stylets. Outer orbital corner acute, directed forwards. Propodus of second and third pereopods with single hair brush on upper anterior surface. Inner dorsal margin of merus of large cheliped with curved toothed flange. Inner margin of carpus of at least one cheliped with distinct bifid tooth.

Description of male pleopod (Fig. 1. E, WAM 24-63).—Viewed directly above upper surface, main shaft not expanded to form distinct head. Lower surface of shaft with ridge terminating in a well-developed, rounded, pubescent lobe proximal to head. Tip bilobed, straight-edged vertically-directed. Upper and lower outer margins of head each with fringe of short vibrissae.

Material examined.—Twenty nine males (20.1-42.5 mm), twenty-six females (18.7-38.4 mm) and twenty-seven juveniles (7.5-20.0 mm) from twenty-one West Australian localities from Barrow I., and between North West Cape and Yal-

lingup. WAM 7662, 7726, 9492, 9613, 9980, 10032, 10455/8, 128/9-46, 24/26-63, 49/73-63, 77-63, 106-63, 107-63, 137-63, 13-64.

Comments.—There is little doubt that Ortmann's suspicion (1897, p. 362) that his name *O. pygoides* is synonymous with *O. convexa* is true. Quoy and Gaimard's original figure and short description of *O. convexa* agree with the material examined here. Kingsley (1880, p. 185) and Miers (1882, p. 385) noted the features of the bifid tooth on the carpus of the cheliped and the hairbrush on the second and third pereopods; both these features are clearly seen in Quoy and Gaimard's figure (in the figure, the hairbrush on right second pereopod has not been illustrated). Miers thought *O. convexa* might be referred to either *O. kuhlii* or *O. cordimana* but *O. cordimana* lacks a stridulating organ on the palm of the cheliped and according to de Man (1881, p. 252), *O. kuhlii* lacks the propodal hairbrushes. In 1960, Dr. Gordon re-examined the male from Shark Bay which Miers (1882) identified as *O. kuhlii* and concluded that it was an adult *O. convexa*.

Distribution.—West coast of Western Australia, from North West Cape to Yallingup and also Barrow I. The record by Balss (1935) from Barrow Island is confirmed. The type locality is Dirk Hartogs Island, Shark Bay.

General Observations and Behaviour

The ghost crabs of Western Australia do not as a rule leave their sand burrows during the day; at night they forage along the strand lines of the beaches, retreating to their burrows or to the sea if disturbed. The burrows of all Western Australian species are near-ventral with simple openings; the excavated sand is carried away from the burrow mouth and dispersed. At Montalivet Is. three species, *O. cordimana*, *O. cceratophthalma* and *O. fabricii* were dug from burrows on one beach and the burrows were not obviously different. However, it is likely that on closer examination, differences in burrow position, shape or construction might be discovered.

By comparison, the appearance of *O. saratan* in the East Aden Protectorate is the daylight feature of the beaches; their burrows are well marked by large volcano-shaped piles of sand alongside the burrow mouths. The crab carries out an "armful" of sand, climbs to the top of the pile and deposits a load there each time.

During the winter of 1961, Mr. J. Brouwer studied a number of burrows of juvenile *O. convexa* at City Beach, near Perth, and he found that the entrances were all well above high water mark and 45-60 feet from the edge of the sea. The burrows were more or less vertical but all entrances were south of the bottom of the burrow, presumably to prevent sunlight from penetrating the burrow.

Mr. Brouwer also recorded that these juveniles survived immersion in freshwater for 12 hours and on release were able to dig burrows again. At Bernier Is., Shark Bay, Ride (1962) reported adult *O. convexa* (as *O. pygoides*) foraging up to one-third of a mile inland following heavy rain. The ability of *O. convexa* to withstand

immersion in freshwater and to actively forage in rain-soaked vegetation may also apply to other species; perhaps de Man's (1888, p. 108) record of *O. cordimana* in freshwater at Sullivan I. and Miers's (1886, p. 239) record of *Ocypode* sp. in freshwater at Fiji are similar examples.

The following observations on *O. fabricii* by Mr. D. G. Bathgate at the Little Lagoon, 1½ miles north of Denham, Shark Bay, on the 12.iii.64 are also worthy of recording here. The official maximum shade temperature at Denham on that day was 114 deg. F. at 1300 hours. Mr. Bathgate's observations on the behaviour of the crabs from 0930 to 1630 hours were almost certainly in response to the very hot, dry conditions when the temperature and water loss of the crabs would be unusually high.

The normal burrows along the beach at Little Lagoon were about 3 feet above the high water mark at 2 feet in depth but remarkably, they were not occupied by crabs during the above daylight observations; about 30 burrows were investigated by Mr. Bathgate and found to be empty. The crabs were actively engaged in digging temporary burrows closer to the water line. The burrows were only about 1 foot from the water line; the completed burrow ran obliquely a distance of about 6 inches, where it reached the water table.

The most remarkable aspect of the crab's behaviour was the fairly regular and very rapid visits to the water in the lagoon to completely submerge for about 2-3 minutes. They returned more slowly to the temporary burrow; there to continue digging, first at the burrow mouth and then deeper in the burrow. About five visits to the burrow were required to excavate the burrow to 6 inch depth; subsequent visits to the same burrow were continued until a total of about 20 visits were made (approximately 2½ hours' duration) after which the crab may commence digging at a new burrow site.

On his return to the area in the cool of the night, Mr. Bathgate noted that the temporary burrows were not being used and were only faintly recognisable, as the rising tide had almost erased them. The crabs at this time were behaving normally, foraging near the strand line and retreating, when disturbed, to their permanent burrows or to the waters of the lagoon.

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3.—Two species of the extinct genus *Sthenurus* Owen (Marsupialia, Macropodidae) from south-eastern Australia, including *Sthenurus gilli* sp. nov.

by D. Merrilees*

Manuscript Accepted 18th August, 1964.

A new species of *Sthenurus*, smaller than any so far known, is described from deposits near Strathdownie, Western Victoria, of presumed Pleistocene age. A variant of the same species occurs in Haystack Cave, Naracoorte, South Australia, and it may have ranged into Western Australia.

A second (larger) species of *Sthenurus*, resembling *S. occidentalis* Glauert, occurs in the Strathdownie deposit. The Haystack Cave deposit also contains a second species of *Sthenurus* resembling *S. occidentalis*. The taxonomic relationships of the larger Strathdownie species, the larger Haystack Cave species, *S. occidentalis* and *S. oreas* are to be considered later in a separate paper.

Introduction

During an investigation of occurrences of the genus *Sthenurus* in Western Australia, I was able to borrow an extensive series of specimens

*C/o Western Australian Museum, Perth, Western Australia.

from the National Museum of Victoria, for comparative purposes. Among them was a large sample from a site near Strathdownie in western Victoria, representing two species. One of these resembled the Mammoth Cave sample from which Glauert (1910 a and b) described *S. occidentalis*; the other did not fit any published description. Data on these two species from Strathdownie were assembled, and conclusions from these data are reproduced below.

Another series of specimens loaned by the South Australian Museum included a large sample of *Sthenurus* from Haystack Cave, Naracoorte, South Australia. Two species were present in this sample, probably the same two species as at Strathdownie. Data on the two species from Haystack Cave are also presented below.

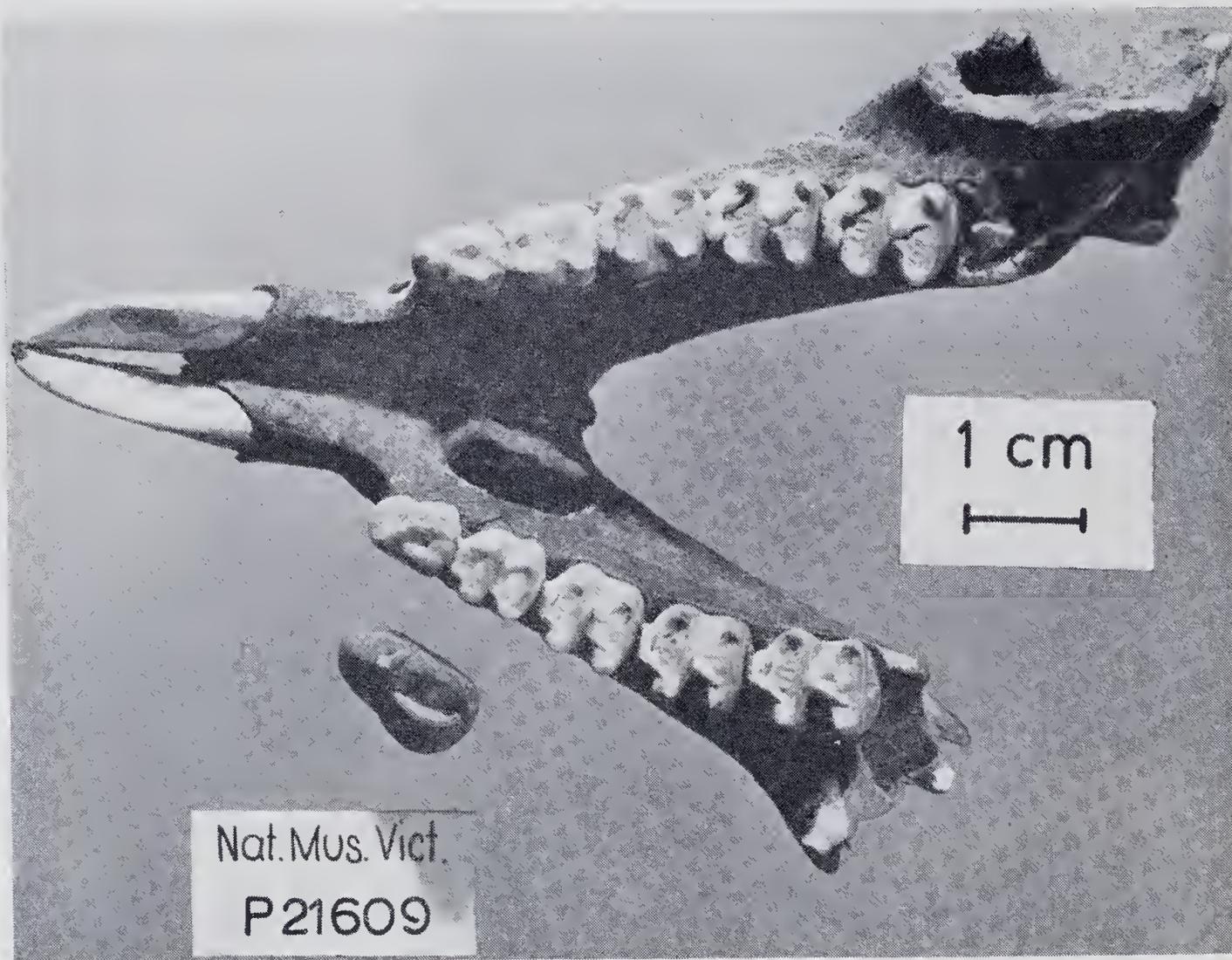
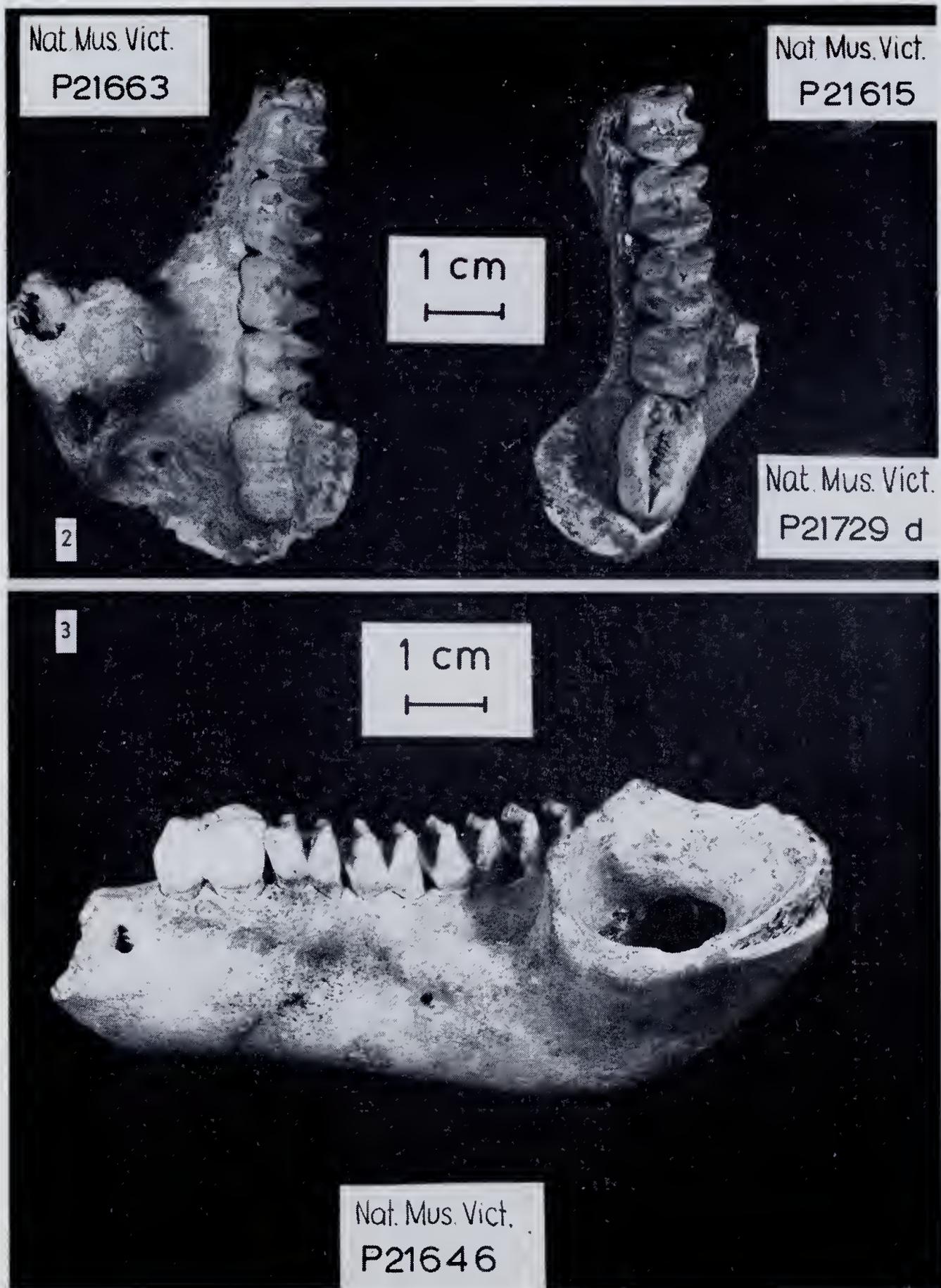


Fig. 1.—*Sthenurus gilli* sp. nov. from Strathdownie, Victoria. Holotype, mandible with left P₄ excavated.



Figs. 2, 3.—*Sthenurus gilli* sp. nov. from Strathdownie, Victoria. 2.—Upper cheek teeth in different aspects, P 21729 d (P⁺) originally separate from P 21615 (molars in maxilla). Note subdued masseteric process, undamaged in P 21663. 3.—Left mandibular ramus, buccal aspect.

Copies of the raw data have been lodged in the libraries of the National Museum of Victoria (Russell St., Melbourne C.1., Victoria), of the South Australian Museum (North Terrace, Adelaide, S.A.) and of the Western Australian Museum (Beaufort St., Perth, Western Australia).

The Strathdownie Deposit

Gill (1957) describes the Strathdownie deposit as containing a rich and varied assemblage of marsupials, with one monotreme. He states that it occurs in a limestone ridge standing some 20 ft. above the level of a plain extending from Casterton to Mt. Gambier, one of a series of such limestone ridges. The limestone is described as a beach or shallow water sediment containing marine molluscs. It is believed to have been subjected to cave formation during the latter part of the Pleistocene, and the fossil remains were found in red "cave earths" revealed by quarrying.

The specimens described below were presented to the National Museum of Victoria in 1956 and 1957 by Messrs. C. Austin, W. Brooker and C. B. Sasse.

The *Sthenurus* sample from Strathdownie

This consists of 186 specimens in an excellent state of preservation, from isolated teeth to maxillae and mandibular rami bearing complete sets of teeth. 65 of these specimens show teeth generally rather larger than those of *Sthenurus occidentalis* from Mammoth Cave, and 121 show teeth conspicuously smaller. It is concluded below that the two groups within the Strathdownie sample represent two species of *Sthenurus*. At least 9 individuals of the larger species are represented, and at least 23 of the smaller.

For statistical purposes, care has been taken that each individual animal has been represented only once for each dimension. For example, when considering the dimension "length" of lower permanent premolar, specimens from the left-hand side were first assembled. Each right-hand lower permanent premolar was then compared with each left-hand permanent premolar in general form and in state and pattern of wear. Any right premolar which could be construed as coming from the opposite side of the same animal as any of the left premolars was then rejected from the statistical treatment, and only those right premolars judged to derive from additional animals were accepted. Tables 1 and 2 record distribution of specimens between right and left sides, and the tables of raw data to be lodged in the libraries of the Western Australian Museum and the National Museum of Victoria record the side from which each specimen measured derives. I have examined 7 skulls or ankylosed mandibles of *Sthenurus* showing the cheek teeth of both sides, in none of which was there any sign of differential form or wear between the two sides.

Thus Tables 1 and 2 record maximum numbers of individuals for each dimension, but without the bias which might result from the double representation of some individuals and single representation of others if every available specimen had been included.

For ease of comparison, data have been tabulated in the same form as Marcus (1962) used for his *Sthenurus andersoni* from Bingara, N.S.W. Dental anatomical terms are as used by Ride (1961); tooth designations are those of Thomas, used for the reasons advocated by him (Thomas, 1922) and by Ride (1964). Methods of measurement are detailed with the records of raw data mentioned above.

Sthenurus Owen

A diagnosis of the genus *Sthenurus*, with some comments, has been published recently by Bartholomai (1963). It should be noted that the premolar designation used by Bartholomai differs from that of Thomas (1922) used herein.

*Sthenurus gilli** sp. nov.

Diagnosis.— M_2 , 3 , 4 narrower than any known species of *Sthenurus* (i.e. than *S. atlas* Owen, *S. andersoni* Marcus, *S. pales* (De Vis) *S. notabilis* Bartholomai, *S. antiquus*, Bartholomai, *S. creas* (De Vis) or *S. occidentalis* Glauert). Lower molars with trigonid basin having an inclined facet to the forward face with several (usually 3) small depressions or furrows in it. Upper molars with wide anterior shelf divided by longitudinal ridglet into larger buccal and smaller lingual portions.

Holotype.—National Museum of Victoria specimen P21609, ankylosed right and left mandibular rami, both lacking coronoid and condylar regions. Full juvenile dentition preserved, except hindmost molar on left. Left permanent premolar excavated, showing crown fully formed, and portion of roots. See Fig. 1.

Type locality.—Shire Quarry, Section 22, Parish of Kaladbro, Strathdownie, western Victoria.

Paratypes.—Same locality as holotype.

(a) Used in statistics, Table 1:—

Nat. Mus. Vict. specimens P21587, 21598, 21607-21609, 21613, 21614, 21618, 21621, 21624, 21642, 21643, 21645-21648, 21654, 21655, 21657, 21659, 21662, 21666, 21677, 21681, 21724c, 21729c, 21732p (mandibular) and P21611, 21615-21617, 21626, 21635, 21637, 21649, 21671, 21674, 21683, 21701, 21724h, 21724i, 21725c, 21729d (maxillary).

(b) Not used in statistics:—

Nat. Mus. Vict. specimens P21595, 21597, 21612, 21619, 21630, 21636, 21652, 21688, 21704, 21706, 21732c, 21732e-g, 21732i-n (mandibular) and P21627, 21634, 21650, 21653, 21663, 21676, 21703, 21724a, 21724d, 21724f, 21725d, 21728a, 21729a (maxillary).

Some isolated molar teeth, both upper and lower, were not included in the statistics because their position in the tooth-row was not certain.

(c) Premaxillary specimens, believed to be referable to *S. gilli*, but not certainly associated with any maxillary specimen:—

Nat. Mus. Vict. specimens P21700, 21730b, 21730d, 21730f, 21730h-i, 21731, 21732r-s, 21733a, 21733c-d.

*Named after E. D. Gill, Curator of Fossils, National Museum of Victoria, in recognition of his stimulating contributions to our understanding of Australian Quaternary events.

Table 1
Dental Data on Sthenurus gilli from Strathdownie, Victoria.

Dimension Examined*		Number of Specimens	Observed Range	Sample Mean	Sample Standard Deviation	Sample Coefficient of Variation
P ³	Length	5	mm. 9.4-10.0	mm. 9.82	mm. 0.25	2.5
	Width	5	8.2-9.9	9.12	0.61	6.6
DP ¹	Length	5	8.6-8.9	8.80	0.12	1.4
	Width	5	8.9-9.7	9.26	0.28	3.0
P ¹	Length	12	15.2-18.3	15.98	0.92	5.7
	Width	12	9.9-12.5	10.95	0.87	8.0
M ¹	Length	10	9.3-10.3	9.79	0.30	3.1
	Width	11	9.1-10.2	9.67	0.36	3.7
M ²	Length	8	10.0-10.9	10.41	0.37	3.6
	Width	8	9.4-10.6	9.95	0.51	5.1
M ³	Length	5	10.3-12.0	11.18	0.62	5.5
	Width	5	9.7-10.8	10.00	0.45	4.5
M ⁴	Length	2	9.9-10.7	10.30	0.57	5.5
	Width	2	9.4-9.5	9.45	0.07	0.7

Lower

Dimension Examined*		Holotype Nat. Mus. Vict. P 21609 (Right Side)	Number of Specimens		Observed Range	Sample Mean	Sample Standard Deviation	Sample Coefficient of Variation
			Left	Right				
I ₁	Depth	mm. 9.5	6	0	mm. 9.4-10.2	mm. 9.73	mm. 0.70	7.2
P ₃	Length	8.1	5	7	8.1-8.9	8.73	0.25	2.8
	Width	6.5	5	7	6.5-8.1	7.34	0.40	5.4
DP ₁	Length	7.8	5	7	7.6-8.4	7.97	0.26	3.2
	Width	7.3	5	7	7.3-7.9	7.48	0.20	2.7
P ₄	Length	13.3	9	7	13.3-15.0	14.36	0.49	3.4
	Width	8.2	9	6	8.0-9.3	8.60	0.41	4.8
	Basin Width	3.8	6	8	3.8-5.5	4.45	0.41	9.2
M ₁	Length	8.5	9	6	8.4-9.3	8.81	0.28	3.2
	Width	8.0	9	6	7.8-8.2	8.01	0.12	1.5
M ₂	Length	9.6	8	4	9.5-9.9	9.67	0.13	1.3
	Width	8.3	8	4	8.2-8.8	8.53	0.20	2.4
M ₃	Length	9.7	4	4	9.7-10.7	10.13	0.36	3.6
	Width	8.8	4	4	8.8-9.9	9.19	0.33	3.6
M ₄	Length	in	2	2	9.5-9.9	9.70	0.18	1.9
	Width	alveolus	2	2	9.1-9.5	9.33	0.17	1.9

* Details of measuring procedures, with estimates of accuracy and consistency, lodged with data on individual specimens in National Museum of Victoria and Western Australian Museum. All dimensions maximal, widths in molars across protoloph or protolophid, depth I₁ perpendicular to long axis of tooth, basin width P₄ across posterior central basin.

Comparison of *S. gilli* with other species

See Figs. 1 (holotype, showing lower dentition), 2 (upper dentition) and 3 (buccal aspect of mandibular ramus), and Table 1.

Distinguishable from *S. andersoni* Marcus by procumbency of lower incisor (much less procumbent in *S. gilli*) and by width of P₃, P₄ and M₂₋₄; in *S. gilli*, P₃ and P₄ wider but M_{2,3,4} narrower than in *S. andersoni*. Trigonid basin projecting relatively further forward, and cheek tooth row (P₃, DP₁, M₁₋₃ inclusive in juveniles) much longer, in *S. andersoni* than in *S. gilli*. Upper permanent premolars not known in *S. andersoni*, but upper molars stated by Marcus (1962) to lack forelink.

Distinguishable from *S. occidentalis* Glauert and from the larger Strathdownie species not only by dental dimensions, but also by lack of

a prominent descending masseteric (zygomatic) process, and by lack of molar ornamentation. In *S. occidentalis* and in the larger species at Strathdownie, the descending process is very marked, projecting downward further than the occlusal surface of the upper cheek tooth row, whereas in *S. gilli* it is so subdued and smoothly rounded as hardly to justify the term "process." In *S. occidentalis* and in the larger Strathdownie species, there is much more ornamentation on both upper and lower molars than in *S. gilli*.

I have been able to make direct comparison of *S. gilli* specimens with only one specimen of *S. oreas* (De Vis), viz. Queensland Museum specimen F3814, figured by Bartholomai (1963—Fig. 5). This specimen, portion of a maxilla, differs markedly from any specimen of *S. gilli*

not only in the greater lengths and widths of molars in *S. oreas*, but also in their showing much more ornamentation.

From Bartholomai's (1963) description of his revised *S. oreas*, it would appear that the mandibular ramus in *S. oreas* closely resembles that of *S. gilli* in form, except that the masseteric crest and masseteric foramen would appear to be a little lower in *S. gilli* (see Fig. 3); however, in almost all quantitative respects (except width of lower permanent premolar), both bone and teeth appear to be markedly smaller in mandibles of *S. gilli* than *S. oreas*.

The small size of the molar teeth in *S. gilli* suffices to distinguish this species from any other species of *Sthenurus*. However, two aspects of tooth morphology also appear to be distinctive of *S. gilli*, those noted in the diagnosis above, one for upper and one for lower molars.

The larger species of *Sthenurus* at Strathdownie

Specimens.—

(a) Used in statistics, Table 2.—

Nat. Mus. Vict. specimens P21586, 21633, 21638, 21640, 21644, 21656, 21724a, 21724b, 21725b, 21729b, 21732a-b, 21732d (mandibular) and P21629, 21641, 21660, 21673, 21687, 21705, 21720b, 21724g, 21725a, 21728c, 21729e (maxillary).

(b) Not used in statistics:—

Nat. Mus. Vict. specimens P21732 o (mandibular), P21672, 21721h, 21728b, 21749 (maxillary) and P21678, 21730g, 21733b, 21733e (premaxillary).

Some isolated lower molars were not included in the statistics because their position in the tooth row was not certain.

Comparison of larger Strathdownie species with other species

See Figs. 4 (showing upper dentition) and 5 (showing lower dentition) and Table 2 (of dental dimensions).

Closely resembles *S. occidentalis* Glauert and *S. oreas* (De Vis) in form. In lengths P_3^3 and widths $M_{1,4}^{1,4}$ considerably exceeds Mammoth Cave sample of *S. occidentalis* (direct comparison—D.M.). In lengths P_4^4 and widths $M_{1,2}^{1,3}$ exceeds Queensland sample of *S. oreas*, according to data published by Bartholomai (1963) and to my direct comparison with one Queensland specimen (F3814—see above). Despite the quantitative differences observed between the large Strathdownie sample and those from Mammoth Cave and from Queensland, I believe the animals concerned were related, and propose to investigate the relationship further. In the meantime, it appears desirable to leave open the matter of the taxonomic status of the larger *Sthenurus* at Strathdownie.

Distinguishable from *S. antiquus* Bartholomai on the form of the lower permanent premolar and the spacing of the lower molars, according to my direct comparison with Queensland Museum specimens F2931 and F2932, figured in association by Bartholomai (1963—Fig. 9). In the larger Strathdownie specimens, each lower

molar overlaps the base of the preceding tooth in the cheek tooth row to a greater extent than in *S. antiquus*. The lingual crest on the lower permanent premolar F2932 of *S. antiquus* inclines inward to a much greater extent, and the buccal crest is relatively much lower, extends less far forward, and is more clearly separated on the rear face of the tooth from the lingual crest, than in any P_4 from the larger Strathdownie species.

Upper incisors of *Sthenurus* at Strathdownie

No specimens were available in the Strathdownie sample which associated upper molars or premolars referable to *S. gilli* with upper incisors. However, available I^1 and I^2 specimens from Strathdownie fell into two distinct groups, larger and smaller; it would appear justifiable to associate the smaller incisors with *S. gilli* rather than with the larger species occurring at Strathdownie. Unfortunately, no specimen showed an I^3 associated with a smaller I^2 or I^1 ; but it was possible to divide the I^3 specimens available into two kinds. One of these groups could be associated with I^2 and I^1 , and clearly derived from the larger species at Strathdownie; furthermore, in form this group resembled the I^3 teeth of *S. occidentalis*. In the second of the I^3 groups, the individual teeth were more strap-like than I^3 in *S. occidentalis*, but were less rugose on the lingual aspect, and bore a less pronounced "fold" in the enamel of the lingual aspect of the antero-occlusal corner of the tooth. Since the larger Strathdownie species resembled *S. occidentalis* in many particulars, it would appear reasonable to assign the more strap-like upper third incisors to *S. gilli* rather than to the larger species.

It is on these grounds that the allotment of incisor teeth to the two different species in the Strathdownie deposit has been made. See Fig. 5.

S. Aust. Mus. specimen P 13687, attributable to *Sthenurus gilli* (see below) does show I^1 and I^3 , but unfortunately not I^2 , in association with cheek teeth distinctive of this species. See Fig. 7. It confirms the division made among the unattached Strathdownie upper incisors.

The Haystall Cave Deposit

According to labels supplied with the specimens from Haystall Cave, all the specimens on loan to me appear to have been recovered from a red to yellow sandy deposit at depths up to 2 ft. 6 in. One left mandibular ramus (P 13682) from the top 6 in. appears to derive from the same animal as right ramus P 13830a from 2 ft. 6 in.; thus it is probable that all the specimens are approximately contemporaneous. They are probably of late Quaternary age.

The sample was collected and presented to the South Australian Museum in 1963 and 1964 by the Cave Exploration Group (South Australia).

The *Sthenurus* sample from Haystall Cave

This consists of 52 well-preserved specimens, most of them juveniles, 24 forming a homogeneous group with larger teeth; and 28 forming a similarly homogeneous group with smaller

Table 2
Dental data on the larger species of *Sthenurus* from Strathdownie, Victoria.
Upper

Dimension Examined*	Number of Specimens		Observed Range	Sample Mean	Sample Standard Deviation	Sample Coefficient of Variation
	Left	Right				
			mm.	mm.	mm.	
P ³ Length	2	0	12.0-12.0	12.00		
P ³ Width	2	0	10.3-10.6	10.45	0.20	1.9
DP ⁴ Length	2	0	10.5-11.5	11.00	0.71	6.5
DP ⁴ Width	2	0	11.2-12.3	11.75	0.77	6.6
P ⁴ Length	2	3	17.1-18.8	18.22	0.65	3.6
P ⁴ Width	2	3	12.1-13.9	13.06	0.75	5.7
M ¹ Length	2	0	12.8-13.2	13.00	0.28	2.2
M ¹ Width	2	0	12.9-13.1	13.00	0.14	1.1
M ² Length	3	1	13.7-14.6	14.18	0.32	2.3
M ² Width	2	1	13.6-14.3	13.83	0.38	2.8
M ³ Length	3	1	14.2-15.5	14.73	0.60	4.1
M ³ Width	1	1	13.6-13.8	13.70	0.14	1.0
M ⁴ Length	1	2	13.0-14.6	13.63	0.85	6.3
M ⁴ Width	1	2	12.7-14.2	13.33	0.84	6.3
Lower						
I ₁ Depth	0	3	12.0-13.3	12.67	0.65	5.1
P ₃ Length	1	2	9.6-10.1	9.90	0.27	2.7
P ₃ Width	1	2	7.7-8.0	7.87	0.16	2.0
DP ₄ Length	1	1	9.7-10.1	9.90	0.28	2.9
DP ₄ Width	1	1	9.0-9.7	9.35	0.49	5.2
P ₄ Length	3	5	16.0-17.6	16.79	0.53	3.2
P ₄ Width	3	6	9.8-10.7	10.29	0.27	2.6
M ₁ Length	1	4	11.5-12.4	11.74	0.38	3.2
M ₁ Width	1	4	10.1-11.0	10.38	0.37	3.5
M ₂ Length	1	1	12.7-12.7	12.70		
M ₂ Width	1	1	11.4-11.9	11.65	0.35	3.0
M ₃ Length	1	1	13.2-13.4	13.30	0.14	1.1
M ₃ Width	1	1	12.0-12.2	12.10	0.14	1.2
M ₄ Length	1	0		12.80		
M ₄ Width	1	0		11.50		

* All dimensions maximal, widths in molars across protoloph or protolophid, depth I₁ perpendicular to long axis of tooth.

teeth. At least 12 individuals of the larger species are represented, and at least 9 of the smaller.

From these groups, the specimens listed below were selected for statistical purposes in the same way as from the two groups at Strathdownie:—

(a) Larger species. S. Aust. Mus. specimens P 13703, 13831 g-h (maxillary) and P 13674-13676, 13678, 13680-13681, 13696, 13711, 13713-13714, 13830a, 13831 c-d (mandibular).

(b) Smaller species. S. Aust. Mus. specimens P 13687 (complete upper dentition of both sides except right I², left I²⁻³), P 13690 a-b, 13691-13694 (maxillary) and P 13688, 13702, 13704, 13706, 13708, 13710, 13717, 13830 b, 13831 a-b (mandibular).

Measurements on these specimens are summarized in Tables 3 and 4.

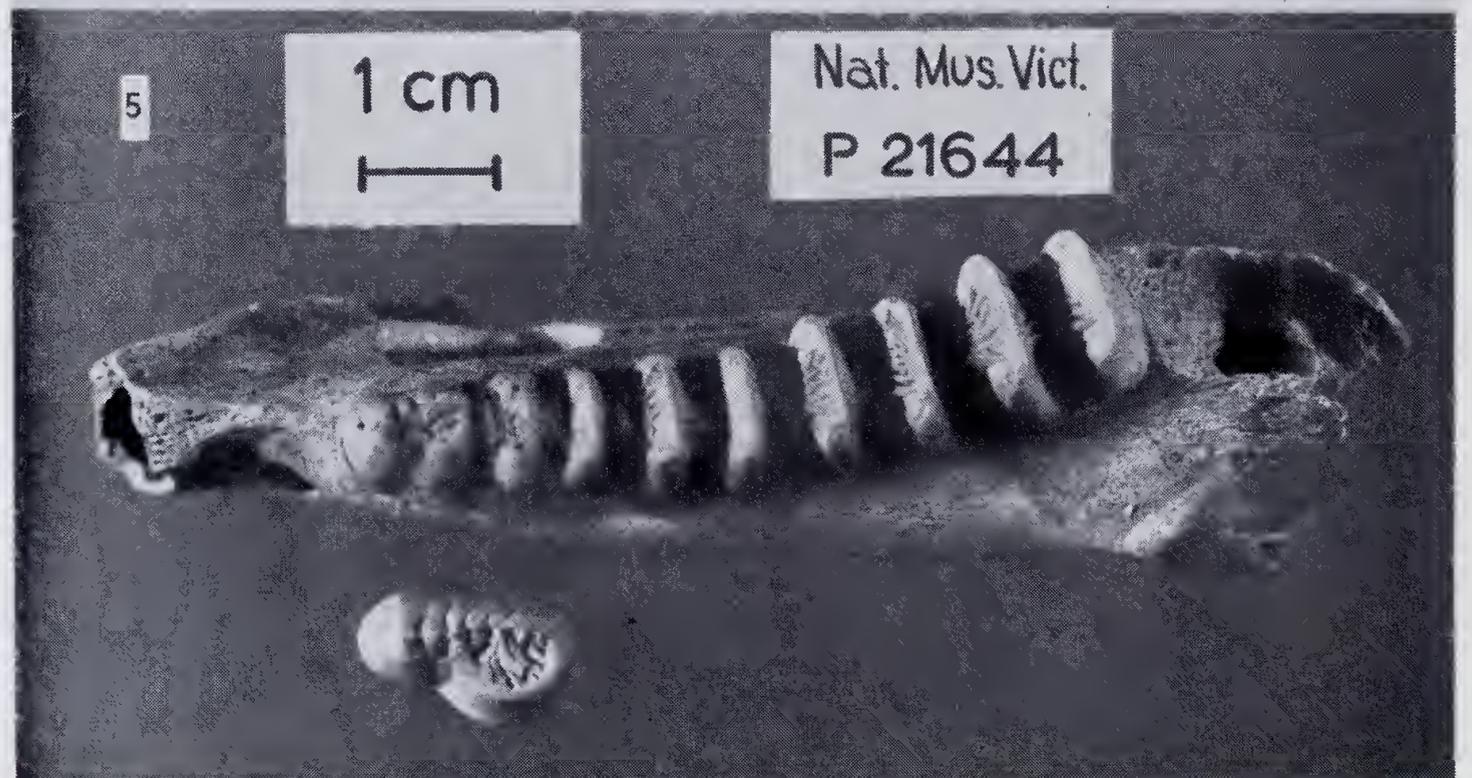
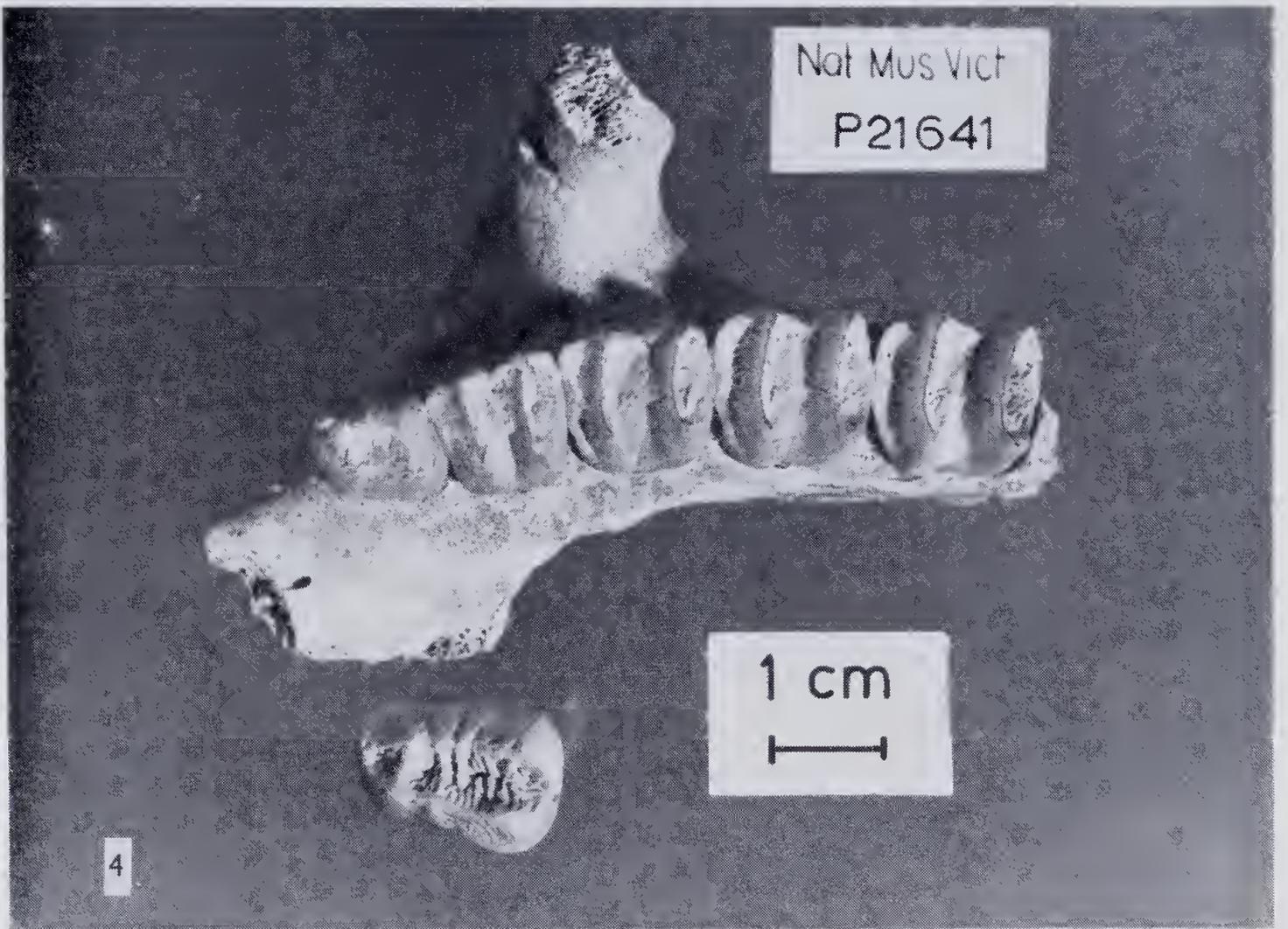
The smaller species of *Sthenurus* from Haystack Cave

Direct comparisons of specimens of the smaller Strathdownie with the smaller Haystack Cave species show that the two are closely similar.

On morphological grounds, one would equate them. Compare Figs. 1, 2 and 3 with Fig. 7 below.

However, mean dimensions in the Haystack Cave sample exceed those in the Strathdownie sample in 28 cases out of 30, and there are even 2 cases (length DP⁴ and width M⁴) in which ranges in the two samples do not overlap. See Tables 1 and 3.

Such a situation, in which strong morphological resemblances between two samples are coupled with quantitative distinctions, has been discussed by Ride (1964). He has proposed numerical tests for the recognition of subspecies in this situation. On Ride's tests, either length of DP⁴ or width of M⁴ could conceivably serve to differentiate as subspecies the Haystack Cave and Strathdownie samples of the smaller *Sthenurus*. But none of the differences revealed by comparison of Tables 1 and 3 below can, in my opinion, be construed as differentiating full species. The Haystack Cave sample appears to me to be merely a geographical or temporal variant of *Sthenurus gilli* as defined above.



Figs. 4, 5.—*Sthenurus* sp., the larger species from Strathdownie, Victoria. 4.—Upper cheek teeth, P₄ excavated. Note prominent masseteric process. 5.—Lower cheek teeth, P₄ excavated.

**The larger species of *Sthenurus* from
Haystack Cave**

Like the smaller species, the larger species at Haystack Cave and at Strathdownie are closely similar in form, but show quantitative differences. Compare Figs. 4 and 5 with Fig. 8, and Table 2 with Table 4. Note that the Haystack Cave sample of lower teeth is the more numerous of the two. In a substantial minority of cases (13 out of 29) mean dimensions (or single measurements where only one specimen occurs) in the less numerous sample fall outside the observed range in the more numerous sample, and in several cases (e.g. length P^1 , depth I_1 , width P_3) there is no overlap in range.

Despite the strong resemblances between the two samples, some doubt therefore remains about the grade of their relationship. Since in any case, the question of relationships of both samples with the Darling Downs (Queensland) sample of *Sthenurus oreas* and with the Mammoth Cave (W.A.) sample of *S. occidentalis* are to be taken up later, the question of conspecificity of the Haystack Cave and Strathdownie samples is not further pursued here. Provisionally, the two samples appear to me to be geographical or temporal variants of one species.

**Possible occurrences of the Strathdownie and
Haystack Cave species of *Sthenurus* in
Western Australia**

A small lower permanent premolar (P_4) of *Sthenurus* was described and figured by Lundelius (1963) from Madura Cave on the Nullarbor Plain. This specimen is now lodged in the Chicago Natural History Museum, but I have examined a plaster cast of it (W. Aust. Mus. specimen 63.6.1). Its length is 14.2 mm., its width 8.1 mm. and its basin width is 3.5 mm., if measurements made from the cast can be taken as accurate. ("Basin width" is the maximum distance separating buccal from lingual crests on the hinder portion of P_4).

The Madura Cave tooth resembles P_4 in both Haystack Cave and Strathdownie samples of *S. gilli* in form, and in length falls within the range shown in both samples. In width it falls within the Strathdownie but not quite within the Haystack Cave ranges, and its basin width is smaller than any in these two samples. Only provisionally, therefore, can it be referred to *S. gilli*.

Since his original discovery at Madura Cave, Lundelius has participated in further excavations there (Lundelius E. L. 1964 pers. comm.)

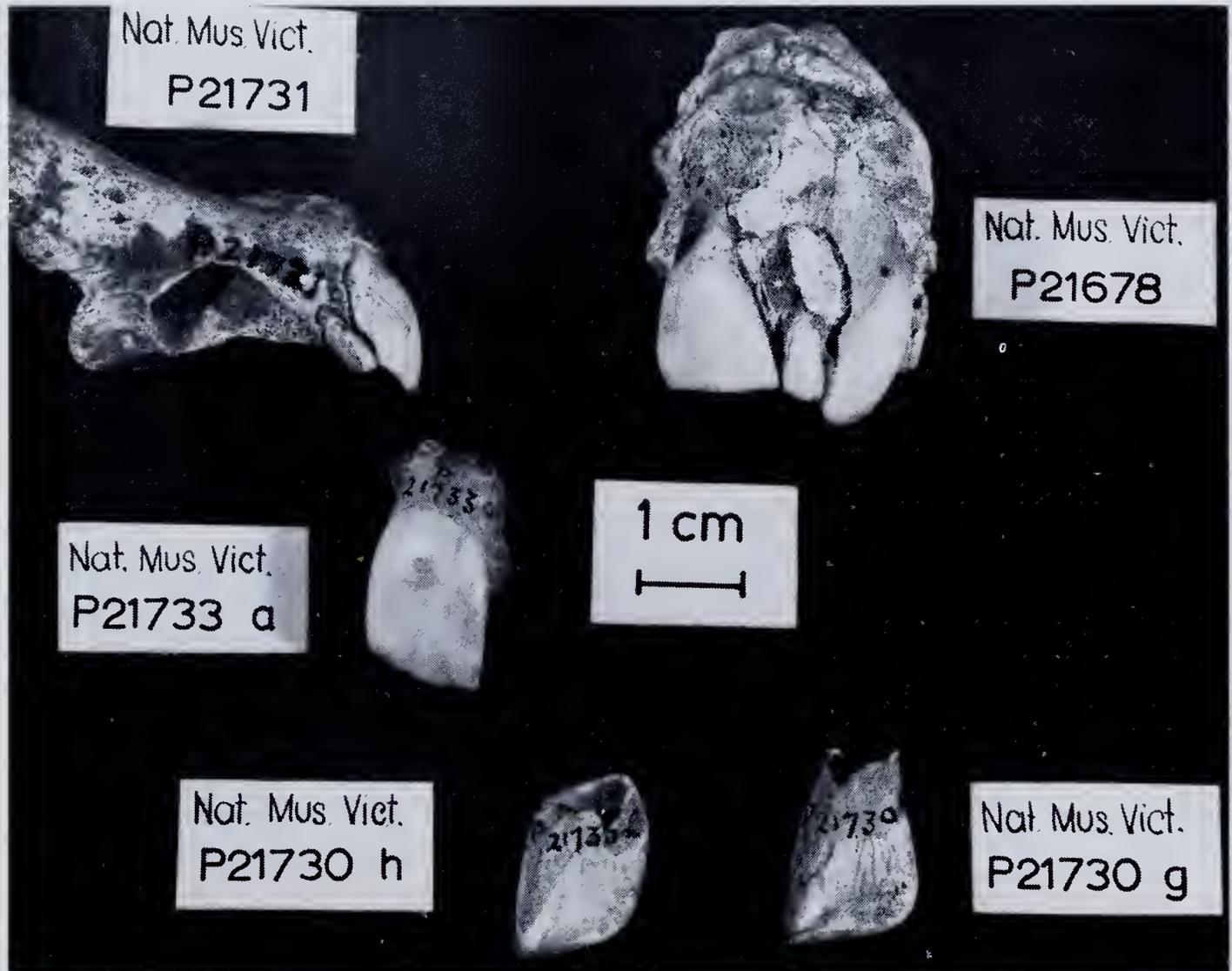


Fig. 6.—Comparison of *Sthenurus* upper incisors from Strathdownie, Victoria. Left, P 21731, P21733 a and P 21730 h attributed to *S. gilli*. Right, P 21678 and P 21730 g attributed to the larger species.

Table 3

Dental data on the smaller species of *Sthenurus* from Haystack Cave, Naracoorte, South Australia.
Upper

Dimension Examined*	Number of Specimens		Observed Range	Sample Mean	Sample Standard Deviation	Sample Coefficient of Variation
	Left	Right				
I ¹ Length	0	1	mm.	mm. c. 5.9	mm. .....	.....
I ² Length	0	1	.....	12.10	.....	.....
P ³ Length	1	3	9.8-10.5	10.15	0.29	2.8
P ³ Width	1	3	8.4-9.3	8.90	0.37	4.2
DP ⁴ Length	1	3	9.3-9.6	9.43	0.15	1.6
DP ⁴ Width	1	3	9.4-10.2	9.80	0.34	3.4
P ⁴ Length	2	4	15.2-16.4	15.82	0.45	2.8
P ⁴ Width	1	4	11.0-12.2	11.48	0.71	6.2
M ¹ Length	0	4	10.0-10.6	10.23	0.27	2.6
M ¹ Width	0	4	9.9-10.6	10.25	0.29	2.8
M ² Length	1	4	10.4-11.7	10.90	0.54	5.0
M ² Width	1	4	10.2-10.9	10.56	0.25	2.4
M ³ Length	1	2	11.3-11.9	11.60	0.30	2.6
M ³ Width	1	2	10.6-11.0	10.77	0.21	2.0
M ⁴ Length	1	1	10.6-11.0	10.80	0.28	2.6
M ⁴ Width	1	1	10.1-10.4	10.25	0.37	3.6

Lower

I ₁ Depth	0	4	9.7-11.2	10.35	0.66	6.3
P ₂ Length	0	5	8.5-9.4	9.10	0.39	4.3
P ₂ Width	0	5	7.1-7.9	7.56	0.30	3.9
DP ₁ Length	0	5	8.1-8.6	8.26	0.19	2.3
DP ₁ Width	0	5	7.3-8.3	7.64	0.42	5.5
P ₁ Length	0	9	13.7-16.2	14.97	0.78	5.2
P ₁ Width	0	9	8.3-9.9	9.01	0.48	5.3
P ₁ Basin Width	0	7	4.1-5.4	4.69	0.52	11.0
M ₁ Length	0	8	8.5-9.5	9.13	0.34	3.7
M ₁ Width	0	9	7.9-9.0	8.37	0.41	4.9
M ₂ Length	0	6	9.3-10.8	9.93	0.53	5.3
M ₂ Width	0	6	8.5-9.7	8.93	0.49	5.5
M ₃ Length	0	4	9.7-11.1	10.35	0.58	5.6
M ₃ Width	0	4	9.1-10.4	9.60	0.59	6.2
M ₄ Length	0	2	9.5-10.4	9.95	0.64	6.3
M ₄ Width	0	2	9.4-10.4	9.90	0.71	7.1

* All dimensions maximal. widths in molars across protoloph or protolophid. depth I₁ perpendicular to long axis of tooth.

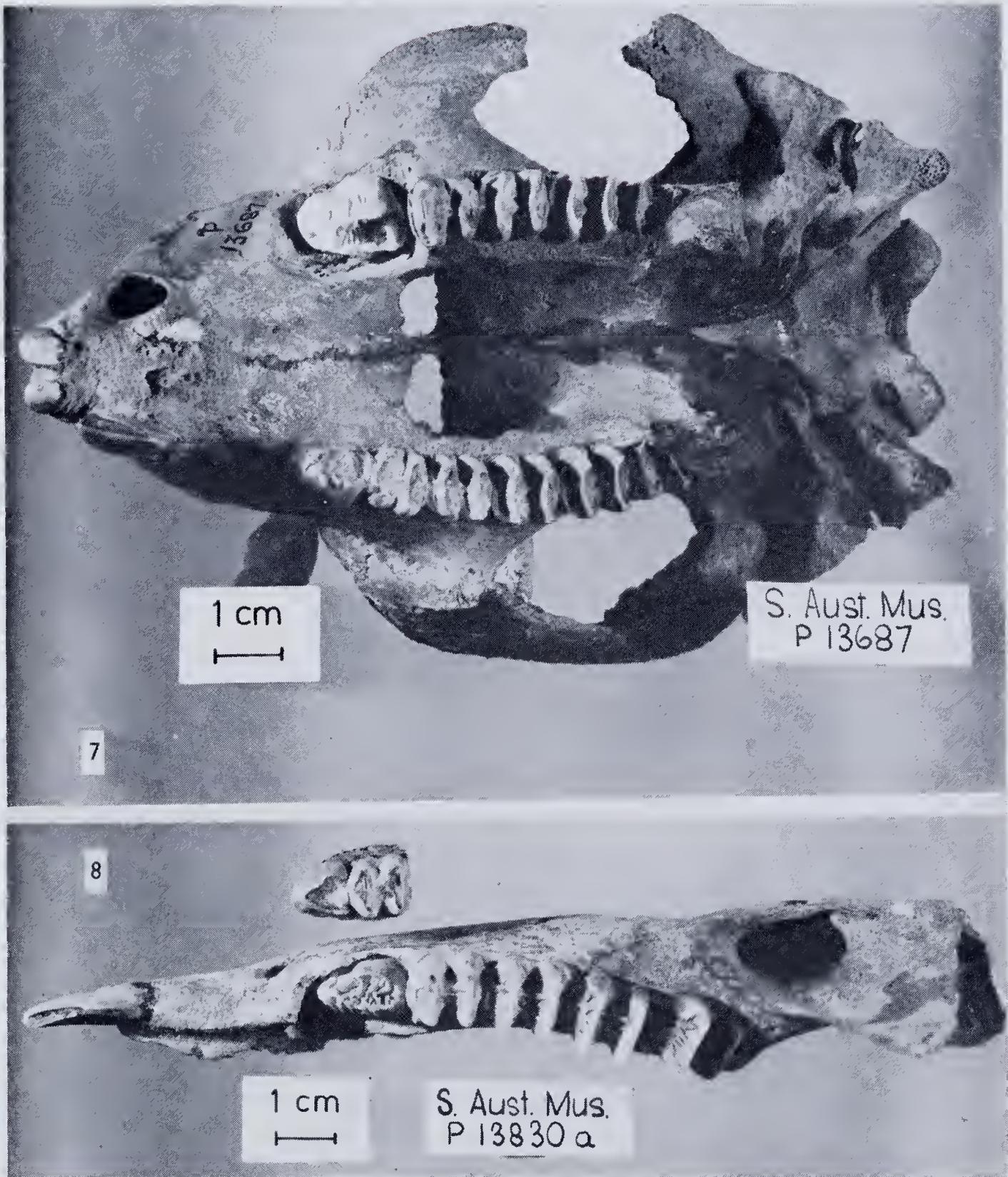
but without finding any more specimens of *Sthenurus*. It is unfortunate that a single premolar does not necessarily provide more than a general guide to the probable size of the molars in *Sthenurus*. For example, *S. oreas* (De Vis) as revised by Bartholomai (1963) has lower permanent premolars which are shorter than those of *S. occidentalis* Glauert, together with lower molars which are longer. Both premolars and molars are similar in form. If, in these samples, only premolars had been known, one might have predicted from them that the molars of *S. oreas* would have been shorter than those of *S. occidentalis*. By analogy, it is possible that the molars of the Madura Cave species of *Sthenurus* may have differed quite markedly from those of *S. gilli*.

Tentatively, however, it may be suggested that *Sthenurus gilli* ranged into Western Australia.

As remarked above, the larger species of *Sthenurus* at Haystack Cave and at Strathdownie resemble *S. occidentalis* from Mammoth Cave, W.A. in form and in size of the lower permanent premolars, but not closely in size of the molars. These samples could conceivably represent geographical variants of a wide-ranging species which once included Western Australia in its range.

Acknowledgments

I am indebted to Mr. E. D. Gill (Curator of Fossils, National Museum of Victoria), to Dr. D. W. P. Corbett (Curator of Fossils and



Figs. 7, 8.—*Sthenurus* from Haystack Cave, South Australia. 7.—Variant of *Sthenurus gilli* sp. nov. Skull with left P^3 and DP^4 removed to expose P^1 . 8.—The larger species of *Sthenurus* at Haystack Cave. Right mandibular ramus with P_3 and DP_4 displaced to the side, exposing P_1 .

Table 4

Dental data on the larger species of Sthenurus from Haystack Cave, Naracoorte, South Australia.

Upper

Dimension Examined*		Number of Specimens		Observed Range	Sample Mean	Sample Standard Deviation	Sample Coefficient of Variation
		Left	Right				
P ³	Length	0	1	mm.	mm.	mm.	
	Width	0	1	....	10.80	....	....
DP ¹	Length	0	1	....	11.00	....	....
	Width	0	1	....	10.60	....	....
P ¹	Length	0	2	16.7-16.8	16.75	0.10	0.6
	Width	0	2	12.0-12.5	12.25	0.35	2.9
M ¹	Length	0	1	....	12.10	....	....
	Width	0	1	....	11.50	....	....
M ²	Length	1	0	....	14.30	....	....
	Width	1	0	....	13.60	....	....
M ³	Length	1	0	....	14.30	....	....
	Width	1	0	....	13.80	....	....
M ⁴	Length	1	0	....	13.10	....	....
	Width	1	0	....	12.70	....	....

Lower

J ₁	Depth	4	1	10.9-11.6	11.26	0.79	7.0
P ₃	Length	8	1	9.4-10.4	9.90	0.42	4.2
	Width	8	1	8.7-9.7	8.98	0.38	4.2
DP ₁	Length	8	1	9.3-10.5	10.05	0.43	4.3
	Width	8	1	8.7-9.9	9.29	0.35	3.7
P ₄	Length	8	3	15.5-17.5	16.45	0.54	3.3
	Width	9	2	9.1-10.6	9.85	0.38	3.8
M ₁	Length	7	2	11.6-12.3	11.90	0.57	4.8
	Width	7	2	9.8-10.9	10.32	0.32	3.5
M ₂	Length	1	3	12.9-14.0	13.70	0.54	3.9
	Width	1	2	11.5-11.9	11.70	0.20	1.7
M ₃	Length	3	0	14.2-14.5	14.37	0.16	1.1
	Width	2	0	12.5-12.7	12.60	0.14	1.1
M ₄	Length	2	0	13.0-13.9	13.45	0.59	4.4
	Width	2	0	11.7-12.5	12.10	0.57	4.7

* All dimensions maximal, widths in molars across protoloph or protolophid, depth I₁ perpendicular to long axis of tooth.

Minerals, South Australian Museum), to Mr. A. Bartholomai (Curator of Geology, Queensland Museum), to Mr. H. O. Fletcher (Curator of Fossils, Australian Museum, Sydney), to Mr. F. L. Sutherland (Geologist, Queen Victoria Museum, Launceston, Tasmania), to the Directors of these Museums and to Mr. J. A. Mahoney (University of Sydney) for the loan of the samples described above and of a wide range of comparative specimens. Messrs. Gill and Bartholomai, and Dr. B. Daily (University of South Australia) also very kindly provided information on the specimens.

I am grateful also to Dr. W. D. L. Ride and to the staff of the Western Australian Museum for constructive criticism of this and ancillary work, and for access to the modern and fossil marsupial collections and to records of the Western Australian Museum, and to Mr. W. B. Sewell for his care with the photographs reproduced herein.

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INSTRUCTIONS TO AUTHORS

Papers may be submitted to the Society in accordance with Rules and Regulations 38 to 41 inclusive (see below). They should be addressed to *The Honorary Secretary, Royal Society of Western Australia, Western Australian Museum, Perth.*

Authors are solely responsible for the factual accuracy and for any opinion expressed in their papers. They are particularly requested to verify references. Alterations to MSS. submitted to the printer will be allowed only under exceptional circumstances, and no changes will be permitted after galley-proof stage.

In the preparation of MSS. authors are required to follow the C.S.I.R.O., *Guide to Authors* (C.S.I.R.O., Melbourne, 1953), except that papers longer than 10,000 words (30 foolscap pages of pica type, with 6 inch lines 40 to the page) will not normally be accepted.

Authors may be required to meet half the cost of preparation of the blocks of diagrams and illustrations.

Authors shall receive a total of 30 reprints free of charge. Further reprints may be ordered at cost, provided that such orders are submitted with the MS.

RULES AND REGULATIONS

38. Every paper intended to be read before the Society or to be published in the Society's Journal must be sent to the Secretaries at least seven days before the date of the next ensuing Council meeting, to be laid before the Council. It will be the duty of the Council to decide whether such contribution shall be accepted, and if so, whether it shall be read in full, in abstract, or taken as read. All papers accepted for publication must be read or otherwise communicated at an ordinary meeting prior to publication.

39. A Publications Committee, appointed by the Council, shall recommend to the Council whether a paper presented to the Society shall be published in the Society's Journal. The Publications Committee may obtain an opinion from any person it may select on the suitability of any paper for publication.

40. Publication in the Society's Journal shall only be available to (a) Ordinary Members, (b) Honorary Members, (c) Non-members resident outside Western Australia, who must communicate the paper through an Ordinary or Honorary Member. No paper shall be accepted from a Non-member resident in Western Australia.

41. The original copy of every paper accepted for publication by the Society, with its illustrations, shall become the property of the Society, unless stipulation is made to the contrary, and authors shall not be at liberty to publish their communicated papers elsewhere prior to their appearance in the publications of the Society unless permission for so doing is given by the Society, or unless the Society fails to publish the paper in the Journal of the year in which it is read or otherwise communicated, or of the succeeding year.

Journal
of the
Royal Society of Western Australia

Volume 48

1965

Part 1

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Editor: R. W. George

Assistant Editor: R. D. Royce

The Royal Society of Western Australia, Western Australian Museum, Perth

JOURNAL OF

THE ROYAL SOCIETY

OF

WESTERN AUSTRALIA

VOLUME 48

PART 2

PUBLISHED 30TH JUNE, 1965

REGISTERED AT THE G.P.O., PERTH FOR TRANSMISSION BY POST AS A PERIODICAL

THE
ROYAL SOCIETY
OF
WESTERN AUSTRALIA

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**Journal
of the
Royal Society of Western Australia**

Vol. 48

Part 2

4.—A History of the Royal Society of Western Australia, and its role in the Community.

Presidential Address, 1964.

By C. F. H. Jenkins, M.A.*

Delivered—20th July, 1964.

Ladies and gentlemen;

I was greatly honoured when this society elected me as President for the year 1945-46 but I regard it as a much greater honour to have the privilege of holding office for a second term, particularly in the Society's Jubilee Year.

I joined the Royal Society in 1929 and have served on the council since 1932. During that period I have been associated with every office excepting that of treasurer and so have been very closely connected with the Society's activities for over 30 years. This experience has encouraged me to investigate the earlier history of the organisation and to present these findings together with a number of general comments as my Presidential Address for this anniversary year.

If any other excuse is necessary for presenting what may be regarded as largely parochial material to a gathering such as this, I might point out that Royal Society presidents in all the other states have given comparable addresses, as did Sir Howard Florey in his 1963 Anniversary Address to the Royal Society of London.

The Royal Society of London is of course, the most celebrated scientific society in the world and received its charter from King Charles II on 22nd April, 1663. The formation of this society marked the development of modern science in Britain and provided a pattern to be followed by such empire countries as South Africa, Canada, New Zealand and Australia, all of whom modelled their societies on the parent body.

Modern science came to Australia with James Cook and Joseph Banks in 1770, but it was not until 1821 that the first scientific society was formed when Sir Thomas Brisbane, Governor of N.S.W. founded the Philosophical Society of Australia. This survived for little more than 12 months, but was followed in 1850 by the Australian Philosophical Society, for the encouragement of Arts, Science, Commerce and

Agriculture. In 1885 this became the Philosophical Society of N.S.W. and in 1866 it assumed the title of the Royal Society of N.S.W.

The Royal Society of Van Diemens Land for Horticulture, Botany and Advancement of Science was formed in 1843, later of course to become the Royal Society of Tasmania. The Royal Society of Victoria was established in 1854, the Royal Society of South Australia in 1877 and that of Queensland in 1884 (Elkin, A. P. 1962, *A.J.S.* 25: 2).

A Royal Society was formed in Canberra in 1930 and at first assumed the name of the Royal Society of Australia. The various state Royal Societies were opposed to this title however and in 1955 it was changed to the Royal Society of Canberra.

Royal Society of Western Australia

The foundations of the Royal Society of W.A. were laid as far back as 1891 when under the presidency of Sir John Forrest (later Lord Forrest) the Western Australian Natural History Society was founded. This society did not publish a journal and failed to survive beyond 1895. Then in 1897 the Mueller Botanical Society was established with Sir John Forrest president (with E. J. Bickford Chairman) and His Excellency the Governor, Lt. Col. Sir Gerard Smith K.C.M.G. Patron. The remaining members of Council were as follows:

Vice Presidents:

Hon. E. H. Wittenoom, M.L.C.
G. Leak, M.L.A.

Hon. Secretary:

F. J. Skewes.

Council:

Dr. F. Tratman.
Dr. F. Wilkinson.
A. W. Milligan.
J. S. Batty.

In 1903 the scope of the Society was broadened and the name was changed to "Western Australian Natural History Society, with which is incorporated the Mueller Botanical Society."

*Department of Agriculture, Jarrah Road, South Perth.

The following comprised the first Council:

Patron:

His Excellency the Governor, Admiral
Sir Frederick Bedford, G.C.B.

President:

C. R. P. Andrews.

Vice Presidents:

Dr. F. Tratman.
B. H. Woodward.
A. Purdie.

Editors:

C. R. P. Andrews.
F. Crossman.

Treasurer and Librarian:

A. Purdie.

Secretary:

F. S. Dobbie.

Council:

A. F. Crossman.
E. W. Hursthouse.
A. Gibb Maitland.
A. W. Milligan.
Justice R. MacMillan.
H. C. Prinsep.

In 1909 the Societies' work broadened still further and the name was changed accordingly to the "Western Australian Natural History and Science Society." The first officer bearers were as follows:

Patron:

His Excellency the Governor Sir Gerald
Strickland K.C.M.G.

President:

Dr. F. Tratman.

Vice Presidents:

A. Gibb Maitland.
Dr. A. Morrison.

Treasurer:

T. Thorpe.

Editors:

H. M. Giles.
C. P. Conigrave.

Secretary:

C. P. Conigrave.

Librarian:

C. P. Conigrave.

Council:

E. S. Simpson.
W. Catton Grasby.
T. N. Lee.
F. G. Brown.
H. M. Giles.

It is recorded that in 1907 several meetings lapsed for want of a quorum and a committee consisting of Messrs. B. H. Woodward, E. A. Mann, J. B. Allan and Dr. J. B. Cleland, was appointed to investigate the possibility of forming a Royal Society or alternatively affiliating with the Royal Society of South Australia. No immediate action was taken however, and the title of Royal Society was not assumed until 1914. The letter conferring this honour was presented to Council by Professor Dakin on

December 2nd, 1913 and published in the "West Australian" on December 13th. The first office bearers for the new Society were as follows:

Patron:

His Majesty King George V.

Vice Patron:

His Excellency the Governor, Major
General Sir Harry Barron,
K.C.M.G.

President:

Professor W. J. Dakin.

Vice Presidents:

A. Gibb Maitland.
Professor A. D. Ross.

Hon Secretaries:

M. A. Browning.
W. B. Alexander.

Hon. Treasurer:

J. J. East.

Hon. Librarian:

A. O. Watkins.

Hon. Editors:

A. Gibb Maitland.
M. A. Browning.
W. B. Alexander.

Council:

H. B. Curlewis.
W. J. Hancock.
A. Montgomery.
E. S. Simpson.
B. H. Woodward.

Functions and Aims of The Royal Society

The main functions and aims of the Society are summarised in paragraph 2 of the 1936 Constitution which reads as follows: "To promote and to assist in the advancement of Science in all its branches." This gives the Society the widest possible scope and places no restriction upon membership, providing correct election procedures are followed.

In addition to producing an annual journal, the Society has conducted regular meetings for the presentation of scientific papers, discussions and popular talks. A perusal of the records show that the Society has concerned itself with many matters of public interest and has offered advice and criticism where these have been considered necessary. In addition to subjects such as Geology and Biology which constitute the major contributions to the Society, papers and reports have been presented on such matters of topical interest as the following:

Spiritual Healing (Vol. X, p xxiv)

Water Divining (Vol. VI, p 112)

Housing (Vol. V, p 62)

Decimal Currency in Australia (Vol. IV, p 16)

Town Planning (Vol. V, p 39)

as well as other subjects of public concern or popular interest.

Special Committees.

The Society has on many occasions appointed working committees to investigate problems of public interest or major importance. Some idea

of the range of subjects covered will be gained from the following list:

- Vermin Committee (Vol. VII, p 112)
- Salinity Committee (Vol. XIII, p xiii)
- Flora & Fauna Conservation Committee (Vol. XIII, p xiv)
- Excursion Committee (Vol. XIV, p xviii)
- Natural Regions Committee (Vol. XIV, p xviii)
- Prawn Committee
- Social Committee
- Standing Committee on Conservation.

The following notes and extracts relating to several of these Committees indicate the enthusiasm and impartiality with which members carried out their tasks.

Spiritual Healing

A Committee consisting of Professor A. D. Ross, Professor G. E. Nicholls and Professor A. C. Fox were appointed to investigate—

- (1) whether the methods of the healing mission were effective in ameliorating suffering due to ordinary diseases;
- (2) the types of cases in which any such benefit was more probable or more pronounced;
- (3) the types of cases, if any, in which definite harm might result.

Interest in the above problem was stimulated by the Hickson Mission and the Society was promised the co-operation of the B.M.A. and the Anglican and Congregational Churches. However, after five months no patient was forthcoming for investigation and the Committee expressed its regret that it could make no personal observations and submitted as a progress report the evidence of the 1914 Lambeth Conference which stated, "Spiritual Healing like all treatments of suggestion can be expected to be permanently effective only in cases of what are termed functional—as apart from organic—diseases." (Vol. X, p. xxiv).

Divining Rod

"On a portion of ground previously proven by Reverend W. Kennedy to be free from any vitiating effects of underground water . . . 2 3/4" hoses were laid several yards apart." Nine tests were carried out with varying water flows through these pipes and only two proved correct. Trials were also carried out with glass jars of various salinity. Mr. Kennedy testing the water by holding small bags of salt while using the divining rod.

The first Committee investigating the divining rod consisted of E. S. Simpson and Professors W. J. Dakin and D. Ross. Dr. Simpson later resigned and Professor Ross and Messrs. A. Webster and W. A. Shelton officially reported: "As the results of other tests described in this report would not justify the expense of field trials necessitating the sinking of wells, the Committee desires to be relieved from further investigations." (Vol. VI, p 116).

As a result of these investigations Mr. Catton Grasby resigned from the Royal Society because he stated that he had suggested the carrying

out of the tests but was not invited to act on any of the Committees. Mr. Grasby later withdrew his resignation.

Houses in Western Australia

Mr. Wright (President, W.A. Institute of Architects) makes adverse comments upon the haphazard subdivision of land in many Perth suburbs, and the cramped conditions which permit up to 20 houses to the acre. He criticises the stereo-type gardens and the ever recurring symmetrical front hedge. His advice is to consult an expert and to "shun the practical man" . . . "He is as ignorant as a Bolshevik and as brainless as a cupie. He is not a practical but a vain fellow and taking his advice generally entails wasted expense and dissatisfaction." (Vol. V, p 64).

"In Russia they think anyone is competent to rule the country except an educated man. In Perth the idea is evidently occurring that one sells the plans of a house along with a pound of butter. Such a house requires a high hedge." (Vol. V, p 71.)

Town Planning

Mr. W. A. Saw stresses the necessity for slum clearance and prevention, and the provision of open spaces. He points out that Claremont has only 1.3% of land available as reserves, the Perth Road Board less than 1%, whereas town planners advocate 10%. Our large cities he says are filled with "physically crushed and mentally warped men and women". (Vol. V, pp 40 & 45.)

Although some of these committees did not fulfil their original promise others like the Salinity Committee under the chairmanship of Prof. Wilsmore, the Natural Regions Committee consisting of Messrs. E. de C. (later Prof.) Clarke, C. A. Gardner and L. Glauert, and the Vermin Committee, produced valuable reports.

Furthering the Cause of Science

In addition to promoting the immediate interests of its members the Royal Society of Western Australia has been untiring in its efforts to further the cause of science both within the State and the Commonwealth.

In 1918 it was represented by Sir Edgeworth David and Mr. J. H. Maiden at a conference of Australia Royal Societies convened by the Royal Society of N.S.W. at the request of the Royal Society of London. This gathering laid the foundations for the formation some years later, of the Australian National Research Council, which was later superseded by the Australian Academy of Science.

In May 1930 Prof. Wilsmore represented the Society at another conference sponsored by the Royal Society of Victoria to consider the formation of a Royal Society of Australia or a federation of State Royal Societies. The matter was further considered at the 1932 meeting of A.N.Z.A.A.S. but was not favoured because it was feared that State societies would lose their identity and this could cause complications where Government grants were concerned.

In 1945 the Western Australian Royal Society suggested to other State Royal Societies that certain reciprocal rights be approved for members visiting interstate. The idea was unanimously accepted and Royal Society members are now privileged to attend meetings in any State although of course, the normal restrictions still apply to voting rights.

In an effort to coordinate the activities of the increasing number of specialist societies appearing in Western Australia, the Royal Society called a meeting of delegates from appropriate organisations and discussed ways in which meeting clashes could be minimised, how societies could best advise one another concerning matters of mutual interest and how the dissipation of effort amongst Western Australian scientific personnel could be reduced.

Following this meeting, held in November, 1959, a letter was received from A.N.Z.A.A.S. indicating, "That it was prepared to play a more active role in Western Australia. This would include compilation of a register of authorities in various fields (including visitors to Western Australia) and conducting special lectures, symposia, etc."

It was agreed that these aims did not clash with those of the Royal Society and it was resolved that as A.N.Z.A.A.S. hoped to establish a part time secretariate in the near future it would be the appropriate body to carry on the work of co-ordination as suggested. This matter has still not been finalised although some progress has already been made but the fact that the last list of Western Australian scientific and allied societies compiled by A.N.Z.A.A.S. numbered 81, indicates the urgent need for some rationalisation measures if these bodies are to function efficiently.

Nature Conservation

Although conservation reports do not figure prominently in the Society's journals, vigorous efforts to protect our native fauna and flora have been made right from the inception of the first Western Australian Natural History Society in 1891.

With Sir John Forrest as President this Society initiated action which finally led to the creation of the 160,000 acre North Dandalup Reserve which was the first large area set aside for the preservation of fauna and flora. Unfortunately this reserve was later released for "timber purposes" despite a petition to His Excellency the Governor Sir Frederick Bedford in 1907.

As early as 1879 the Mueller Botanical Society wrote to the Commissioner of Railways deploring "the wanton destruction of wildflowers growing on the Perth-Fremantle line" and asking him to "prevent any further desecration of the flora on the line beforementioned and also on all other lines in the colony". Similar comments were also sent to the Director of Public Works and the Inspector of Telephones.

Other reservations influenced by the Society's action include Barrow Island, the Stirling Ranges and John Forrest National Park.

The Society combined with the Pastoralists Association in pressing for the protection of the Wild Turkey and was a contributing factor

in having the Vermin Regulations altered so that they would not apply to emus in the lower south-west. The Society has also arranged deputations to the controlling authorities to ensure the preservation of fauna at Pelican Point, Butlers Swamp (now Lake Claremont) and various other areas. It opposed the construction of an airstrip on the Abrolhos Islands, the establishment of exotic birds on Rottnest Island, and joined other bodies in advocating the preservation of ethnological features on Depuch Island.

The Royal Society has always maintained a keen interest in the welfare of Kings Park and while it opposed the building of a swimming pool in the reserve it was one of the prime movers for the establishment of a Botanical Gardens. It strongly supported action initiated by the National Parks Board of Western Australia and organised a deputation led by Mr. C. Shedley to the then Minister for Lands Mr. L. E. Kelly on February 2nd, 1959. No immediate decision was obtained but negotiations continued until the end of the year when the Minister for Lands Mr. Bovell announced the Government's decision to establish the Gardens and to appoint a director.

In 1960 the Royal Society established a "Standing Committee on Conservation" (Chairman C. F. H. Jenkins) to carry on the work commenced by the Sub-committee on National Parks and Reserves (Chairman W. D. L. Ride) appointed by the Australian Academy of Science. The Royal Society Committee comprised the original Academy Sub-committee plus several new members appointed by Council. This Committee has strongly supported efforts to publish the Academy report on National Parks and Reserves and was finally successful in arranging co-operation between the Australian Academy of Science and the National Parks Board of Western Australia in financing this project. By reason of its personnel this committee has close association with many Government Departments and is doing everything possible to ensure the preservation of suitable flora and fauna reserves as well as other sites of scientific and cultural interest.

The Society's present policy on conservation, particularly in relation to acclimatisation contrasts strongly with that presented by the Hon. Walter Kingsmill in his address entitled, "Acclimatisation" read before the Society in 1918. Few would now agree with Mr. Kingsmill's statement that, "Perhaps the most wonderful instance of the value and success of acclimatisation may be found in New Zealand . . . looked upon now as a sportsman's paradise." Nor will they join with him in lamenting the failure of red deer to establish at Albany and Cape Leeuwin, or Indian black buck to survive on the Murchison. Rather will they rejoice that the present evidence of this acclimatisation era is mainly restricted to the kookaburra, two species of doves and several species of fish.

Royal Society's Medal

In order to mark the centenary of the birth of Lord Kelvin (June 26th, 1924), the Royal Society decided to institute an award for outstanding work in science, to be known as the

Royal Society's Medal. Because of its association with the Kelvin celebrations this medal is often incorrectly referred to as the Kelvin Medal.

The rules provide that the recipient of the medal shall be chosen by the Council following recommendations from a special Medal Committee and that awards shall not be made more frequently than every 4 years.

The following awards have been made up to the present time:

- Dr. W. J. Handcock—1924: For this pioneering studies in radiography. Unfortunately his devotion to this work seriously undermined his health. (Vol. X, p xvii)
- Dr. E. S. Simpson—1929: For contributions to the scientific knowledge of mineralogy and geology in Western Australia. (Vol. XV, p xvii)
- Mr. W. M. Carne—1933: For outstanding work in the field of plant pathology, particularly the disease of Bitter Pit in apples. (Vol. XIX, p xi)
- Mr. A. Gibb Maitland—1937: For long and distinguished work in the field of Western Australian geology (Vol. XXIII, p xi)
- Professor E. de C. Clarke—1941: For distinguished service as teacher and research worker in geology (Vol. XXIX, p 171)
- Mr. Ludwig Glauert—1945: For his outstanding contributions to Australian Zoology (Vol. XXX, p vi)
- Mr. C. A. Gardner—1949: For his distinguished work on the Western Australian flora (Vol. XXXV, p v)
- Dr. H. W. Bennetts—1955: For distinguished work in veterinary science and particularly for investigations into entero-toxaemia of sheep and the effects of Western Australian poison plants on domestic stock (Vol. 40, p 1)
- Professor E. J. Underwood—1959: For outstanding work in the field of animal nutrition (Vol. 43, p 67).

Finance and Endowment

Finance

Two sources of income have been available to the Royal Society and its fore-runners—members subscriptions and Government grants or subsidies. The subscription to the Mueller Botanical Society was 10s. 6d. and of course was quite insufficient to finance the printing of a journal. Soon after its foundation therefore, the Society approached the Government for substantial assistance and wrote to the Premier and Colonial Treasurer, the Right Honourable Sir John Forrest, P.C., K.C.M.G., as follows:

Sir,

We have the honour to inform you that at a meeting of the Council of the Mueller Botanic Society, held on Thursday the 7th

inst., the following resolutions were unanimously passed for presentation to your Government:

1. "That this Society which is established for the public good, in view of the promised assistance of the Government, communicate with the Right Honourable the Premier and Colonial Treasurer, requesting that a sum of at least £500 per annum be placed on the Estimates for 1897-8 for the use of the Mueller Botanic Society of Western Australia."

2. "That the time has arrived when such assistance as set forth in the foregoing resolution is absolutely necessary to the efficient working of the Society as an institution calculated to benefit not only its members but the community of Western Australia generally."

3. "That the following reasons be given in the Society's communication to the Honourable Premier, showing the need of such monetary assistance, and the uses to which it is intended the money should be placed."

- (a) "That the Society have established a Herbarium for the benefit and use of the public, which shall be conducted on a somewhat similar basis to the Museum.
- (b) "That it is the intention of the Society to establish as soon as the necessary accommodation can be secured, a Botanical Library of the most complete and reliable works; such Library to be open to the Public for general reference.
- (c) "That provision is to be made on the next quarter's syllabus for the establishment of elementary and advanced classes for the education of the younger members of the community and others desirous of studying Botany or any relative science. The need for such classes is obvious, and the work and expense entailed by their establishment would be by no means small. The importance of this particular department of the Society's work will be readily recognised, and it is essential that in a colony possessing such floral wealth as does Western Australia, instruction in technical botany should be given to the people."
- (d) "That a series of lectures dealing with botanical subjects in general are being delivered, which up to the present have been most successfully rendered, and also have proved educational and interesting."

For carrying into effect the foregoing resolutions it will, of course, be necessary that the Society should have proper office accommodation, for its library, etc., in rooms centrally situated and easily accessible.

*Employment of Officers and their
Remuneration.*

Certain officers will be required in conducting the affairs of the Society as follows:

A professed Botanist, who may be secured at a salary of £300 per annum; a Secretary (the duties of this office in such an institution will necessarily be numerous) at a salary of, say, £150 per annum; a Librarian to supervise the Society's library Herbarium, at a salary of £50 per annum.

The salaries of the above officials will amount in all to £500 per annum. This sum, as stated in the second resolution, is absolutely necessary in order that the Society may discharge those duties for which it has been established, and which necessarily devolve upon such an institution. It is anticipated that the membership fees may in time, realise the amount necessary to pay rents, furnish the library, and defray general expenses.

In submitting to your favourable consideration the foregoing facts and figures in connection with the efficient working of the Society we think it hardly necessary to remind the Government who are so well acquainted with Western Australia and its resources, of the need existing here for such an institution as the Mueller Botanic Society. Its sphere of usefulness is unlimited: and, further, having for its main object the development of some of the important resources of a progressive and independent Colony, we have perfect confidence in approaching its Government and Parliament for support and sympathy.

In conclusion therefore, we thank you in anticipation of the favourable consideration you will extend to the Society and awaiting your reply,

(Sgd.) E. J. Bickford,
Chairman/Secretary.

Needless to say the request was not granted in full and the first Government contribution was a promise of £50 per annum. This was not maintained regularly however, and the records make repeated references to deputations to the Premier for renewed or increased grants.

With the formation of the Western Australian Natural History Society, the subscription was maintained at 10s. 6d. but for a time the Government Grant was raised to £75. Then in answer to a request for further assistance the Society received a severe setback. The Treasurer advised that a formula had been devised for determining grants to various societies based upon membership. On this basis the Natural History Society was entitled to £15. In 1912 the grant rose to £25 and in 1913 it reached £50. Then in 1914 the Colonial Treasurer authorised the Government Printer to spend £30 on the Society's printing to compensate for the absence of a grant. The subscription was also raised to £1 1s. for ordinary members and 10s. 6d. for Associates. In 1915 the Government Printer was authorised to print 100 pages at 7s. 6d. per page, but due to a misunderstanding

additional printing was submitted and the Government accused the Society of indulging in "sharp practices." The misunderstanding was explained away and for some time the printing of the journal was authorised as funds became available, but without regular Government assistance.

In 1922 finances were at such a low ebb that a committee was formed to investigate the conducting of a Wild Flower Show and exhibition to raise funds for the Society and a subscription list was started to assist in the publication of Vol. VIII of the Society's journal. £45 was collected towards printing costs but the exhibition was abandoned. Consideration was also given to raising the subscription but Council finally withdrew the recommendation.

In 1924 a deputation waited on the Government pointing out that our Royal Society was the only one in Australia not receiving Government assistance and requesting an annual grant of £100. No immediate decision was obtained but in 1926 a grant of £75 per year was provided and later this was raised to £100.

Then in 1931-32 the Financial Emergency Act was applied to the Royal Society grant and the Government contribution was reduced to £80. In 1935-36 the grant was lifted to £90 and the next year it was restored to £100.

In 1944 due to rising costs the Society was again in serious financial difficulties and action taken during that and subsequent years is summarised herewith in a report submitted to Council in June, 1949 by the Hon. Editor (Mrs. C. F. H. Jenkins).

"Summary of steps taken to stabilise the financial position of the Royal Society of Western Australia and to expediate publication of the Journal.

August 1944:

Detailed case drawn-up by President (Dr. Prider), Dr. Watson, Mr. Foreman and Dr. Nicholls and presented in writing to the Hon. The Premier, Mr. Willcocks. Dr. Prider and Dr. Nicholls discussed the matter with the Under Treasurer (Mr. Reid), January, 1945. Mr. Willcocks approved special grant of £100.
March, 1945:

Mr. Willcocks further approached for more substantial assistance, but further assistance refused.

November, 1945:

The President (Mr. Jenkins) addressed a communication to the Premier (Mr. Wise) and in March, 1946 discussed the position with the Under Treasurer (Mr. Reid) who consented to the following concessions:—

1. Increase of Annual Grant from £100 to £200.
2. Printing of Volume 32 (1945-46) without cost to the Society.
3. Society to live within its means from then on.

October, 1948:

Mr. Jenkins discussed the deteriorating financial position again with the under Treasurer (Mr. Reid) and the Government

Printer (Mr. Wyatt). The following was then approved:

1. The Government Grant of £200 per annum to cease.
2. Cost of Volume 34 (1947-48) to be borne by the Government.
3. Journal to be limited to 150 pages.
4. The arrangement to be reviewed after one year to ascertain cost to be borne by the Government."

This arrangement continued unaltered until 1952 when a letter was received from the Acting Under Treasurer Mr. K. Townsing drawing attention to the rising costs of printing and concluding with the following paragraph:

"Before the Government Printer is authorised to continue printing the Journal, I would like your Society's assurance that it will meet cost in excess of £500."

I again discussed the position with Mr. (now Sir) Alex. Reid, the Under Treasurer who stated that the old agreement would stand until further notice.

Between 1954 and 1957 further negotiations took place between the Society and the Under Treasurer concerning a change in journal format and some modifications in the financial arrangements but the basic policy remained unchanged.

In 1956 consideration was given to doubling the subscription rate and for appropriate increases to be made in the figures for Life Membership. The views of members were requested by circular and finally the rates were raised to £2 2s. for full members and £1 1s. for Associate Members as from the beginning of the year 1956-57.

Endowment Land

From the earliest days of the Mueller Botanical Society strenuous efforts have been made to obtain a Government grant of land on which to erect a permanent home for the Society. As far back as October 1897 funds were sought from the State Government for the employment of staff and reference was made to provision of "the necessary accommodation". Later in 1904 Chairman Mr. Bickford stressed the importance of obtaining premises both for meetings and to house the Society's library and collections.

In 1916 representatives of various interested bodies including the Institution of Engineers and the Royal Society appointed a deputation to present a case to the Government for a grant of land. Nothing came of this move but rumours were rife concerning extensive additions to the Museum and it was hoped that the society would obtain further accommodation in the old portion. In 1927 the Royal Society convened a meeting of appropriate societies to discuss the acquisition of land for a central building. As a result of this meeting the following motion was carried and forwarded to the Hon. Premier Mr. P. Collier.

"We the undersigned, who were appointed by a joint meeting of the Royal Society of Western Australia, Chemical Society, Engineering Standards' Society, West Australian Field Naturalists Club, Historical

Society, Economic Society of Australia & N.Z., League of Nations Union, West Australian Society of Arts, British Astronomical Association (W.A. Branch), and the Town Planning Association, beg to draw the attention of the Hon. the Premier to the fact that the various associations of scientific workers in this state are at present hampered in their operations through lack of a convenient and suitable meeting place, lecture hall and house room for their books and apparatus.

Your memorialists beg respectfully to submit that the provision of accommodation in a central position in Perth for the housing of such societies would fittingly form part of the building scheme which the Government has decided to undertake as part of the Centenary Celebration . . ."

Signed W. M. Carne,
Royal Society of Western Australia.

E. O. Shann,
Historical Society.

F. E. Allum,
Economic Society.

In a later communication it was suggested that suitable facilities might include a lecture hall to seat 200 people and a library 40 ft. x 20 ft.

In the Annual Report for June 1929 the Secretary reported that, "at present there seems little prospect of securing adequate accommodation for no Government funds are available." Later in 1936 a further conference was held with the Institution of Engineers and the prospect was discussed of obtaining rooms in a University building planned for erection on the corner of Hay and William Streets. In 1937, the Societies' honorary solicitor the Hon. Mr. John Nicholson advised that negotiations to obtain Government land in Irwin Street had failed but stated that the Premier's Department had directed attention to a block on the corner of Beaufort Street and James Street and two blocks opposite Perth Boys' School. Negotiations for these blocks were never successfully completed and no serious efforts have been made to revive the issue, although in 1954 the Royal Society and other scientific bodies investigated the possibility of a building being erected on the Deanery site in St. George's Terrace. But the decision to retain the Deanery ended this project. In 1957 the Institution Engineers asked if the Royal Society were interested in joint negotiations to purchase a house in West Perth, but as favourable arrangements were then under way with the Museum the Society did not accept the offer.

Endowment Fund

In May 1928 the Society established an endowment fund based upon a donation of £100 from Major R. Thynne. The purpose of this fund was, and I quote, "To give a guarantee of publication which it has not previously been possible to do." Then in 1936 a most ambitious scheme was suggested by Mr. E. W. Edwards who recommended that leading business firms be approached with the idea of establishing an

endowment fund of £50,000. Needless to say this scheme proved to be unworkable.

However, from time to time moneys were added to the Endowment Fund in the hope of building up sufficient finance for a building project but rising costs greatly outstripped the growth of the fund which now stands at approximately £1,000 and all building schemes have now been abandoned.

Membership

Membership of the Mueller Botanical Society was, as the name would suggest, confined mainly to those interested in botany, but because of its great scientific and popular appeal, the State's flora attracted the attention of both scientists and amateurs. As the Society grew, its expanding interests were reflected in the various name changes which culminated in the present title of Royal Society.

Shortly after the Royal Charter was granted in November 1913 His Majesty King George V graciously consented to become Patron of the Royal Society (March 10th, 1914) and so Western Australia followed South Australia as the second state in the Commonwealth to be granted Royal Patronage. His Excellency Major General Sir Harry Barron was then elected Vice Patron and succeeding monarchs and governors have honoured the Society by occupying these respective positions up to the present time.

Neither the Royal Society nor its predecessors have ever required special academic qualifications of their members and as a consequence the earlier membership in particular reflected a very wide variety of interests.

Although membership numbers were small in the earlier societies the influence they wielded was disproportionately large. This is easily explained however, by the names which appear on the membership rolls.

For instance the inaugural chairman of the Mueller Botanical Society was the Hon. E. H. Wittenoom M.L.C. and Sir John Forrest K.C.M.G. was elected President with E. H. Wittenoom Vice President. His Excellency the Governor Lt. Col. Sir Gerard Smith K.C.M.G. was elected Patron and the Vice Patron was G. Leak M.L.A. Other members included Hon. J. W. Hackett M.L.C., Sir George Shenton and of course numerous professional scientists.

During its first year the Royal Society's membership stood at 85 but by 1923 the numbers had grown to 253, and included an Archbishop, the Chief Justice and other members of the judiciary, four politicians, seven university professors, 13 medical practitioners, the Director of Education, the Director of Agriculture and many prominent business men. The present membership of 246 indicates that the Society has grown very little in recent years and the personnel represented shows that we are attracting mainly working scientists. While this is regrettable, a similar change has occurred in other state Royal Societies and is the outcome of the ever increasing specialisation which characterises the present age.

I do not propose to deal in any detail with individual members but it is pertinent to point out that many of the State's most eminent scientists have been associated with the Society

and that the standard of the papers published has earned the Royal Society of Western Australia a very high professional status both at home and overseas. Early workers such as J. H. Maiden, L. Diels, E. Pritzel and W. V. Fitzgerald in the botanical field; J. T. Jutson, A. Gibb Maitland, E. de C. Clarke and E. Simpson as geologists and mineralogists and B. H. Woodward, J. Dakin, W. Michaelson and L. Glauert as Zoologists set a standard which has been worthily maintained.

The only contemporaries I shall mention in this brief summary are several foundation members who have maintained their association with our Society. Three of these, Mr. W. B. Alexander, Mr. F. R. Feldtmann and Dr. D. A. Herbert, have been honoured tonight by election to Honorary Membership. The others to which I wish to refer are Sir John B. Cleland and Professor A. D. Ross. Sir John Burton Cleland is the senior member of the Royal Society. He was elected to the West Australian Natural History Society on May 22nd, 1906 and joined the 1906-7 Council, and was co-editor. In 1908/9 he was Chairman of the Society and formed part of a sub-committee which considered the formation of the Royal Society.

Dr. Cleland was born in 1878 and was educated at the Prince Alfred College in Adelaide and Sydney University. He came to Western Australia in 1906 as Government Pathologist and Bacteriologist, having spent 2 years at the London Hospital as Cancer Research Scholar. In 1908 he was appointed Acting Principal Medical Officer and Acting President of the Board of Health in Western Australia. He resigned in 1909 to join the New South Wales Department of Health where he remained until his appointment to the Chair of Pathology at the University of Adelaide, a post he held until his retirement in 1948.

Although a medical man, his recreational activities included anthropological, botanical and mycological interests. It is in the latter field that he has achieved an eminent position in the Australian scientific world and his book "Toadstools and Mushrooms and Other Larger Fungi of South Australia", is a standard reference book.

Sir John Cleland was elected an Honorary Member of our Society in July 1963.

Professor Ross was elected to the Western Australian Natural History and Science Society on March 11th, 1913 and other members joining that night were Professor Wilsmore, Professor Whitfield and Professor Woolnough. Professor Ross and A. Gibb Maitland served as Vice Presidents under the foundation president of the Royal Society, Professor Dakin, and Professor Ross first occupied the Presidency in 1916. He again held this office in 1923. Some indication of Professor Ross' enthusiasm can be deduced from the fact that during this second term 14 new members and 45 nominations were passed at one meeting. Professor Ross is the only member to have occupied the presidential chair for a third term and this he did in 1940-41.

In recognition of his services to the Society and to science Professor Ross was elected as an Honorary Member in July, 1957.

Housing

The first meeting of the Mueller Botanical Society in 1891 was held in the Council room of the Town Hall and the Society continued to meet there until 1897. Meetings were later held at the Department of Agriculture, "West Australian Chambers," St. George's Terrace, and then in the Technical School, at the invitation of the Director, Mr. Alex Purdie. In 1905 the West Australian Natural History Society established its headquarters at the Museum, but in 1909 it became necessary to move and some meetings lapsed for want of a meeting room. In 1910 the Society was given accommodation in the Department of Agriculture next to Government House, but was forced to move the following year. After extensive investigations arrangements were made to share the rooms of the Theosophical Society on the third floor of the West Australian Chambers, St. George's Terrace, at a weekly rental of 10s. This covered cleaners and lighting, also the loan of a lantern providing the Society provided an arc lamp. The society to "make good any damage".

The society's library and herbarium were also accommodated and the rent was later raised to 30s. This was only agreed after efforts to find other suitable quarters and amongst the prospects investigated was the Perth Literary Institute. Early in 1916 the society received notice to quit from the Theosophical Society and was fortunate once again to find accommodation at the Museum.

The society remained at the Museum until July, 1940, when it moved to the 7th floor of the University-owned Gledden Buildings. The Institution of Engineers leased the entire top floor of the building and accepted the Royal Society as tenants. The original rent requested was £40 per annum, but negotiations finally closed at £30 for the first seven years rising to £40 thereafter. The society agreed to procure its own library shelving and the Institution of Engineers had the option of purchase after five years. In 1954 the rent was raised to £60 a year and finally to £100 a year. For 17 years the Society was comfortably housed in Gledden Buildings, and for much of that time it was able to employ the Institution of Engineers' clerical staff for typing and the distribution of notices.

Then in 1957 the University terminated its lease to the Institution of Engineers and although the Royal Society supported the engineers and others in a strong protest to the University, in the belief that scientific organisations could expect and had indeed been promised, some preferential treatment in the matter of accommodation in Gledden Buildings, these representations were unsuccessful and the Society was once again forced to find a new home.

It is perhaps some consolation to note that the Royal Society of London found itself in a somewhat similar plight in 1866. The incident is reported in "Nature," December 28th, 1963, p. 1259, as follows:—

The occupancy of Burlington House by the Royal Society, which began in 1857, did not long remain undisturbed, for in 1866 the Government decided to allocate it to

the Royal Academy. The manner in which this event was announced seems to indicate that the Royal Society was not esteemed as highly in ruling Government circles as the Fellows might have wished, or may indeed have imagined, or that in some way it had been outmanoeuvred. The first information that the Society had of the impending move came from the columns of The Times of 1867, in the form of a statement that the Government had decided to give the Royal Academy a permanent lease of Burlington House, with the right to extend northwards. Sir Edward Sabine, the President, was away at the time—let me hasten to add very properly so, as it was during the summer vacation—but then, as now, the Society had an alert treasurer, Prof. W. A. Miller, who promptly wrote to the Prime Minister, Lord Derby, to enquire if the announcement was true. It was.

Fortunately the eviction from Gledden Buildings coincided with an expansion and building programme at the Museum and the accommodation which is now so generously provided by the Trustees has given members many of the facilities for which they have been seeking so long.

Publications

The Journal of the Royal Society of W.A.

One of the most important functions of our Society is of course the printing of the annual Journal and various steps to ensure continuity of publication have been outlined under the heading of "Finance."

The first journal produced was that of the Mueller Botanical Society in 1899 two years after the foundation of the Society. Eleven parts were printed up to December, 1902, then the name of the society was changed and the Western Australian Natural History Society published six numbers between May, 1904 and February 1909. Under the name of the Natural History and Science Society of Western Australia three more numbers were produced between August 1909 and 1914. The first issue being numbered Vol. III No. I. The first volume under the title of Royal Society of Western Australia appeared in 1916 and was numbered Vol. I.

One of the main objectives of all our journal editors has been to ensure the rapid publication of papers once they have been received and various expedients have been adopted in attempts to achieve this. For instance in May, 1923 it was decided to print each paper as soon after delivery as possible and to make authors reprints available immediately. This practice was later discontinued because, in the case of taxonomic papers, the early distribution of authors reprints did not constitute "publication" under the "International Rules of Zoological Nomenclature."*

Throughout the depression and war years the Society maintained its publication with very great difficulty. Lack of finance hampered the Society and lack of manpower and facilities greatly impeded the Government Printer. For

*This rule has since been revised.

several years after the war, efforts to retrieve the situation were not completely successful and in June, 1944 the Hon. Editor (Mrs. C. F. H. Jenkins) submitted a report to Council summarising the reasons for various delays, itemising the steps which had been taken to try and improve the situation and concluding with the following comments:

While the delay in printing is to be regretted, it was inevitable under war-time conditions, and in the post-war era the position has been aggravated by power break-downs, the latter affecting private industry as well as the Government Printer.

It is obvious from the figures presented that the printing of the Journal has been greatly expedited in the last twelve months.

From actual experience there is little evidence to suggest that there would be any great advantage from a speed of publication point of view in leaving the Government Printer. On the other hand, once this policy has been adopted, especially in view of the recent negotiations with the Under Treasurer, it is unlikely, should the Society again find itself in financial difficulties, that a very sympathetic hearing would be given by the Government to any request for further assistance.

In order to reduce some of the confusion associated with the correct year of publication and the actual printing date of the journals produced during this period it was decided to designate each publication with a volume number only, although of course, the date of publication was clearly indicated inside. This practice is still being followed.

With the building of new premises for the Government Printer conditions gradually improved and in 1957 the President Dr. A. Wilson was able to report further favourable arrangements with the Government Printer which can be summarised as follows:

1. The Journal shall be printed by the Government Printer free of charge to the Society.
2. The Journal shall consist of 410 copies of each of four parts per year, each part being restricted to 32 pages.
3. The Journal shall have the new type face and format of Volume 39 (1955).
4. The number of text figures, plates and maps shall not be arbitrarily fixed but shall be comparable to that allowed in the average of previous volumes of the Journal. Any difference of opinion concerning the number of allowable illustrations shall be resolved by discussion between the Government Printer and the Editor of the Journal after the Referees' reports on the suitability for publication of the papers concerned are available.
5. The excess cost involved in the preparation of the blocks for coloured illustrations (i.e. excess over cost of black and white illustrations) shall be met by the Society.
6. Cost of the reprints of papers shall be borne by the Society.

A later request for 600 copies of each issue was refused and the present arrangements (20/9/63) provides for 410 copies of 32 pages free plus 160 extra copies by purchase and any additional pages to be paid for at cost.

A notable concession was the Government Printer's agreement to carry the cost of blocks. Previously these had been made by a private firm, the Society and the author sharing the cost equally.

The Proceedings of the Royal Society of W.A.

In the earlier publications of the Society it was customary to publish the Annual Report, Balance Sheet and other relevant information but in later years these have been excluded to allow greater space for papers. To meet this deficiency a duplicated "News Letter" was instituted in April 1961 and in June of the same year the title was altered to that of, "Proceedings of the Royal Society of Western Australia". This publication has been well received by members and is being continued.

Contributions

Contributions to the Mueller Botanical Society dealt of course with plant matters only but the later societies welcomed any type of scientific paper. An analysis of the articles submitted shows that at all times papers on natural science have greatly predominated and that while a few articles dealing with the physical sciences were contributed to the earlier volumes none have been received in recent years. This is of course to be expected as more and more specialist bodies and publications become established. As with most other Australian Royal Societies, papers on Geology, Zoology and Botany greatly outnumber those on any other subjects and together they total 84% of the Royal Society's publications—the break down being Geology 36%, Zoology 30% and Botany. 18%.

Library

The Royal Society library at present numbers some 6,000 volumes and although a few books are included, stocks consist mainly of scientific journals which have been received from Universities and other scientific institutions in exchange for our publication.

Exchange agreements at present exist with 225 scientific institutions in 47 overseas countries as follows:—

Argentina	French W. Africa
Austria	Germany
Belgium	Holland
Brazil	Hungary
Bulgaria	India
Canada	Indo-China
Ceylon	Indonesia
China	Ireland
Cuba	Israel
Czechoslovakia	Italy
Denmark	Japan
Egypt	Yugoslavia
England	Madagascar
Ethiopia	Malaysia
Finland	Mauritius
France	New Zealand

Norway	Switzerland
Pakistan	Tanganyika
Poland	Uruguay
Portugal	Uganda
Puerto Rico	U.S.A.
South Africa	U.S.S.R.
Spain	Venezuela
Sweden	

A further 250 Journals are distributed to institutions within the Australian Commonwealth.

The housing of the library has always presented a problem for sufficient space has never been available and lack of money has prevented an adequate binding programme. At present the Society's library is integrated with that of the Western Australian Museum and we are fortunate in having the services of the Museum librarian. Even now however, bulk stocks of our journal are in storage elsewhere. There is a continuing demand for back numbers to meet new exchanges and so hundreds of volumes need to be retained. At one stage it was necessary to hire storage space when surplus publications could not be placed with accommodating members. Amongst the temporary housing which has been used for these journals may be mentioned the basement of the Museum, the storage files of the West Australian Newspapers Ltd., an abandoned chapel used for storage by the Department of Agriculture, Adelaide Terrace, the roof of the University Chemistry Buildings and a strong room in the Supreme Court.

Some of the more specialised journals such as Chemical Abstracts are on permanent loan to the Perth Technical College and a few rare volumes, which were passed for safe keeping to the Public Library during the last war, are still held by the State Library.

Management

The management of the Royal Society has been vested for many years in a Council consisting of a President, 2 Vice Presidents, Past President, Treasurer, Librarian, Jt. Hon. Secretaries and 8 additional members. Originally the two secretaries were appointed to represent the physical and natural sciences, but in actual practice one attends to Council duties and the other to notices and affairs connected with the general meetings.

Ten Council and ten general meetings are normally held during the year with a two month's recess in mid summer. In earlier times however, the Society met every month and in one year as many as 25 meetings of council were held.

Of the various sub-committees appointed from time to time one of great importance is the Publications Committee. This body examines very carefully all papers submitted to the Society for publication, selects referees and is generally responsible for ensuring that the publication standard is maintained at a high level.

Although the rules of the Royal Society and its predecessors have been revised from time to time to meet changing circumstances their

main object has been to promote the study of science in all its branches and to provide members with the maximum facilities to achieve this end. The latest major revision was conducted in 1936 by the society's honorary solicitor the Hon. John Nicholson and was associated with the Society's incorporation. The Certificate of Incorporation was actually received in 1937.

During the last war normal meetings of the Society were interfered with by blackout restrictions and for several years evening meetings were cancelled. To ensure continuity of publication and routine business however, an executive committee met monthly at 4.30 p.m. and reported to a quarterly meeting of the full Council.

Formation of Sections

As far back as 1904 the advisability was discussed of forming Geological, Botanical and Zoological Sections within the Natural History and Science Society, but no definite action was taken. Later the Royal Society of New South Wales was questioned on the formation of its Field Naturalists' Section, but again no action followed and the formation of the Western Australian Naturalists' Club in 1926 settled this particular issue.

In 1924 consideration was given to the formation of a Physical Chemistry and Mathematics Section within the Society, but again without results. It was not until April 1932 that the first Section, a Biological Section, was finally formed under the chairmanship of H. Womersley. Twenty-five members attended the inaugural meeting and the Section continued to meet regularly until October 1936 when attendance declined and it was recommended to the parent Council that meetings be called only at the request of the Chairman (C. F. H. Jenkins) and no further meetings of this Section have been held.

The main purpose underlying suggestions for the formation of sections was to provide facilities for specialised groups who might otherwise be tempted to form separate organisations to the detriment of themselves and the parent body. It is felt by many that in a State such as Western Australia with a very limited scientific population much useful effort may be dissipated by the formation of small specialist bodies. These often have inadequate finance to run a publication and after the first burst of enthusiasm may fade out or merely struggle along.

The Western Australian Naturalists' Club with several virile groups illustrates the mutual benefits which can accrue from the judicious formation of sections.

The Future

From this brief survey it is clear that the Royal Society and its predecessors had much greater influence on public affairs in years gone by than is the case today. For this reason some people believe that Royal Societies as a group have outlived their usefulness and that they are threatened with ultimate extinction.

As the oldest scientific Society in Western Australia and one which is still quite virile after many years service to Western Australian science I contend that the Royal Society of Western Australia still has a very important role to play, although perhaps a different one from that of 50 years ago. In an age of ever increasing specialisation when it is becoming more and more difficult even for scientists to understand one another, the Royal Society should have an important function in bringing together different branches of science and also presenting science to the layman.

This function was well expressed by Bishop Riley in his Presidential Address to the Western Australian Natural History Society as far back as 1907 and I quote:

How often do we find men going outside the particular subject on which by training they are competent to dogmatise, to speak on other subjects full of difficulties even for the learned, with utmost assurance. To correct such a possibility it is well to join a Society like this. I mean it is well for the unscientific student, for in the presence of men of learning he finds out how little he knows, which is the first step, as we all admit, in the pursuit of knowledge. It is good too, for the learned to come amongst the ignorant, for a man finds out where his knowledge is weak when he tries to explain to others things about which they know little.

While it seems inevitable that specialists will continue to try to learn "more and more about less and less," within the Royal Society these specialists have an opportunity to learn something about other branches of science and to counteract the restrictive effects of specialisation. Unfortunately, some members do not recognise this function of the Society and so attendances vary according to whether the programme has a botanical, a zoological or a geological flavour. The speakers themselves are not always without blame for these conditions because of their failure to cater for the layman or the non specialist. It should be possible to make the subject of most papers acceptable to a mixed audience (specialist and non specialist) and to rely on the published version to indicate the scientific status of the contribution.

Associated with the gradual reduction in the non-scientific membership of the Royal Society there has been a noticeable decline in the social status of such functions as the Annual Meeting. There are those who regret the passing of the more formal Conversaziones held in the Perth Town Hall, the Karrakatta Club or the University, when the effects of the Presidential Address were softened by a lavish supper and a wide variety of exhibits, some relating to high fashion and others to science.

Another noticeable change is the attitude of the Press to scientific news. Bishop Riley's Presidential Address from which I have just quoted was published in full and many other papers and discussions of that era occupied up to two columns of the morning paper, but now a completely new set of values restricts the average reader to a diet of war news, scandals, sporting highlights and science fiction.

Most will agree however, that these changes are inevitable and that any attempt to put the clock back would be futile. But one thing is certain, that despite the various changes in our Society's personnel and status, its scientific integrity and importance are as sound as ever. In emphasising the scientific attributes of our work its practical significance is sometimes overlooked, but it should be realised that many of the geological papers published by our members have had a direct bearing on the development of the State's vast mineral resources and that the botanical and zoological contributions have provided fundamental information which is essential to a proper understanding of our flora and fauna.

When it is remembered that most contributors to the Journal are either Government Officers or University research workers, and that all work connected with the preparation and editing of the papers is done in an honorary capacity, it will be obvious that our Journal provides the Government with the cheapest possible means of disseminating the results of scientific work done in this State. In view of this fact and the past record of the organisation, we believe that the Royal Society of Western Australia has a most important role to play in the continued development of the State, and that our Society is entitled to the strongest possible support from scientific workers, the lay public and the Government.

5.—The *Amphibolurus maculatus* species-group (*Lacertilia*, *Agamidae*) in Western Australia

By G. M. Storr*

Manuscript accepted—16th February, 1965.

The "species" *Amphibolurus maculatus* of authors consists in Western Australia of ten taxa: *A. femoralis* sp. nov., *A. fordii* sp. nov., *A. m. badius* subsp. nov., *A. m. maculatus* (Gray) *A. m. griseus* subsp. nov., *A. m. dualis* subsp. nov., *A. i. rubens* subsp. nov., *A. i. isolepis* (Fischer), *A. i. gularis* Sternfeld and *A. i. citrinus* subsp. nov. Length of appendages relative to trunk varies with age, sex and latitude. Some, if not all, of these lizards live only for one year. Their habitat preferences and phylogeny are discussed.

Introduction

Until recently this section of the genus *Amphibolurus* presented no difficulties. With the limited series available to them, Loveridge (1934) and Glauert (1961) believed that it only consisted of the species *maculatus* Gray, the nominate race occurring in south-western Australia, and the race *gularis* Sternfeld from further north and east.

Much material has been collected in the last few years, and the simple concepts of earlier workers have had to be abandoned. First it became evident that in certain areas *gularis* and *maculatus* were sympatric, which required their recognition as full species, each, as it happened, divisible into four races. Moreover, another two species were discovered. Thus, instead of one species and one subspecies, there are now known from Western Australia four species and at least six subspecies.

Except for specimens kindly lent by Messrs. A. Kluge and D. Bradshaw, all material examined is lodged in the Western Australian Museum. Unless stated to the contrary, all localities are in this State.

Amphibolurus maculatus Group

Diagnosis

This group consists of small to medium-sized, active, non-burrowing, non-climbing agamids in which the homogeneous dorsal scales are strongly uncarinate, the alignment of the keels converging back towards the midline. There are no nuchal and dorsal crests. There is little or no development of clumps of tubercles behind the gape and on the side of neck.

Additional characters shared by all taxa

Head, body and base of tail moderately depressed. Tail long and tapering gradually. Supraciliary ridge acute. Rostral ridge moderately acute and entirely superior to fairly large nasal shield. Nostril a little nearer to orbit than tip of snout. Rostral and mental distinctly larger than labials, which are scarcely different in size and shape from the scales above and below them. Scales on top of head moderately large and rugosely uncarinate. Scales on neck very much smaller than those on head and back. Scales on back and upper surface of limbs and tail strongly imbricate and keeled. Scales on sides of body smooth or weakly keeled and much smaller than dorsals and ventrals. Preanal and

femoral pores well developed in males, but often indiscernible in females. Toes long and slender with 24-37 lamellae under the fourth. Claws long and sharp. Adult and subadult males marked below with characteristic black pattern.

Differentiation of Species

The four species are distinguished mainly on dorsal coloration and pattern, the extent and shape of the ventral markings in males, the extent of the femoral pores, the alignment and continuity of the preanal pores, the degree of lateral compression of toes, and the nature of subdigital carination. Because the best characters are confined to or easily ascertained only in adult males, the identification of females and juveniles may prove difficult.

Many females, perhaps most, will be recognisable by some development of the characters that are species-specific for males. In any case they will be closely associated with males of their own species and will seldom be collected without them. With juveniles, coloration and pattern should be compared with those of adults from the same area (either directly or by reference to the descriptions herein), and a careful search should be made for pores under medium-power microscope. When pores are not evident their future extent and alignment can be guessed at by locating the sharp boundary between the large anteroventral scales of the thigh and the small posteroventral scales.

Distribution

The *maculatus* species-group is restricted to the more arid parts of Australia, and is especially found in sandy country with low, open vegetation. The four species in Western Australia collectively range throughout the State except the extreme north and south-west.

Key to species (based on male characters)

1. Pores more than 32 and extending more than half-way down thigh; throat marked with black 2
Pores fewer than 33 and extending only to middle of thigh; no black on throat *femoralis*
2. Alignment of preanal pores strongly arched forwards; gular markings solid black; post-gular markings extend at least to anterior part of abdomen *isolepis*
Alignment of preanal pores not strongly arched forwards; gular markings not solid black; post-gular markings confined to chest 3
3. Pores more than 36 and extending to knee; a black chevron on throat *maculatus*
Pores fewer than 43, not extending on to distal quarter of thigh; throat spotted with black *fordii*

*Western Australian Museum, Perth, Western Australia.

***Amphibolurus maculatus badius* subsp. nov.**

Holotype.—R 18624 (in Western Australian Museum), an adult male collected by G. M. Storr and B. T. Clay on October 31, 1961.

Type locality.—15 miles south-east of Cardabia, Western Australia, in lat. 23° 15' S and long. 113° 55' E.

Paratypes.—R 18618 (18 mi. SSW of Bullara); R 16986-90, R 18605-10 (Ningaloo); R 16985 (7 mi. SE of Ningaloo); R 16872, R 16983, R 18611-7 (12 mi. SSE of Ningaloo); R 16875, R 16879 (15 mi. SSE of Ningaloo); R 16973-4 (14 mi. N of Cardabia); R 16969-70 (11 mi. N of Cardabia); R 16968 (8 mi. N of Cardabia); R 18619-23 (4 mi. N of Cardabia); R 16955-65 (3 mi. SE of Cardabia); R 18625 (11 mi. SE of Cardabia); R 18626-8 (4 mi. S of Gnaraloo); R 18629-35 (18 mi. N of Quobba); R 18637-41 (Quobba); R 17317, R 18642-3 (6 mi. S of Quobba); R 18644-56 (24 mi. N of Carnarvon).

Diagnosis.—The small size and reddish coloration distinguish *badius* from all other races of *maculatus*.

Description.—Head and tail brown; back reddish brown to brick-red. Yellow dorsolateral stripe from neck to rump, either continuous or broken by short, dark brown, transverse bars constricted in middle (where they cross dorsolateral stripe) and thus shaped like hourglass. These bars contract on tail into spots which coalesce to form dark dorsolateral stripe of irregular width. Immediately below these dark bars and spots a pale lateral stripe. Edge of lower jaw bright yellow. Remainder of under-surface whitish, except for following black or dark grey markings in male: chevron-shaped mark on throat, and bar across chest which is broken or constricted at midline.

Upper labials 10-14. Line of 41-57 pores extending almost to knee, continuous or slightly broken at midline and bowed slightly forwards. Gulars and ventrals keeled. Toes compressed, denticulate along outer edge of their upper surface. Lamellae under fourth toe 24-31, V-shaped in section and spinosely bicarinate, the inner series of keels apical and much the larger, the outer series lateral and often indiscernible except on distal phalanx. Maximum snout-vent length: males 52, females 54.

Distribution.—Mid-west coast of Western Australia from Ningaloo south to Carnarvon, thence east and south-east to Doorawarra and Narryer.

Comments.—North of the Gascoyne River, suitable habitat for this race is practically continuous in coastal dunes and near-coastal sandplains. Here the lizards are not only very numerous, but also undergo little geographical variation.

The coastal country from the Gascoyne to the Wooramel River is low-lying and consists largely of mangrove and samphire swamps; inland from these are plains of heavy soil, equally unsuitable for *A. maculatus*. The species is thus restricted in this region to isolated ridges of red sandy loam. The scattered populations on these ridges differ slightly and variously from typical *badius*. Though tentatively placed with *badius*, specimens from 23 miles SSE of Carnarvon, 9 miles W of Doorawarra, and from

Narryer, have not been used for descriptive purposes.

***Amphibolurus maculatus maculatus* (Gray)**

Uromastix maculatus J. E. Gray, 1831, a synopsis of the species of the Class Reptilia, p. 62, in Griffith's "Animal Kingdom" 9.

Grammatophora gaimardi Duméril & Bibron, 1837, "Erpétologie générale" 4: 470. Near Shark Bay (Quoy & Gaimard).

Material examined.—R 13153-9, R 20465-93 (Bernier Island); R 13146-52 (Dorre Island); R 12771 (Gregory, Peron Peninsula); Bradshaw collection (6 mi. S of Denham); R 13291 (8 mi. N of Galena); R 13139 (33 mi. E of Ajana); R 18592 (20 mi. SE of Kalbarri); R 11358 (5 mi. E of Kalbarri); R 16929-35 (14 mi. S of Kalbarri); R 18659-60 (Port Gregory); R 18661 (4 mi. S of Geraldton); R 22256-63 (Cliff Point); R 13411 (Stockyard Gully); R 12210, R 12689-91 (Jurien Bay); R 13441-2, R 18662 (lower Hill River).

Diagnosis.—Larger and duller than *maculatus badius*; smaller and browner than *maculatus griseus* and having relatively longer appendages.

Description.—Dorsally dull brown, with or without fine black spots. Creamy to brownish yellow dorsolateral stripe from neck to rump, continuous or broken by short transverse bars constricted in their middle by dorsolateral stripe and thus shaped like hourglass or dumb-bell. Above and below dorsolateral stripe a series of small pale spots alternating with dark transverse bars. Lower half of transverse bars coalesce on tail to form continuous dorsolateral stripe of irregular width. Pale grey lateral stripe from neck, over insertion of arm, to groin where it continues down inner edge of thigh; it reappears on outer edge of thigh and extends back to proximal half of tail. Dark ventrolateral stripe from axilla, back along flanks and both sides of thigh, to base of tail. Underneath whitish except for following black markings in males: small patch on chin, spots on lower lips, chevron on throat (bowed outwards and thickest anteriorly), and rhombic or kite-shaped patch on chest.

Upper labials 10-15. Line of 40-53 pores extending almost to knee, continuous or broken and slightly or moderately bowed forwards at midline. Gulars and ventrals keeled. Toes slightly compressed and moderately denticulate along outer edge of upper surface. Lamellae under fourth toe 25-37, V-shaped in section, sharply bicarinate, the inner series of keels apical, the outer series lateral and much the smaller. Maximum snout-vent length: males 58, females 59.

Distribution.—Coastal dunes and near-coastal sandplains of Western Australia from Shark Bay (Bernier and Dorre Islands and Peron Peninsula) south to the lower Hill River.

Comments.—In his original description of *maculatus* in 1831, Gray gave no details of the provenance of his type, except to indicate that it was in the Paris Museum. It was almost certainly the unique specimen on which Duméril & Bibron based *gaimardi* in 1837. At any rate these authors declared the two to be synonymous, and Gray's redescription of *maculatus* in 1845 is obviously adapted from Duméril & Bibron's excellent account of *gaimardi*.

The precise locality of the type of *gaimardi* is unknown. Quoy & Gaimard, during their visit to Shark Bay on the *Uranie* in 1818, made general collections on Dirk Hartogs Island and Peron Peninsula. I know of no material of *maculatus* from Dirk Hartogs Island.

***Amphibolurus maculatus griseus* subsp. nov.**

Holotype.—R 21708 (in Western Australian Museum), an adult male collected by G. M. Storr on November 11, 1963.

Type locality.—14 miles west of Boorabbin, Western Australia, in lat. 31° 15' S and long. 120° 05' E.

Paratypes.—R. 13140 (8 mi W of Coorow), R 14021 (10 mi. S of Coorow), R 5740 (Manning), R 12296 (Dumbleyung), R 6074 (Kuerin), R 12616 (Tarin Rock), R 2520-3 (Ongerup), R 21742-4 (Lake Magenta Reserve), R 10482 (Ravensthorpe district), R 21530 (Holt Rock), R 21709 (14 mi. W of Boorabbin).

Diagnosis.—Distinguished from nominate *maculatus* by its large size, much shorter tail, greyer coloration, and broad reddish dorsolateral stripe.

Description.—Dorsally grey or brownish grey. Broad orange-red dorsolateral stripe from neck to rump, sometimes continuous but usually broken by black or dark brown transverse bars shaped like dumb-bells. Lower half of these bars extend on to tail as a more or less continuous line of spots, and upper half extend forward, almost to eye, as a crooked black line. Broad greyish white lateral stripe from side of neck, over insertion of arm and along flanks, to groin where it continues along inner edge of thigh, reappearing on outer edge and extending back to proximal half of tail where it is usually whiter than on flanks. Broad, more or less broken, black or dark brown ventrolateral stripe from axilla, back along flanks and both edges of thigh, to proximal quarter (or less) of tail. Underneath whitish, except for following black markings in male: small patch on chin, spots on lower lips, chevron on throat (more angular than in nominate race, and with the junction of the arms tending to be prolonged forward, so that its shape is almost that of a tuning-fork), and large anchor-shaped patch on chest.

Upper labials 10-15. Line of 42-57 pores extending to knee, continuous or slightly broken and very slightly bowed forwards at midline. Gulars and ventrals smooth. Toes slightly compressed and denticulate. Lamellae under fourth toe 26-33, V-shaped in section sharply bicarinate, the inner series of keels apical, the outer series lateral and weaker. Maximum snout-vent length: males 67, females 65.

Distribution.—Sandplains of the south-western interior of Western Australia from Coorow south to Ongerup, and east to Boorabbin and Ravensthorpe.

Comments.—Specimens from the Coorow-Marchagee sandplain differ from typical *griseus* in their slightly keeled rather than smooth gulars and ventrals, indicating some relationship to the southern populations of nominate *maculatus*, which at Jurien Bay are only 60 miles to the west. Nevertheless, in their coloration and general proportions they hardly differ from typical *griseus*.

The known eastern limit of *griseus* in the north is at Boorabbin. Since the plant and soil formation it inhabits ceases about 50 miles east of Boorabbin, it is unlikely that its known range will be greatly extended in this latitude. In the south, however, suitable habitat extends eastward from Ravensthorpe (the present limit) to the Great Australian Bight. A small greyish *Amphibolurus* has been observed, but not collected, on bush tracks through dense mallee-heath south of Mt. Ragged. At Truslove (39 miles north of Esperance) I collected an adult female (R 17648) whose coloration is so different as to preclude its placing with *griseus*. This specimen has a snout-vent length of 52.5 mm. Dorsally it is pale grey. There is no dorsolateral stripe, and the unbroken and unconstricted blackish brown transverse bars are irregularly rectangular. Along the midline there is a series of short blackish brown dashes, and there are small spots of a similar colour between the transverse bars. It probably represents another race of *maculatus*, though in its proportions and structure it agrees with *griseus*.

***Amphibolurus maculatus dualis* subsp. nov.**

Holotype.—R 23637 (in Western Australian Museum), an adult male collected by G. M. Storr and A. M. Douglas on October 8, 1964.

Type locality.—7 miles south-southeast of Cocklebidy, Western Australia, in lat. 32° 08' S and long. 126° 08' E.

Paratypes.—R 23638-94 (7 mi. SSE of Cocklebidy).

Diagnosis.—Distinguished from all other races of *maculatus* by marked sexual differences in dorsal coloration. Males are very like those of *m. griseus*, but females are drab (generally dull brown with inconspicuous pattern).

Description.—Male dorsally brownish grey flecked with black on head and along midline of back and tail. Moderately broad dorsolateral stripe from neck to rump, orange-red, becoming pale posteriorly, continuous or narrowly



Fig. 1.—Location of specimens of four races of *Amphibolurus maculatus*. Cross indicates position of Truslove, where the peculiar R 17648 was collected.

broken with black. Dorsolateral stripe bordered above by series of blackish spots which usually coalesce to form a ragged-edged streak. Moderately broad greyish white lateral stripe from neck to anterior part of tail, interrupted at insertion of hindleg and obscurely present on both sides of thigh. Black ventrolateral stripe. Underneath whitish except for following black markings: on mental and adjacent scales, extending back as a broken or continuous stripe on lower lips; moderately broad chevron on anterior half of throat, continuous with or separate from narrow stripe extending back on to side of neck and anteroventral surface of arm; rhomboid patch on chest usually curved anteriorly and prolonged backwards on midline so that its resultant shape resembles anchor (when small) or silhouette of hawk (when large).

Female dorsally dull, slightly reddish, brown. Broad dorsolateral and lateral stripes, greyish white, narrowly edged with dark brown. On each side of dorsolateral stripe and below lateral stripe a series of dark brown spots, usually well spaced from each other but occasionally only separated by a few white dots. In most specimens some of the dark spots break dorsolateral stripe by obliquely and narrowly joining with their opposite number. In a few specimens the three series of brown spots align transversely to form broken bars. Tail narrowly and obscurely banded with white dots (probably homologous with those between dorsolateral dark spots). Underneath whitish except for more or less vague grey markings corresponding to black of males.

Upper labials 9-14. Line of 37-53 pores extending to (or almost to) knee, narrowly broken and slightly bowed forwards at midline. Gulars and ventrals smooth. Toes slightly compressed, denticulate along outer edge. Lamellae under fourth toe 24-30, sharply bicarinate, the outer series of keels slightly weaker. Maximum snout-vent length: males 57.5, females 59.

Distribution.—Only known from the type locality, which is in the narrow zone between the southern edge of the Nullarbor Plain and the Great Australian Bight.

Comments.—The above population was discovered after the submission of this paper for publication and I am grateful to the Hon. Editor for permission to describe it here.

These lizards were found in a small area of mallee-spinifex growing on shallow reddish loam over limestone. They constitute a partial exception to the generalisation (discussed later) that taxa inhabiting reddish soils have a reddish dorsum. The coloration of males is much the same as in *griseus*, but females are only a little less red than the substrate. It is possible that this race has evolved since the relatively recent colonisation by *griseus* of an arid, red-soil habitat, and that selection for harmony between coloration of dorsum and soil is much weaker in males than in gravid females.

***Amphibolurus fordii* sp. nov.**

Holotype.—R 19151 (in Western Australian Museum), an adult male collected by J. R. Ford on January 1, 1963.

Type locality.—12 miles north-west of Coolgardie, Western Australia, in lat. 30° 49' S and long. 121° 02' E.

Paratypes.—R 18663-70, R 19148-50 (12 mi. NW of Coolgardie); R 18671 (Comet Vale); R 17336 (18 mi. SSE of Karonie); R 12950 (12 mi. NW of Cundeelee); R 18672-3 (10 mi. E. of Zanthus).

Diagnosis.—Generally similar to *maculatus* but distinguished by fewer pores (which do not extend on to distal quarter of thigh), spotted throat of males, and narrow, unbroken, black-edged dorsolateral stripe.

Description.—Dorsally reddish brown, somewhat browner on head and greyer on tail. Head, back and tail (all or singly) may be finely spotted with black. Grey dorsolateral stripe from neck to rump, narrowly edged with black. Above and below dorsolateral stripe a line of black spots, the upper series terminating on rump, the lower series continuing on to tail where they coalesce to form black dorsolateral stripe. Grey lateral stripe, considerably broader than dorsolateral stripe, from axilla along flanks and both sides of thigh to middle of tail. Lateral stripe bordered below by black ventrolateral stripe from axilla to base to tail. Underneath whitish except for following black markings in males: spots or short bars on throat (sometimes so aligned as to suggest a chevron) and transverse bar on chest, narrowly prolonged on to forearm and often narrowly extended back on midline (in the latter event the resultant shape of the patch resembles the silhouette of a hawk).

Upper labials 12-16. Line of 34-42 pores extending three-quarters way down thigh, broken and slightly bowed forwards at midline. Gulars smooth. Ventrals weakly keeled and imbricate on chest, becoming smooth and juxtaposed on abdomen. Toes slightly compressed, their outer edge denticulate. Lamellae under fourth toe 28-34, obtusely V-shaped in section with a series of sharp keels along apex and one or more series of smaller keels along outer side of lamellae. Maximum snout-vent length: males 51.5, females 53.

Distribution.—Sandplains of the south-eastern interior of Western Australia from Comet Vale and Coolgardie east to the southern edge of the Great Victoria Desert.

Comments.—This species has been named after Mr. J. R. Ford, an Honorary Associate of this Museum, who collected the holotype and many of the paratypes.

An adult male (R 18694) from Boorabie (150 miles north-east of Loongana) has been excluded from the type series. It is paler and has fewer pores (33) and more subdigital lamellae (35) than any of the paratypes. It may prove to belong to another race. Boorabie is 300 miles ENE of Zanthus, the nearest locality of typical *fordii*.

The distribution of *fordii* is almost contiguous to that of *maculatus griseus*; yet the two taxa differ markedly: *fordii* is much the smaller, and being reddish in coloration, is superficially most like *badius* of the races of *maculatus*. Since gene-flow seems to have long ceased between these neighbouring taxa, *fordii* can hardly be

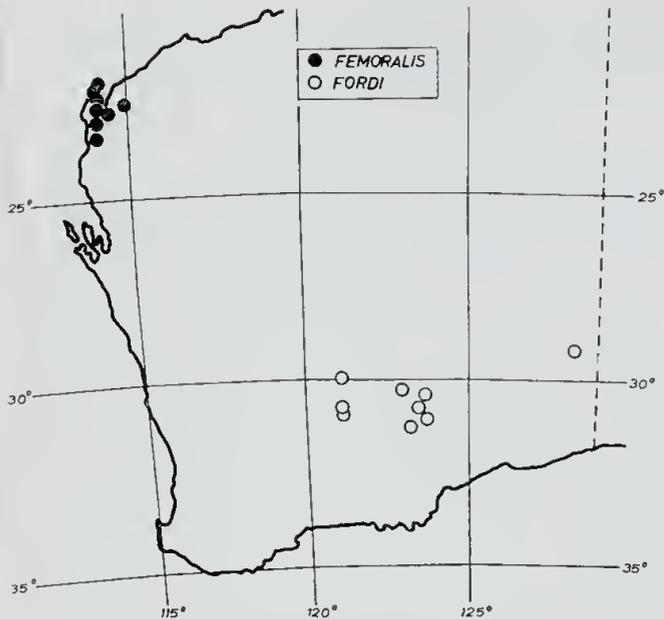


Fig. 2.—Location of specimens of *Amphibolurus femoralis* and *fordi*.

treated as another race of *maculatus*. Moreover, in certain respects, e.g. the reduction in femoral pores and of black on the throat of males, it is less like *maculatus* than the species about to be described.

Amphibolurus femoralis sp. nov.

Holotype.—R 17008 (in Western Australian Museum), an adult male collected by G. M. Storr and B. T. Clay on October 19, 1962.

Type locality.—23 miles north-east of Giralia, Western Australia, in lat. 22° 29' S and long. 114° 33' E.

Paratypes.—R 9008 (Northwest Cape); R 18685 (5 mi. N of Learmonth); R 18683-4 (6 mi. S of Learmonth); R 18681-2 (13 mi. S of Exmouth Gulf HS.); R 17013-8 (9 mi. NE of Yanrey); R 18686-92 (9 mi. NE of Giralia); R 17100-4 (4 mi. W of Bullara); R 18678-80 (18 mi. SSW of Bullara); R 18674-6 (15 mi. SE of Cardabia).

Diagnosis.—Coloration much paler than in other members of this species-group and pattern more obscure. Pores less numerous and not extending beyond middle of thigh. Black ventral markings in male confined to chest.

Description.—Dorsally pale brick-red, finely dotted with brown. Narrow, discontinuous, grey dorsolateral stripe sometimes discernible between neck and rump. A more prominent pale lateral stripe from axilla to middle of tail, with an interruption at insertion of thigh. Above this a dark brown stripe on tail, which is represented on body by a slight clumping and darkening of dorsal spots. Vaguely defined strip of grey below lateral stripe. Underneath whitish except for black patch on chest of males that would be kite-shaped but for its narrow extension on to fore-arms.

Upper labials 11-15. Line of 18-32 inconspicuous pores scarcely extending to middle of thigh and broadly discontinuous at midline. Gulars smooth or weakly keeled. Ventrals weakly to moderately keeled. Toes long, slender and compressed, the outer margin of their upper

surface strongly denticulate. Lamellae under fourth toe 26-37, V-shaped in section, their apex bearing a series of sharp keels largest and highest on middle phalanges. Claws long and slender. Maximum snout-vent length: males 57, females 54.

Distribution.—The Exmouth Gulf region of Western Australia, from Northwest Cape and Yanrey south to the Tropic.

Comments.—Although *femoralis* has been represented in this Museum since 1946, its distinctiveness was not appreciated till A. Kluge found it sympatric with *Amphibolurus isolepis* in September, 1961. I am indebted to Mr. Kluge for pointing out its femoral characters and for the loan of his series of this and related species.

Amphibolurus isolepis isolepis (Fischer)

Grammatophora isolepis Fischer, 1881, Arch. Naturgesch. 47: 232. Nickol Bay, Western Australia (F. von Mueller).

Material examined.—R 3447 (La Grange); R 1087-96 (Wallal); R 2117 (De Grey); R 14592-3 (Strelley); R 14594 (7 mi. SE of Port Hedland); R 17057-8 (Bocdarie); R 18745-79 (Mundabullangana); R 17068 (12 mi. E of Mundabullangana); R 17062-3 (15 mi. E of Mundabullangana); R 17078 (20 mi. SE of Mundabullangana); R 18780-5 (28 mi. SE of Mundabullangana); R 12625-8, R 13064-5, R 13314, R 18798-9 (Woodstock); R 20012-3 (7 mi E of Mt. Ulric); R 18795-7 (Millstream); R 18786-91 (Cossack); R 17022 (Nickol Bay); R 18792-4 (Karratha); R 14337, R 14349-54 (Legendre Island, Dampier Archipelago); R 5017-8 (Warrawagine); R 4022-6 (Canning Stock Route); R 3946, R 3957-8 (Well 35, Canning S. R.); R 4057 (Well 32, Canning S. R.); R 3932-4 (between Wells 31 and 36, Canning S. R.); R 3924-9 (Well 31, Canning S. R.) R 3916 (Well 30, Canning S. R.); R 3904-5 (Well 29, Canning S. R.); R 21453 (Tennant Creek, N.T.); R 13142-4 (Yardie Creek); Kluge 445-7 (5 mi. SW of Vlaming Head); R 18701-8 (2 mi. SW of Vlaming Head); R 21351 (Northwest Cape); Kluge 398, 402, 404-5 (6 mi. SE Vlaming Head); R 18709, Kluge 481 (10 mi. SE of Vlaming Head); R 18718-21 (4 mi. S of Learmonth); R 18710-6 (6 mi S of Learmonth); Kluge 362-3, 365, 370, 387-93 (7 mi SSW of Learmonth); Bradshaw collection (Learmonth and 4 mi. NW of Exmouth Gulf H. S.); R 18717 (12 mi. SW of Exmouth Gulf H. S.); R 16992-3 (16 mi. NE of Ningaloo); R 18718-21 (4 mi. S of Exmouth Gulf H. S.); R 18722-4 (13 mi. S of Exmouth Gulf H. S.); R 18699-700 (18 mi. SSW of Bullara); Kluge 346-53 (6 mi. N of Warroora).

Description.—Dorsally reddish brown, irregularly freckled with blackish brown and spotted with yellowish brown (spots of latter colour may be absent, or narrowly edged with dark brown so as to form ocelli). Pale, dark-edged dorsolateral stripe from occiput to tail, becoming increasingly broken and obscure posteriorly. A similar pale, dark-edged lateral stripe, from shoulder to groin, extends on to tail as a series of pale spots; in adult males it extends forward, above tympanum and through orbit and lores to snout. Between pale lateral and dorsolateral stripes, and also immediately above latter, a widely spaced series of dark brown spots, the first series tending to coalesce in males to form

a broad stripe. Lips yellow. Underneath whitish except in adult and subadult males which have a broad strip of jet black from snout to middle of abdomen, constricting at gular fold and dilating on chest. Adult males also have a dark stripe on anteroventral surface of arm which extends forward to posterior edge of tympanum; it may (but normally does not) continue forward from tympanum, as an increasingly narrow stripe between eye and lips, to about level of nostril. Anteroventral surface of hind-legs also black in fully adult males. Adult females may have male ventral pattern indicated by pale grey flecking, especially on throat.

Upper labials 10-13. Continuous line of 43-62 pores extending almost to knee and strongly arched forward at midline (pores much smaller in females but clearly discernible). Gulars keeled and imbricate, becoming very small towards gular fold. Ventrals largest on chest where they are strongly keeled and imbricate, becoming smaller and smoother on abdomen. Toes slightly compressed and weakly denticulate along their outer edge. Lamellae under fourth toe 25-35, V-shaped in section, weakly keeled apically (in some specimens, especially females, keels sharp and in two series). Claws moderately long. Maximum snout-vent length: males 68, females 70.

Distribution.—Arid and semiarid regions of tropical Western Australia from the southern parts of the Kimberley Division south-west to the Pilbara region and south-east into the Northern Territory, with an isolated population from Northwest Cape south to Warroora.

Comments.—In spite of its geographical separation (by the next race) from the main bloc of *i. isolepis*, the Northwest Cape population is not so distinctive as some others. The lizards inhabiting the alluvial plains of the middle Fortescue are very dark and, like those from nearby Woodstock, are rather larger than coastal animals.

Even more distinctive is the population inhabiting Legendre, a low calcareous island in the Dampier Archipelago. The dorsal coloration of the single adult (a male with snout-vent length of 52 mm) is quite bereft of red, and its tail is relatively longer than any other specimen of Pilbara *isolepis*. The rest of the series are juveniles ranging in snout-vent length from 24.5 to 38 (av. 29). They were collected in June, at which time on the mainland juveniles are considerably larger and adults have not been collected (see Table IV). This population is either smaller in size than those of the mainland or (more probably) breeds later. It may prove worthy of subspecific distinction.

Fischer gave the locality of *isolepis* merely as Western Australia. His description, however, was so detailed as to leave little doubt that it applied to Pilbara lizards. Dr. H. Wermuth (Staatliches Museum für Naturkunde, Stuttgart) has informed me (*in litt.*, 27/vii/64) that the types were collected at Nickol Bay in 1880. Dr. Wermuth has kindly lent me the types, an excellently preserved male and female with catalogue number 2051. They agree closely with our Pilbara mainland series. The tail of the syntype male is intact and relatively much shorter than in our Legendre Island male.

Amphibolurus isolepis rubens subsp. nov.

Holotype.—R 18740 (in Western Australian Museum), an adult male collected by G. M. Storr and B. T. Clay on November 3, 1961.

Type locality.—Yanrey, Western Australia, in lat. 22° 30' S and long. 114° 48' E.

Paratypes.—R 17019-20 (4 mi. E of Onslow); R 12624 (Koordarrie); R 17009-12 (9 mi. NE of Yanrey); R 18743-4 (14 mi. E of Yanrey); R 18741-2 (Yanrey); R 17004-7 (23 mi. NE of Giralia); R 18725 (9 mi. NE of Giralia); R 13125, R 13318 (176-mile Tank, 22 mi. NE of Winning); R 18736-9 (16 mi. NE of Winning); R 5331 (Marilia); R 5009 (Mia Mia); R 18695-8 (6 mi. SE of Gnaraloo); R 16953 (Yalobia).

Diagnosis.—By far the largest known race of *isolepis*. Juveniles and subadults similar in coloration to those of nominate race. Adults much paler, the assumption of a rosy flush, especially in males, almost completely masking dorsal and lateral colour pattern.

Description.—Adult male dorsally brownish pink, brownest on head and reddest on tail. Dorsal spots and dorsolateral stripe barely discernible. No black on side of head and body, except for spot anterior to oblique prolongation of gular fold. Ventral black more extensive and continuous than in other races of *isolepis*: it covers chin and throat (except for ventrolateral surface of jaw) and ventrolateral (and often ventral) surface of fore limb; broad patch on chest extends back on to abdomen (where it becomes narrow only towards pubis) and spreads broadly on to anteroventral and ventral surfaces of hind limbs, the black ceasing posteriorly along femoral pore line, though triangle between vent and preanal pores usually black. All ventral black continuous except occasionally for break on posterior of abdomen.

Adult female covered with pinkish flush, but not to same extent as in male, and much more of subadult pattern persists. Back covered with

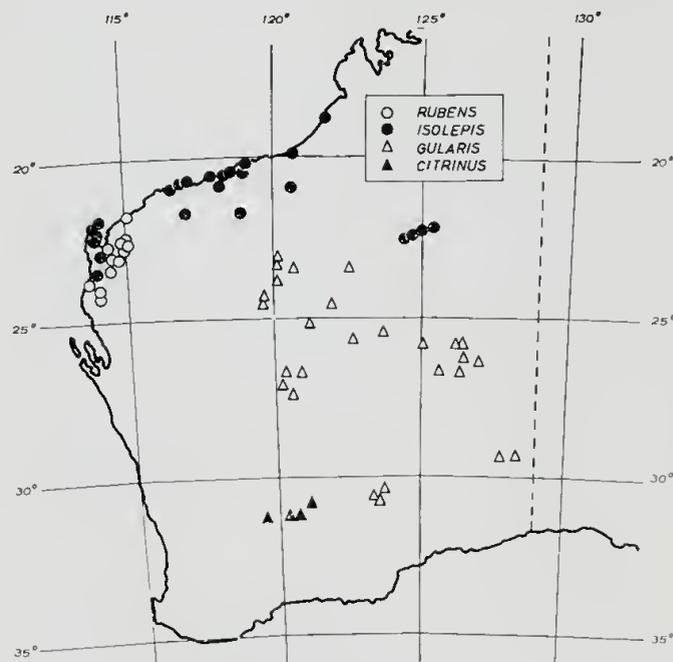


Fig. 3.—Location of specimens of four races of *Amphibolurus isolepis*.

brown spots, mixed with dark-edged pale spots (indiscernible on palest specimens). Brown spots not usually discernible on sides of body; they are represented on tail by brown stripe.

Upper labials 11-15. Continuous line of 53-70 pores extending to end of thigh and strongly arched forward at midline (pores much smaller in females but clearly discernible). Gulars imbricate and smooth or weakly keeled. Ventrals keeled, largest on chest. Toes slightly compressed, weakly to moderately denticulate along their outer edge. Lamellae under fourth toe 30-35, v-shaped in section, weakly to moderately keeled (usually in an apical series but occasionally with an additional smaller series on outer slope of lamellae). Maximum snout-vent length: Males 83, and females 77.5.

Distribution.—The Exmouth Gulf region of Western Australia from Onslow south to Gnarlaloo and Yalobia.

Amphibolurus isolepis gularis (Sternfeld)

Amphibolurus maculatus gularis Sternfeld, 1924, Abh. Senck. Naturf. Ges. 38: 231. Hermannsburg, Northern Territory (M. von Leonhardi).

Material examined.—R 8421-3 (Lake Disappointment); R 13593, R 13599 (Jigalong); R 18800-3 (Ethel Creek HS.); R 18804 (25 mi. S of Ethel Creek HS.); R 18805-8 (Mundiwindi, new site); R 18809-11 (Ilgararri Creek); R 18812-9 (10 mi. S of Ilgararri Creek); R 18820-4 (20 mi. NE of Three Rivers HS.); R 15834-8 (17 mi. NE of Weld Spring, Canning S.R.); R 15854-5 (Pierre Spring, Canning S.R.); R 21113-4 (14 mi. E of Wiluna); R 21108-11 (35 mi. E of Wiluna); R 21074 (21 mi. W of Carnegie); R 21055-61 (58 mi. ENE of Carnegie); R 21028-9 (7 mi. NW of Lake Breaden); R 21026 (16 mi. E of Todd Range); R 14609-14 (40 mi. N of Warburton Range); R 14615, R 22041, R 22194 (Warburton Range); R 18227 (8 mi. W of Warburton Range); R 18828-9 (35 mi. E of Warburton Range); R 15712 (Featherstonehaugh Hill); R 15724 (Gahnda Rock-hole); R 19781-2 (Albion Downs); R 12409-11, R 18825-6 (Kathleen Valley); R 12948-53 (12 mi. NW of Cundeelee); R 21666-71 (5 mi. NW of Cundeelee); R 21684-8 (13 mi. NE of Cundeelee); R 13002-21, R 18860, R 21690-6 (Queen Victoria Spring); R 18861 (Iltoon, 125 mi. NNE of Loongana); R 18862-8 (Boorabbie, 150 mi. NE of Loongana).

Diagnosis.—Distinguished from nominate race mainly by colour and pattern. Dorsal coloration brighter, with greater development of ocelli. Dorsolateral stripe usually breaking up into pale, dark-edged spots. Much more black in adult males on side of body and head, with black of throat extending to edge of jaw.

Description.—Dorsal coloration orange brown to brick-red, finely spotted with black. Along each side of midline an irregular series of pale spots, narrowly edged with dark brown and sometimes coalescing to form short, rounded, transverse or longitudinal bars. Pale, dark-edged dorsolateral stripe from posterior edge of tympanum to proximal quarter of tail, usually broken behind shoulder to form a series of elongate spots. Above and below dorsolateral stripe a series of dark brown or black spots. Pale lateral stripe on flanks (similar in width and colour to dorsolateral stripe but seldom

broken) becoming ventrolateral as it extends irregularly forward to lips and backward on to tail. Pattern on flanks of males usually masked by broad strip of velvety black which, with decreasing width, extends forward across ear and above lips to tip of snout, and backward on to anteroventral surface of hind-leg. Lips yellow. Underneath whitish except in adult and subadult males which have throat, chest and anterior part of abdomen solid black (the same areas, especially throat, may be speckled with grey in gravid females).

Upper labials 10-16. Continuous line of 44-64 pores extending to end of thigh and strongly arched forward at midline. Gulars small and weakly keeled and imbricate. Ventrals larger and more strongly keeled, especially on breast where they are also mucronate. Toes slightly compressed and weakly denticulate along their outer edge. Lamellae under fourth toe 26-35, V-shaped in section and sharply keeled (one series of keels along apex, and one or two series on outer slope of proximal lamellae). Maximum snout-vent length: males 62, females 66.5.

Distribution.—The Gibson and Great Victoria Deserts of Western Australia, west to the sources of the Fortescue and Gascoyne Rivers, Wiluna and Queen Victoria Spring, and east into the southernmost part of the Northern Territory (and probably the north-west of South Australia).

Comments.—This race is excellently figured in colour by Lucas & Frost (1896).

Despite its enormous range, *gularis* undergoes little geographical variation. Northern specimens are redder and a little larger than those from the south. The dorsal coloration in the Cundeelee-Queen Victoria Spring population tends towards orange; it is only in this respect and its slightly smaller size that it approaches the next race.

Amphibolurus isolepis eitrinus subsp. nov.

Holotype.—R21706 (in Western Australian Museum), an adult male collected by G. M. Storr on November 11, 1963.

Type locality.—2 miles west of Boorabbin, Western Australia, in lat. 31° 12' S and long. 120° 17' E.

Paratypes.—R 21710 (12 mi. E of Southern Cross), R 21707 (2 mi. W of Boorabbin); R 14121, R 14125 (Dedari); R 18830-7 (12 mi. NW of Coolgardie).

Diagnosis.—Distinguished from *gularis* by its yellow rather than reddish dorsal coloration. Also smaller and with relatively shorter tail and broader head.

Description.—Dorsally lemon-yellow with scattered spots of black (males) or dark brown (females) mixed with irregularly shaped, narrowly brown-edged, pale spots sometimes coalescing to form rounded transverse bars. Pale dorsolateral stripe, narrowly edged with brown, from nape to shoulder from which it continues as a series of pale spots similar to but larger than those along middle of back. Lateral stripe similarly broken into a series of dark-edged pale spots. Between lateral and dorsolateral series of pale spots a series of dark brown spots simi-

TABLE I

Mean length of head, etc. in males, expressed as per cent. length of trunk, and the ratio width to length of head, with female data in parentheses.

	Number of specimens	Percentage length of trunk				Ratio, width to length of head
		Head	Tail	Hind-leg	Fore-leg	
Femoralis	23 (11)	34 (34)	380 (351)	130 (126)	57 (57)	0.75 (0.77)
Fordi	13 (4)	37 (35)	327 (304)	124 (115)	57 (54)	0.77 (0.78)
Badius	26 (11)	37 (37)	357 (339)	116 (111)	56 (55)	0.73 (0.74)
Maculatus	17 (11)	36 (35)	362 (323)	117 (111)	56 (54)	0.76 (0.76)
Griseus	13 (9)	36 (35)	317 (301)	113 (107)	57 (55)	0.78 (0.78)
Dualis	22 (11)	38 (37)	323 (303)	121 (113)	57 (55)	0.77 (0.79)
Isolepis	58 (52)	39 (38)	328 (319)	123 (119)	57 (56)	0.74 (0.73)
Rubens	40 (19)	40 (36)	334 (324)	123 (119)	57 (56)	0.74 (0.74)
Gularis	75 (63)	39 (36)	317 (298)	129 (121)	58 (56)	0.75 (0.76)
Citrinus	6 (5)	39 (38)	279 (263)	119 (111)	58 (56)	0.80 (0.83)

lar to those on back. As in *gularis*, flank pattern masked in males by broad strip of velvety black which, decreasing in width, passes forward across ear and above lips to tip of snout, and backward on to anteroventral surface of hind-leg. Lips yellow. Underneath whitish except for broad velvety black patch on throat of males, continuous with large triangular patch on chest, its apex hardly reaching to abdomen and its base narrowly extending on to arm. Throat may be speckled in gravid females.

Upper labials 12-15. Continuous line of 50-58 pores extending to end of thigh and strongly arched forward at midline. Gulars juxtaposed or weakly imbricate, smooth or weakly keeled, becoming very small in vicinity of poorly developed gular fold. Ventrals large and keeled on chest, becoming smaller, juxtaposed and smooth on abdomen. Toes relatively short and stout, slightly or not compressed, weakly denticulate. Lamellae under fourth toe 24-34, U-shaped in section, weakly or moderately bicarinate, the outer series of keels usually becoming very small on distal phalanges and sometimes disappearing. Maximum snout-vent length: males 50, females 57.

Distribution.—Sandplains between Southern Cross and Coolgardie in the southern interior of Western Australia.

Comparative Mensuration and Meristics

The following measurements were made on all animals old enough to sex by coloration:—length and width of head, and length of tail, foreleg and hindleg (the last two measurements exclusive of claw). All these measurements, except width of head, were expressed as percentage length of trunk (snout-vent length minus length of head); the means of these and of the ratio width to length of head are given in Table I. The length of appendages relative to trunk and the ratio width to length of head all decrease with age. To illustrate one of these effects, Table II gives the relative length of hindleg for various size groups in two races of *isolepis*. Upper labials, subdigital lamellae and pores were counted in a substantial proportion of each sample; means and standard deviations are given in Table II (the number of pores are based solely on male counts).

All appendages are relatively shorter in females than males. The disparity is greatest in the tail (6%) and least in the foreleg (3%). The ratio width to length of head averages 1% greater in females than males.

The taxa within each species are tabulated in a north-south sequence, which reveals the tendency for relative length of appendages (except foreleg) to decrease from north to south, in accordance with Allen's rule. The ratio width to length of head increases from north to south. These trends operate within species and not between them. For example, the northernmost race (*badius*) of *maculatus* is shorter-legged than the southernmost race (*citrinus*) of *isolepis*. It so happens that *maculatus* is a short-legged (and long-tailed) species compared to *isolepis*. Differences in relative proportions are very pronounced between *femoralis* and *isolepis rubens*, even though their ranges are largely concurrent.

That the relative length of appendages within a race is a function of age rather than size is demonstrated in Table II. Overall mean relative length of hind-leg is almost identical in *i. isolepis* and *i. rubens*, but for any given snout-vent length the hindleg is considerably longer in the latter. Now *rubens* is a larger lizard than *isolepis*; hence individuals of the same size as *isolepis* would be younger.

Two more latitudinal trends are revealed in Table III, viz. increasing upper labials and decreasing subdigital lamellae from north to south. Lamellar counts in *m. badius* and *i. isolepis* are anomalously low.

Longevity

Of our large series of *i. isolepis*, the precise date of collection is known for 131 specimens. When these are classified chronologically, as in Table IV, it is seen that there is no overlapping of generations. Only juveniles have been collected in autumn; they grow throughout winter, mature rapidly in early spring, continue to grow after breeding, and die by the following

TABLE II

Mean length (mm) of hind-leg, expressed as per cent. length of trunk, for different size-groups of males in two races of *isolepis*, with number in sample in parentheses.

Snout—vent length	<i>i. rubens</i>	<i>i. isolepis</i>
80-84	110 (2)	.....
75-79	118 (6)	.....
70-74	121 (12)	.....
65-69	126 (10)	117 (9)
60-64	129 (5)	120 (16)
55-59	131 (3)	121 (12)
50-54	127 (2)	130 (12)
45-49	.....	131 (9)

autumn. In *i. gularis* the generations overlap in summer and autumn. Otherwise each sample consists of a single generation, the individuals of which vary considerably, but normally, in snout-vent length. In *m. maculatus* the generations overlap only in summer. But as all three taxa are poorly represented by summer and autumn samples, there could well be a general overlapping of generations from December to May, in which case the maximum age of the lizards would be about 18 months. Mean longevity is no doubt considerably less, and for all practical purposes these lizards may be deemed annual. The data for the other six taxa, though fragmentary, are not inconsistent with the above pattern.

Most of the large size-variation within generations is probably due to protraction of the breeding season. In summer 1961-2, females of *i. isolepis* contained large yolky eggs as early as November 2 and as late as March 4.

Habitat Preferences

The species *isolepis* occupies habitats that are generally characterised by great summer heat and low irregular rainfall. The race *citrinus* alone is found in an area where winter rains are fairly reliable. The remaining races, with the partial exception of the Cundeelee-Queen Victoria Spring population of *gularis* and the

North West Cape population of *isolepis*, occur where winter and spring are normally seasons of drought.

Generally *isolepis* favours light reddish soils sparsely vegetated with spinifex (*Triodia* spp.). There are some exceptions to this generalisation, notably the western population of *citrinus* which occurs on yellow sand covered with a fairly dense shrubbery of Myrtaceae and Proteaceae, and the dark mid-Fortescue population of *i. isolepis* which occurs on alluvial flats that support a dense sward of soft grasses after rain. Rocks are a rare feature in *isolepis* habitats. However, the nominate race may be found among granite boulders along the banks of the Maitland River at Karratha, and on sheets of limestone north-east of Ningaloo. The essential features of *isolepis* habitats (and indeed for all members of the species-group) are some bare ground on which to forage and take up heat, and some dense vegetation into which the lizards may scurry when hard-pressed, though normally they prefer, when chased, to run from one open space to another.

The various races of *maculatus*, even including *badius*, occur in areas where effective rain is largely confined to winter. The soils are usually sandy and, except in the north, not reddish. The prevailing vegetation is shrubby rather than grassy, and low trees may be plenti-

TABLE III

Mean (*M*) number of upper labials, lamellae under fourth toe, and pores, with sample size (*N*) and standard deviation (*S*).

	Upper labials			Subdigital lamellae			Pores		
	N*	M.	S.	N*	M.	S.	N.	M.	S.
Femoralis	62	12.8	1.1	59	32.0	2.5	19	24.4	3.0
Fordi	38	13.6	1.1	39	31.5	1.9	15	37.7	2.6
Badius	56	11.6	1.0	55	27.6	1.7	33	47.2	3.3
Maculatus	43	12.6	1.2	43	30.2	2.5	12	46.3	3.2
Griseus	43	12.8	1.0	42	29.0	1.8	9	45.0	4.2
Dualis	33	11.9	1.0	32	28.0	1.6	17	44.2	4.3
<i>Isolepis</i>	40	11.4	1.2	30	30.0	2.8	43	52.9	3.8
Rubens	19	12.5	1.0	19	33.0	1.6	32	60.7	3.7
Gularis	87	13.0	1.0	60	30.6	1.9	53	53.9	4.1
Citrinus	22	13.0	0.9	22	28.0	1.7	9	53.8	2.7

* The two sides of a single animal are counted as a sample of two.

TABLE IV

Range (*R*) in snout-vent length (mm) at different months of the year, with mean (*M*) and number (*N*) in samples (which have been partitioned into generations).

	<i>i. isolepis</i>			<i>i. gularis</i>			<i>m. maculatus</i>		
	N.	R.	M.	N.	R.	M.	N.	R.	M.
December	...	...	...	1	22	22	2	29-31	30.2
January	...	...	...	6	27-35	30.7	1	29	29
February	...	...	...	...	...	...	...	...	...
March	...	...	...	...	...	...	7	24-34	30.1
April	...	...	...	2	38-39	38.5	...	...	...
May	8	28-40	33.5	...	...	...	29	30-49	41.3
June	5	33-45	37.8	...	...	...	...	...	...
July	...	...	...	17	31-52	42.4	35	36-55	47.8
August	32	34-54	43.5	20	34-59	44.4	...	...	...
September	29	46-65	55.1	2	48	48	1	52	52
October	9	44-60	52.3	...	...	...	7	48-58	50.4
November	31	43-65	55.8	18	42-65	53.1	...	...	...
December	...	...	...	21	47-59	54.9	6	49-56	52.4
January	...	...	...	50	46-66	54.9	10	48-59	52.4
February	11	55-65	60.0	...	...	...	...	...	...
March	6	62-70	66.9	25	50-63	56.3	...	...	...
April	...	...	...	6	58-66	62.6	...	...	...
May	...	...	...	1	61	61	...	...	...

ful. In the few places where *maculatus* and *isolepis* are sympatric, as at North West Cape and east of Southern Cross, no differences are evident in habitat preferences.

Amphibolurus fordi occupies an area in which scanty rains are received in summer as well as winter. It is confined to isolated patches of red sand clothed with small spinifex and scattered mallee, a habitat it shares with the southernmost populations of *i. gularis*.

Although its geographical range is small, *femoralis* occurs in a variety of habitats. North-east of Giralda it is restricted to the almost bare tops of red sand dunes, whereas the much larger *i. rubens* monopolises the spinifex-covered interdunes. A little further west, beyond the range of *rubens*, *femoralis* is sympatric with *i. isolepis* and *m. badius*. It has been found with both of these on heavy loam vegetated with spinifex. It has also been found with *isolepis* on stony, clayey soils, and with *badius* on red dunes clothed with proteaceous shrubbery.

Phylogeny

The common feature in the colour pattern of the various members of this species-group are the pale lateral and dorsolateral stripes, which are otherwise rare in *Amphibolurus*. However a pale dorsolateral stripe occurs in *Physignathus*, *Diporiphora* and *Tympanocryptis*. Strongly keeled dorsal scales are also shared by members of these genera with the *maculatus* group. In their dorsal colour pattern these genera tend to combine pale longitudinal stripes with dark transverse bands, as in *Tympanocryptis lineata* and *Diporiphora* spp. Among the *maculatus* group this kind of pattern is best preserved in *maculatus* itself, where the break in the transverse bars may represent a former vertebral stripe now submerged in the dorsal ground coloration.

Despite their bright colours and bold patterns, all members of the species-group are inconspicuous against their natural background. The general coloration matches well with the substrate. All but three taxa occur on reddish soils, and all except these three are dorsally reddish. The pattern too is responsive to the environment. The transverse bars of *maculatus* are useful in habitats where the vegetation is high and dense enough to throw numerous shadows. But on the bare sunlit ground of arid habitats, barring would undoubtedly be disadvantageous. Furthermore, in arid habitats the dorsolateral stripe has undergone some modification. In *femoralis* and *i. rubens* it has almost disappeared; while in *i. gularis* and, to a lesser extent, *i. isolepis* it tends to break up into ocelli similar to those on the back.

While it is not unlikely that *maculatus* is the most primitive member of the group in colour pattern, it is not at all certain that it is primitive in other characters. With respect to number of pores and extent of ventral black in males, *femoralis*, *fordi*, *maculatus* and *isolepis* form a series. Whether the series has been formed by reduction, addition or both, there seems to be no way of ascertaining.

Regarding pores, I favour the hypothesis of reduction. Successive loss of preanal pores from near the midline would reduce the strong arch

of *isolepis* to the slight bow of *maculatus* and *fordi* and the straight alignment of *femoralis*. Such a sequence demands the loss of pores (a common event in the Agamidae) rather than the evolution in *isolepis* of a unique alignment of preanal pores.

The extent of ventral black is roughly correlated with body size. *I. citrinus* is clearly derived from *i. gularis*; it is considerably smaller than its parent race and has less ventral black. Conversely *i. rubens* is much larger than its presumed parent, *i. isolepis*, and has much more ventral black. In the series *m. griseus*, *m. maculatus* and *m. badius*, decreasing size is accompanied by decreasing ventral black. Within a taxon the ventral black (first attained by males when their snout-vent length is between 40 and 50 mm) continues to spread with growth, even after breeding. Hence change in the number of pores and relative extent of ventral black could be consequent of phylogenetic change in body-size.

Body-size is not consistently influenced by non-biotic factors such as latitude. Whereas *maculatus* increases in size from north to south, the opposite obtains in the sequence *isolepis-gularis-citrinus*. On the other hand the prior presence in a habitat of another member of the group could well determine whether an invader would advantageously increase or decrease its body size. With a snout-vent length of up to 67 mm, *griseus* is by far the largest race of *maculatus*, which is otherwise a smaller species than *isolepis*. East of Southern Cross *griseus* coexists with *citrinus* (SVL up to 57), the smallest race of *isolepis*. In the sandhill country east of Exmouth Gulf, *rubens* (SVL up to 83 and much the largest race of *isolepis*) coexists with *femoralis* (SVL up to 57).

Over most of the State the *maculatus* group is represented by only one species—*isolepis* in the north-east, and *maculatus* in the south-west. It is probable that the greater part of the evolution of the taxa has been allopatric, and that their morphological divergence has been acquired during their adaptation to the physical environment. More or less recently, certain taxa have expanded their range and have locally become sympatric with other members of the group. The taxa geographically intermediate between *maculatus* and *isolepis*, viz. *femoralis* and *fordi*, are especially exposed to competition. It is possible that each of these has independently undergone selection for sexual precocity, and that their reduction in pores and ventral black are concomitants of this precocity.

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6.—The Field Occurrence of the Mt. Padbury Meteorite

By W. H. Cleverly*

Manuscript accepted—16th February, 1965

Fragmentation of the Mt. Padbury meteorite, a newly discovered mesosiderite, probably occurred at the penultimate stage of atmospheric flight, distributing fragments over a very small impact ellipse, the larger fragments being embedded several inches in the soil. The concentration of nearly 99% of the material in a circle whose area is only 0.4 that of the whole ellipse is notable and suggests that the line of flight was nearly vertical with only some minor fragments scattered further out when fragmentation occurred. Further fragmentation probably occurred on impact, and subsequently the material suffered considerable weathering and redistribution of the resulting fragments by secondary processes. This may indicate that the fall occurred many years ago—possibly centuries, but the unstable mineral lawrencite in the meteorite could have produced the same effect in a very short time.

Location

The find was made on Mt. Padbury station, the homestead of which is situated 68 miles north-north-west of Meekatharra. The site of find was 9 miles from the homestead on a bearing slightly south of east, at a point on 118° 15' east longitude and 25° 42' south latitude. The mountain from which the station takes its name is closely visible to the north-north-east.

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The country about the site is, perhaps, best described as "mulga plain". It carries stunted mulga and is very poor pastoral country (Fig. 1). There is a stony soil cover and a tough ferruginous hardpan occasionally outcropping, but more often at depths up to one foot. Occasionally this hardpan is exposed at the surface or occurs as detached floaters.

History of the find and its recovery

This new meteorite find was made on 12th March, 1964 by Mr. W. C. Martin, senior partner in the Mt. Padbury Pastoral Company, during the course of mustering sheep. Despite protests from a companion that the material was valueless, Mr. Martin took some pieces from one of the "outcrops" back to the station homestead. There his partner, Mr. A. H. Bell, attempted to "dolly" one of the pieces for gold and also applied an oxy-acetylene flame to the material, causing a white metal to run from it. Still puzzled, Mr. Bell forwarded pieces to the School of Mines in Kalgoorlie for identification. There they came to the attention of the writer and were identified as a mesosiderite, a stony-iron meteorite of rare type.

Mr. Bell described the occurrence in general terms as possibly several hundredweights of material, occurring in four or five small outcrops



Fig. 1. Mass 1.—The largest piece of the Mt. Padbury meteorite (195 lb.) in situ, with detached fragments in foreground. Mr. W. C. Martin, the finder (on left) and his partner, Mr. A. H. Bell, who called attention to the material. Note the stony, almost "gibber-plain" surface and the poor mulga vegetation.



Fig. 2.—Side elevations of three major fragments showing weathering effects. The upper surfaces of all are original dimpled surfaces. Top left: spheroidal core after loss of up to 2 in. by exfoliation from the underside. Bottom right: upward wedging cracks sub-divide the mass into individuals which weather spheroidally. Top right: cracking and weathering advanced, a well-defined spheroid in the middle. The two large specimens are one foot wide.

rising above the natural cement and spread over an area about thirty yards square. Knowledge of the manner of occurrence of meteorites has frequently been lost in the past through thoughtless collecting, and this occurrence appeared from Mr. Bell's description to be unspoiled and to provide an ideal opportunity for accurate recording of details of distribution of the pieces. In response to a request from the writer, the finders removed no further material and it was subsequently possible to record and collect from the outcrops with due care. Each outcrop was found to consist of a very badly weathered and disintegrating boulder of meteorite, embedded in the soil.

Distribution and state of the material

The larger pieces of meteorite were embedded to about the depth of the ferruginous hardpan, but no worthwhile material was recovered from below ground level. Each large mass showed more or less spheroidal weathering like boulders of dolerite. The material in the ground was completely decomposed and consisted of detached exfoliated slabs or scales of "onion-skin" type; the term "iron shale" is sometimes applied to decomposed material of this nature. It was collected with the intention of determining the

extent and weight of each mass rather than with any hope that it might be of value for petrographic study. Each outcrop could be lifted off its weathered underpart. From the underside of some masses cracks extended upward dividing them into spheroidally weathering parts (Fig. 2). Mass 3 was so frail as to fall apart at a touch. In contrast, the upper surfaces of Masses 2 and 3 were dimpled and appear to be original surfaces; this dimpling on Mass 2 is shown in Fig. 3. Portion of the lateral surface of Mass 1 also showed this structure. This survival is noteworthy because lower parts embedded in the ground were surrounded by up to 4" of iron shale. That thickness might owe something to swelling consequent upon oxidation and hydration.

Of Mass 4, initially about 22 kg. in weight, the largest surviving fragment weighed only 0.7 kg., and the remainder was divided into hundreds of small fragments. The great bulk of the curving or irregular fragments were quite useless as specimen material but the rare rounded or ovoid pieces from this or other sources were of relatively high specific gravity and fresh internally. Such rounded pieces are the innermost cores of the spheroidally weathered masses.



Fig. 3.—Mass 2 disintegrated by secondary agencies and drifted apart. The largest pieces show the dimpled upper surface. There are quite a number of fragments in the foreground but the small pebbles are a soil constituent not meteoritic. Hammer length, 1 foot.

Following detachment of fragments as a result of weathering, there had been some secondary distribution of material by soil creep, rainwash or sheet floods, resulting in small eluvial or alluvial trails of fragments. There is also a possibility that rare, unusually wide floods of the Murchison river might have covered this point. Fragments which could be referred on the basis of proximity and slope to a particular parent mass were mapped and recorded as the eluvium of that mass (Figs. 4 and 5).

There remain some minor fragments of no evident parentage and these probably belong to at least three categories. Some groups of fragments could have resulted from disintegration of other original masses of small dimensions. "Mass" 7 (Fig. 5) is a group of 15 such fragments, the largest 0.3 kg. in weight, envisaged as parts of a hypothetical mass of about 1.2 kg. A fragment weighing 0.35 kg. found between Masses 1 and 6 was larger than any fragment in the eluvial trail of Mass 1 but had the exfoliated form and was quite isolated. Distribution of such fragments by human agency is a possibility; the site is close to an area which was thoroughly prospected for manganese. Finally, some pieces may be original and unrelated to distribution effects of weathering. A piece in this category is an ovoid one weighing 0.6 kg. and occurring 20' in direction 170° from Mass 5 without accompanying debris. Fragments not known to be related to a parent mass are listed in the table of weights as "aberrant".

Reasons for the primary distribution of mass

When a meteorite is found as a number of related fragments, there are at least four possible reasons:

- (a) Fragmentation pre-dating entry to the earth's atmosphere.



Fig. 4.—Eluvial spread from Mass 1 looking westerly towards the source. Fragments have been placed upon white sample bags. No attempt has been made to mark all the very numerous fragments near the source.

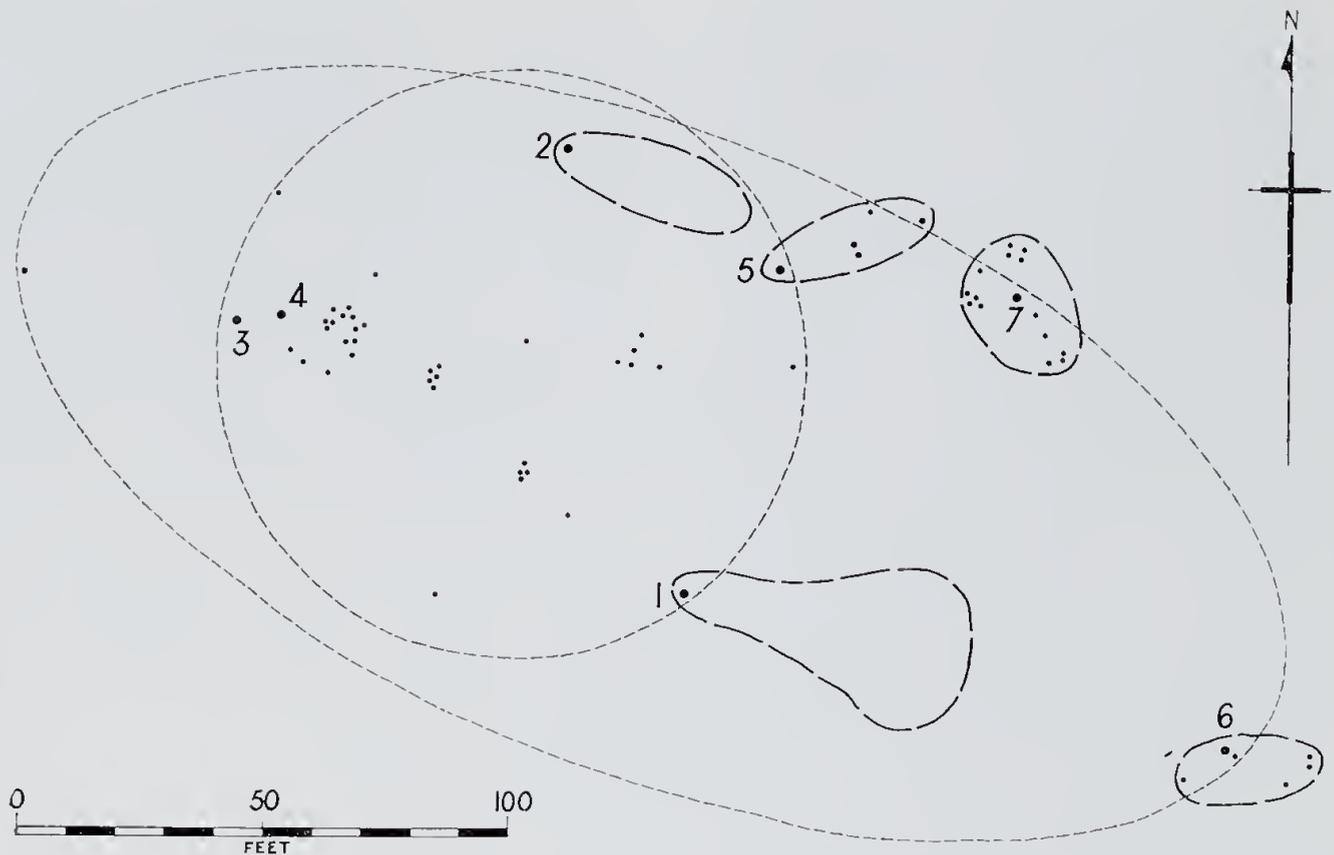


Fig. 5.—Distribution of the fragments of the Mt. Padbury meteorite. Larger masses are numbered and their eluvium is included within the broken lines. The very numerous fragments of Masses 1 and 2 are not shown individually. The circle is of 120 feet diameter, the ellipse 130 feet x 275 feet.

- (b) Fragmentation consequent upon heating and the stresses of atmospheric flight.
- (c) Fragmentation on impact.
- (d) Disintegration by weathering and distribution by surface agencies.

The first impression in the field was that the major masses formed a triangle of about 90 feet side and their distribution might be due to fragmentation on impact. When further pieces were flagged it was evident that the distribution was roughly elliptical. This is the characteristic distribution of a shower of meteorite fragments.

If a group of fragments is visualized traveling earthward and gradually dispersing in flight then a cone of paths is formed. Generally, when the axis of the cone is not vertical, the earth's surface forms an elliptical impact area. In theory, the special case of a vertical axis and a circular impact area is also a possibility but such a special case will be a rarity. Ellipses of meteorite distribution are known varying from rough patterns to near-perfect ones.

The plot of the distribution (Fig. 5) illustrates the pattern recognized in the field. After allowing for the reconcentration of eluvial fragments with their parent masses, 94.4% of the weight of the collected material is represented by Masses 1 to 4 at the corners of a triangle and 98.7% lay within a circle of 120 feet diameter; the whole of the material can be included within an ellipse measuring 130' x 275', an area of 0.6 acre.

The stony soil and tough ferruginous hardpan would combine with the somewhat brittle nature of the meteorite itself to effect breakage on impact, and fractures will have been initiated by atmospheric flight stresses. However, the grouping of the fragments within a small area is the only real evidence for breakage on impact rather than before impact. The elliptical distribution favours arrival of the meteorite as a number of pieces and another point in favour is that the larger masses (which are numbered in order of decreasing weight) were embedded according to their weights. Mass 1 was embedded more than 8", Masses 2 and 3 more than 6", Mass 4 several inches, Mass 5 for 2" and Mass 6 not at all. A depth of 2" to 4" is to be added for the three largest masses, being the thickness of the thoroughly weathered shells. These depth figures are too consistent to be fortuitous and, in any case, there appears to be no reason why fragments scattered on impact should be embedded to such depths. The very small size of the ellipse suggests fragmentation at a very late stage in flight; more commonly, ellipses are measurable in miles.

It is a possibility that the dimpled surfaces present on the three biggest masses are parts of the original surface because at least two or three of the dimples coincide with large silicate grains and they could therefore be an ablation effect. They might represent parts of a posterior surface, somewhat protected during oriented atmospheric flight. However, the state of the material is such that it is impossible to attempt a reconstruction and this idea therefore remains as speculation.

Table 1
Weights (kilograms) of Mt. Padbury Meteorite

Mass 1	Main mass	88.65	Total 113.5
	Weathered debris	17.70	
	Eluvium	7.15	
Mass 2	Largest piece	31.80	Total 71.8
	Other pieces—10.9, 1.5, 1.4, 0.7	14.50	
	Weathered debris	24.15	
	Eluvium	1.35	
Mass 3	Largest piece	24.00	Total 62.1
	Other pieces—10.2, 3.1, 2.7, 1.6, 1.0, 0.6	19.20	
	Weathered debris	18.90	
Mass 4	Largest piece	0.70	Total 21.9
	Other pieces, mostly weathered debris	21.20	
Mass 5	Largest piece	5.50	Total 8.9
	Other pieces, including eluvium	3.40	
Mass 6	Largest piece	1.10	Total 1.6
	Other pieces, including eluvium	0.50	
Mass 7	Eluvial fragments, largest 0.3		1.2
Aberrant fragments			3.1
Fragments not precisely located (including specimens submitted to School of Mines)			1.1
Total weight of weathered material			285.2

It is usually accepted that when meteorite fragments are distributed in an ellipse the largest fragments travel furthest because of their greater momentum. In the present instance, therefore, the direction of flight would be westerly, the bulk of mass being at the western end. Whether this argument remains valid for such a small ellipse is not known.

As a result of the limited time available many small fragments were not collected either from the surface or from the soil beneath the masses.

This deficiency is likely to be compensated or over-compensated by the weathered condition and consequent enhanced weight of much of the material.

A rough estimate of the fresh weight may be made as follows:— It is assumed that all but a few of the larger masses are in a thoroughly rusted condition, that the meteorite was about two-thirds metal and that subsequent rusting doubled the original weight of the metallic portion. The weight of the partly weathered material (285.2 kg, see Table 1) should therefore be reduced by two-fifths of the weight of the thoroughly weathered fraction. On this basis, a round figure of 250 kg. is perhaps the closest approximation that can be made to the weight of the unweathered mass immediately after fall. The total weight of the material is equivalent to 627 lbs. and the estimated "fresh" weight is 550 lbs.

Acknowledgments

The greater bulk of the Mt. Padbury meteorite is in the collections of the Department of Geology, School of Mines of Western Australia, Kalgoorlie (catalogue numbers 9,625 and 9,635 to 9,658). A specimen of weight 5.5 kg is lodged in the Western Australian Museum, Perth (12,294). The generous gift of this material by Messrs. Martin and Bell is gratefully acknowledged as is also their kindness to the writer during the time he spent recovering the material.

Mr. M. K. Quartermaine took the photograph used as Fig. 2.

Dr. G. J. H. McCall kindly read the manuscript and suggested some minor amendments. A petrographic description of this material is being prepared by Dr. McCall and will be published in support of this initial account.

7.—The Inheritance of Dorsal Pattern in *Crinia* Species (Anura Leptodactylidae)

By A. R. Main*

Manuscript accepted—27th April, 1965

An analysis of the genetic factors controlling the inheritance of dorsal pattern in the polymorphic species *Crinia insignifera*, *C. glauerti*, *C. pseudinsignifera* and *C. georgiana* has been made by classifying the phenotypes of offspring from 75 crosses. The results are interpreted as indicating a simple genetic mechanism controlling the phenotype as follows: ridged, homozygous; warty and smooth, as for ridged but with modification of expression developing with age of young frogs; lyrate, heterozygous; weak lyrate, homozygous. The weak lyrate phenotype appears to be easily confused with the typical phenotype.

Introduction

Polymorphism in the genus *Crinia* has been discussed by Moore (1954, 1961) and Main (1961). I suggested (1961) that the morphs present on Rottnest Island could be interpreted as homozygous (phenotype ridged) and heterozygous (phenotype lyrate) for the genetic factors controlling dorsal pattern, and also pointed out that a complete analysis would depend on breeding animals for several generations. The results of these breeding experiments are given below. Numerous crosses were made with the idea of breeding from the F₁ animals; however, none has survived beyond the late summer of its first year. Despite the failure to complete that part of the experiment the results help in understanding the inheritance of the dorsal pattern. The length of larval life varies under laboratory conditions. *C. georgiana* with a larval life of upward of 40 days is the shortest while *C. insignifera* and *C. glauerti* are longest with 90-100 days. Larval mortality was proportional to the length of larval life, about 60% of eggs and larvae in *C. georgiana* metamorphosed. In *C. insignifera*, success fell to around 10%. The net result of all these rearing experiments is that from 75 crosses about 1000 young frogs have been reared and categorised.

Description of Phenotypes

The phenotypes of *Crinia georgiana* (Tschudi) and *C. insignifera* Moore are illustrated in Figures 1 and 2. The phenotype in the other *Crinia* species are so similar to those of *C. insignifera* that illustration is not warranted.

At the commencement of my studies on the genus *Crinia* my primary interest lay in understanding the geographic and reproductive limits of each species. Consequently the analysis of the phenotypic variation within each species was left. However, I did keep records of the

variation in each local population studied. In order to record the variation present I arbitrarily named certain phenotypes and defined their limits (Main, 1957: 31). The four categories were—ridged, smooth, lyrate, warty. In these phenotypic classes the dominant colour (which may be brown, fawn, gray, black) has been ignored and emphasis placed entirely on texture of the dorsal surface. This paper deals with the inheritance of phenotypic variation within each species.

As breeding and rearing progressed it became clear that the arbitrary categories did not coincide precisely with genetic characters. In particular, (a) the ridged and smooth phenotypes are connected by very infrequent intermediates; that these should be regarded as one category is supported by the experimental results, and (b) the warty phenotype has a genetic basis in *C. georgiana* different from that of other species, hence, the supposition that the phenotypes called "warty" are equivalent is unfounded. Experimentally, warty *C. georgiana* appears to be genetically similar to the ridged animals. In other species where the so-called "warty" phenotype occurs, it is not dark with rows of warts as in *C. georgiana*, but pale with irregular warts and indistinct light and dark patches dorsally. These pale, warty animals can be distinguished from smooth animals by the absence of dark flanks (Figure 1,2), and from lyrate animals by the absence of the crescentic ridges over the scapular region. In *Crinia insignifera*, so-called warty or weak lyrate animals, when crossed, produce offspring which suggest that qualitatively such animals are not lyrate in genotype. This last point will be discussed more fully in the results where all lyrate and weak lyrate parents have been listed in the same table.

Crosses

Matings were made as follows: (a) when a single female was to be mated to many males *in vitro* crosses were made by the method of Main (1957). In these cases the parents were preserved. (b) when a single male was mated to a single female the two animals were left clasping in a dish of water until the eggs were laid. Such crosses are called natural to distinguish from *in vitro* as used above. The parents were then removed, toe-clipped for individual identification and held outside in holding pens so that they could be used the following season for matings to their F₁s. Unfortunately these animals were not photographed as a record of their phenotype, consequently at present there is no way of confirming the phenotypic grading given when the mating was registered.

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Figure 1.—Phenotypes of *Crinia georgiana* (Tschudi) Top row; (left to right) ridged, weak lyrate ♀ of cross 680 (Table 3,h), weak ridged. Bottom row; smooth, warty, lyrate.

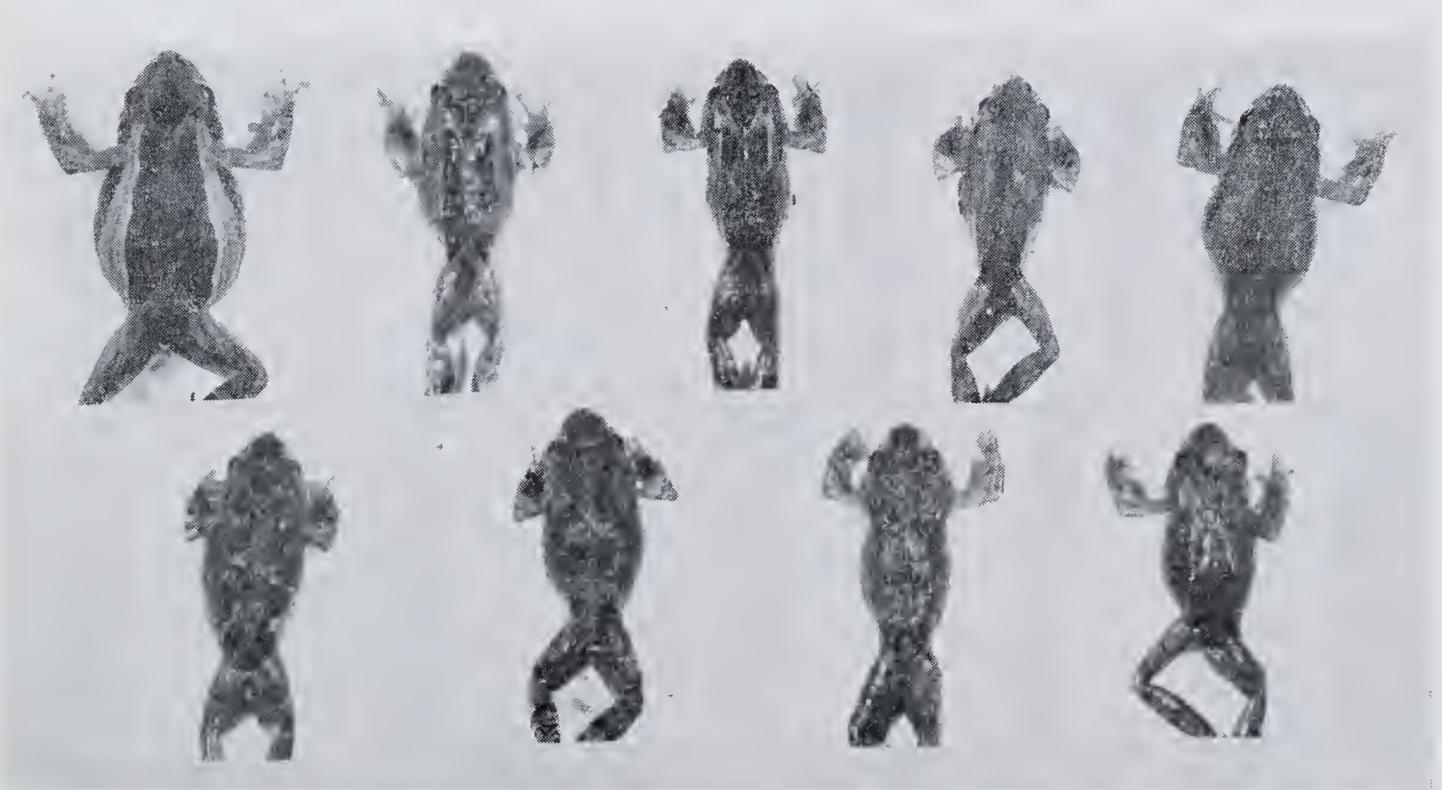


Figure 2.—Phenotypes of *Crinia insignifera*. Top row; (left to right) gradations from typical ridged to smooth. Bottom row; variations in expressions of lyrated phenotype.

TABLE 1

Phenotype of offspring resulting from crosses between various combinations of phenotypes of *Crinia insignifera*.

Cross No.	Parental combination	Offspring	
		Ridged	Lyrate
a.			
462	Ridged ♀ x lyrate ♂	5	12
470		21	18
622		2	4
661		0	5
856		1	2
857		0	5
	Total	29	46
b.			
469	Lyrate ♀ x ridged ♂	0	6
475		7	5
716		2	0
733		12	11
810		0	1
902		0	1
	Total	21	24
c.			
472	Lyrate ♀ x lyrate ♂	6	16
473		7	8
615		3	2
625		0	1
694		0	1
723		0	42
882		0	1
884		0	3
	Total	16	74

Results

Crinia insignifera

Table 1, a, gives results of ridged ♀ crossed to lyrate ♂. According to the hypothesis (Main 1961) the two phenotypes should be equally frequent. A test by chi square gives a value of 3.8 and p of almost 0.05 which is poor agreement with the hypothesis. The results of the reciprocal cross are given in Table 1, b. Again the two phenotypes were expected to be equally frequent among the offspring and the results are in good agreement with expectations.

The results presented in Tables 1, a and 1, b, reveal that from five crosses (661, 857, 469, 810 and 902) a total of 18 lyrate and no ridged offspring were produced. Several explanations can be offered to account for these results; (a) it may be simply chance, (b) the lyrate phenotype has a general superiority over the ridged; (c) if the genetic system controlling the dorsal pattern is at one locus, at which there may be one of two alleles, then in the crosses producing no ridged animals each parent may have been homozygous for a different allele. In this last case all the offspring would be heterozygous and lyrate in phenotype. Inspection of the original data reveals that the lyrate parent in each of the anomalous crosses was categorised as follows, 661 'normal', 857 'weak', 469 'weak', 810 'weak', 902 'normal'. 'Weak' lyrate parents do not appear to be associated with crosses from which ridged and lyrate offspring were obtained. This suggests that 'weak' lyrate animals are homozygous and not heterozygous and when the results of crosses

857, 469 and 810 are removed from the tables the results do not differ significantly from equality.

The results of crosses in which both parents were lyrate in phenotype are presented in Table 1, c. The phenotypes of offspring in cross 723 are unlikely to be the result of crossing two heterozygotes. At the time the phenotypes of the offspring were scored, 42 had metamorphosed and 26 were unmetamorphosed; the unmetamorphosed offspring could not be scored phenotypically. The metamorphosed frogs and late stage larvae were then kept for rearing. Ridged animals are not usually delayed in metamorphosis and there is no reason to believe that the late metamorphosing animals would differ from the first 42 in phenotype.

The female parent of cross No. 884 was categorised as 'weak' and parents used in the other crosses were categorised as 'normal'. If the results of crosses 723 and 884 are not considered because they could be interpreted as being between a heterozygote and homozygote from which no ridged animals could be obtained, all crosses in Table 1, c produced 16 ridged and 29 lyrate offspring. In the event that heterozygotes (lyrate) and homozygotes (weak lyrate) cannot be distinguished in freshly metamorphosed animals we would expect ridged and lyrate to be in a 1 : 3 ratio. Test by chi square gives p of slightly less than 0.05 indicating a poor fit and a deficiency of lyrate which may be due to chance or a deficiency of the homozygote (weak lyrate) phenotype.

There have been three crosses involving the smooth morph of *C. insignifera* in the present series of results. Firstly, in cross No. 733 where a ridged ♀ crossed to smooth ♂ produced 8 offspring categorised upon metamorphosis as ridged. However, as growth proceeded 4 of the ridged became indistinct and finally were categorised as smooth. The two other crosses involved the reciprocal cross of smooth and lyrate; No. 619 (smooth ♀ x lyrate ♂) produced 3 ridged and 2 lyrate offspring while No. 149 (lyrate ♀ x smooth ♂) yielded 2 ridged and 1 lyrate. The results of the last two crosses are qualitatively similar to crosses ridged x lyrate.

Crinia glauerti Loveridge

This species has a long larval life, and is consequently difficult to rear to metamorphosis. Only five crosses involving this species have produced offspring and the results are presented in Table 2. These results are consistent with those already presented for *C. insignifera*.

Crinia pseudinsignifera Main

This species does best under fluctuating environmental conditions and is difficult to rear under constant temperature conditions. There are results from only two kinds of combinations for this species; two crosses lyrate ♀ x ridged ♂ (Nos. 142 and 894) produced 3 offspring from each cross all being categorised lyrate; and one cross lyrate ♀ x lyrate ♂ (No. 888) produced 3 ridged and 4 lyrate offspring. These results are statistically consistent with those already presented for *C. insignifera*.

TABLE 2

Phenotype of offspring resulting from crosses between various combinations of phenotypes of *Crinia glauerti*.

Cross No.	Parental combination	Offspring		
		Ridged	Lyrate	Smooth
a.				
631	Ridged ♀ x ridged ♂	5	0	0
b.				
626	Ridged ♀ x lyrate ♂	4	3	0
651		5	7	0
652		15	13	0
	Total	24	23	0
c.				
629	Smooth ♀ x ridged ♂	9	0	8

Crinia georgiana

This species has a very short larval life and many crosses were made in the hope of rearing offspring to sexual maturity and so breeding from the F₁ animals.

Table 3a shows the phenotypes of offspring resulting from crossing ridged ♀ x ridged ♂, in all cases only ridged animals result. Table 3b gives the phenotype of ridged ♀ x lyrate ♂; in this case both categories were found in the offspring in equal proportions. There is only one reciprocal cross (No. 367); lyrate ♀ x ridged ♂ yielded 5 ridged and 2 lyrate offspring. No cross produced exclusively lyrate offspring so there are no difficulties of interpretation such as arose when discussing results in Table 1 for *C. insignifera*.

The smooth and warty categories are more common in *C. georgiana* than in other Western Australian species of *Crinia*. For some time it was thought that the smooth animals may represent the recessive homozygote, in which case crosses of ridged x smooth should produce only lyrate offspring. Tables 3c and d show the results of such crosses; of 112 offspring none was lyrate, 12 were regarded as weakly ridged, the others normally ridged. This gives no support to the supposition that smooth animals represent the recessive homozygote.

Various combinations of other phenotypes crossed with smooth animals are shown in Table 3, c, i, g and h. The cross smooth x smooth produces only ridged or weakly ridged offspring and similar results arise in cross smooth x warty. At metamorphosis the offspring from the cross smooth x lyrate produce 2 phenotypes, ridged and lyrate. When these are reared some of the ridged animals turn into smooth. Ignoring the subsequent development of the offspring the results are not different from those obtained by crossing ridged x lyrate. However, one reciprocal cross, No. 680, (Table 3, h) produced 69 lyrate offspring from a total of 85 eggs. Such a result can only be interpreted if parents were each homozygous for the different alleles in the genetic system controlling dorsal pattern so that the F₁s were all heterozygous and lyrate in phenotype. Such a result suggests that the lyrate genotype is dominant in expression.

The results of crosses involving various combinations of ridged, warty and lyrate are shown in Table 3 i, j, k, l, m. Warty x lyrate crosses resemble ridged x lyrate crosses while ridged x warty resemble ridged x ridged.

TABLE 3

Phenotype of offspring resulting from crosses between various combinations of phenotypes of *C. georgiana*.

Cross No.	Parental combination	Offspring	
		Ridged	Lyrate
a.			
383	Ridged ♀ x ridged ♂	64	0
395		23	0
479		41	0
480		34	0
	Total	162	0
b.			
129	Ridged ♀ x lyrate ♂	23	22
196		3	3
396		6	9
398		9	7
400		6	2
	Total	47	43
c.			
370	Ridged ♀ x smooth ♂	4	0
662		33	0
768		28	0
	Total	65	0
d.			
482	Smooth ♀ x ridged ♂	12	0
483		21	0
872		14	0
	Total	47	0
e.			
202	Smooth ♀ x smooth ♂	4	0
222		12	0
848		16	0
	Total	32	0
f.			
221	Smooth ♀ x warty ♂	12	0
484		17	0
	Total	29	0
g.			
197	Smooth ♀ x lyrate ♂	4	1
205		1	8
224		8	2
391		6	4
402		7	3
408		5	7
497		3	11
	Total	34	36
h.			
365	Lyrate ♀ x smooth ♂	1	3
680		0	69
847		0	1
	Total	1	73
i.			
368	Lyrate ♀ x lyrate ♂	1	3
392		2	4
	Total	3	7

TABLE 3.—continued.

Cross No.	Parental combination	Offspring	
		Ridged	Lyrate
390 394	j. Lyrate ♀ x warty ♂	3	4
		14	7
	Total	17	11
403	k. Warty ♀ x lyrate ♂	9	10
	Total	9	10
405	l. Warty ♀ x ridged ♂	20	0
	Total	20	0
481	m. Ridged ♀ x warty ♂	32	0
	Total	32	0

Discussion

The present results are fragmentary; there is not equal depth for all species nor even for all combinations of morphs. Nevertheless, it seems clear that in all species of *Crinia* so far tested the cross ridged x ridged produces only ridged offspring and ridged is then homozygous for the genetic factor producing this dorsal pattern. Results of crosses involving either lyrate x lyrate or lyrate x ridged suggest that lyrate can be interpreted as being heterozygous. Cross 680 (lyrate ♀ x smooth ♂, Table 3, h) is strong evidence contrary to this hypothesis and suggests that morphs categorised as lyrate include heterozygous and homozygous animals. Some results presented in Table 1 are in agreement with such a suggestion.

The problem of whether, in the field, the homozygote (weak lyrate) is lethal or occurs in very low frequency has not been resolved. Main (1961) believed it was lethal. This interpretation is not supported by the present data; it is more likely to be semi-lethal since the results of crosses 469, 723, 810 and 857, Table 1 and 680 Table 3, h suggest that a phenotype readily confused with lyrate is present in some popula-

tions. In crosses, such phenotypes produce results markedly different from crosses in which typical lyrate animals are used.

The present results have some bearing on the problem of the nature of the factors affecting the smooth and warty phenotype. In field observations and when categorising field caught animals, large series from a number of localities could be arranged in a way which suggested that no break between weakly ridged animals and patternless animals (Figures 1 and 2) occurred. The results already presented in Tables 2 and 3 suggest that warty and smooth are ridged animals in which there is an impairment of expression of the dorsal pattern. This interpretation is supported by the observation of individually marked young animals as they grew in the departmental yards. In a number of such observations the ridge pattern gradually became less and less distinct until finally the animals were categorised as warty or smooth. These results suggest that in scoring phenotype frequency in the field, all non-lyrate phenotypes can be grouped together.

The cause of the altered expression in the ridged genotype is not clear. It appears not to be related to temperature because changes in expression were observed in young frogs held at a constant temperature of 71°F., or 62°F., and in others held in the open in departmental yards. Frequency of occurrence of patternless animals in the field is variable; they are absent from Rottnest and their frequency tends to increase towards the south in *C. georgiana*. In *C. pseudinsignifera* they are relatively rare and decrease towards the east.

Acknowledgments

The work reported was supported by a Research Grant from the University of Western Australia.

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1965

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Editor: R. W. George

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The Royal Society of Western Australia, Western Australian Museum, Perth

JOURNAL OF
THE ROYAL SOCIETY
OF
WESTERN AUSTRALIA

VOLUME 48

PART 3

PUBLISHED 20TH DECEMBER, 1965

REGISTERED AT THE G.P.O., PERTH FOR TRANSMISSION BY POST AS A PERIODICAL

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Journal
of the
Royal Society of Western Australia

Vol. 48

Part 3

A new genus of Temnospondyli from the Triassic of Western Australia*

by J. W. Cosgriff†

Manuscript received 21st July, 1964; accepted 22nd September, 1964.

Abstract

Early Triassic vertebrates recently collected in Western Australia include two species of a new genus of Amphibia (order Temnospondyli) which is closely allied to *Rhytidosteus capensis* of the Cynognathus Zone of South Africa and to *Peltostega erici* and *P. wimani* of the Posidonomya beds of Spitzbergen. The type species, based on four partial skulls, a lower jaw and numerous skull, lower jaw, and dermal shoulder girdle fragments, occurs in exposures of the lower Triassic Blina Shale of the West Kimberley District. The second species is based on a partial skull found in a core sample of the Kockatea Shale from an exploratory oil well in the South-western District. A new superfamily (Rhytidosteioidea) and a revived family (Rhytidosteidae) are proposed to receive *Rhytidosteus*, *Peltostega* and the new genus (*Deltasaurus*). The close relationship of the well core species of the type species supports microfloral evidence for the contemporaneity of the Kockatea and Blina Shales.

Introduction

The Blina Shale is exposed in three large synclines at the northwestern end of the Fitzroy trough in the West Kimberley District and narrow strips of outcrop have been mapped in the northeastern part of the Canning Basin more than 300 miles southeast of Derby. Exploration wells in the large syncline which extends inland from the coast at King Sound disclose thicknesses from 650 feet to 1,000 feet. The shale forms clay soil plains with occasional residual rubbles. Outcrops are rare and no type section has been designated. The upper 100 feet, consisting of thinly bedded sediments, are exposed in steep slopes on the southern flank of the Erskine Range near the Great North Highway, 70 miles southeast of Derby. These slopes contain the principal localities at which fossil vertebrate material has been collected.

The first collection of vertebrate fossils from the Blina Shale was made in 1953 by field parties of the Bureau of Mineral Resources during an investigation of the geology of the Fitzroy Trough. Brunnschweiler (1954, p. 42-44) recognized the Triassic age of the vertebrate and invertebrate fossils and redefined the unit as a Formation to be included with the overlying

Erskine Formation in the Derby Group. His report is supplemented with further description and mapping by the Bureau of Mineral Resources (Guppy and others, 1958 and Veevers and Wells, 1961) and a summation is given by McWhae and others (1958, p. 82-83). Vertebrate material in the collection of the Bureau of Mineral Resources was lent to the University of California Museum of Paleontology for study by the author.

A more extensive collection was made in June and July, 1960 by a joint expedition of the Western Australian Museum and the University of California Museum of Paleontology. Personnel included Dr. C. L. Camp of the Department of Paleontology, University of California as party leader, Dr. W. D. L. Ride, Director of the Western Australian Museum, Dr. K. G. McKenzie, then of the University of Western Australia, Mr. D. Merrilees of the Western Australian Museum and the author. Camp (1963) has contributed a history of the expedition which describes field activities in the Fitzroy trough and also an unsuccessful search for fossil vertebrates in the Northern Territory. McKenzie (1961) mapped the fossiliferous localities and investigated the stratigraphy. His report includes a synopsis of the field work, detailed descriptions of the lithology and vertebrate localities, a locality map and an analysis of the depositional environment.

The specimens obtained by the expedition are divided between the two institutions according to agreement. In addition to the genotypic species described in this report the Blina fauna includes four other temnospondylous amphibians, a coelacanth, a lungfish, an actinopterygian, shark teeth, large pieces of bone which may represent a marine reptile and enigmatic platy structures of organic origin which may be derived from a vertebrate. Subsequent papers will include descriptions of these latter forms and analyses of the paleoecology and stratigraphic significance of the Blina vertebrate fauna.

The Blina Shale also contains plant and invertebrate fossils. Balme (1963) has identified the microplankton and microflora. He also notes the presence of "... equisetalean, and probably lycopodiaceous, stem fragments." at

*A contribution from the University of California Museum of Paleontology.

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the Erskine Range exposures. *Isaura* and *Lingula* from Fitzroy Trough are noted by Brunnschweiler (1954) and McKenzie (1961). Invertebrate fossils from Blina exposures in the northeastern Canning Basin (Veevers and Wells, 1961, p. 110) include *Isaura*, *Lingula* and a pelecypod, cf. *Pseudomonotis*, (all determined by R. O. Brunnschweiler), and a worm burrow, *Diplocraterion*, (determined by A. A. Öpik). An internal cast of a cephalopod shell, too poorly preserved for identification, was found on the surface at the Erskine Range.

A partial skull, referred to the genus founded for the Blina amphibian in this report, was found in a core sample of the Kockatea Shale of the Perth Basin. B.M.R. 10 (Beagle Ridge Bore) was drilled in 1959 on the western coast between Perth and Geraldton by Oil Drilling and Exploration (W.A.) under contract to the Bureau of Mineral Resources. The occurrence has been described by Dickins, McTavish and Balme (1961).

The formation has only one surface exposure of some 25 feet at Kockatea Gully near its junction with the Greenough River (Playford and Willmot, in McWhae and others, 1958, p. 83). Various bores in the basin record thicknesses from 1,091 feet to 1,531 feet. The surface exposure and core samples from the bores are siltstone, shales and sandstones.

The microflora and invertebrate fauna from B.M.R. 10 offer precise evidence for assigning an age to the Kockatea skull and, by inference, to the vertebrate fauna of the Blina Shale. Mesozoic vertebrates rarely occur in sediments which have been directly dated by plant and invertebrate fossils and the singular good fortune of finding a vertebrate fossil in a well core is augmented by this association. Balme (1963) has described the microplankton and microflora from B.M.R. 10, from Kockatea cores taken from other wells and from the surface exposure, noting the occurrence of many of the same taxa in the Blina Shale. He equates the Blina and Kockatea Shales in time, assigning an early Scythian age to both. The invertebrates from B.M.R. 10 (Dickins and McTavish, 1963) include "*Lingula*", five pelecypods, three ammonites and an annelid. The composite fauna is early Scythian. Two of the ammonites, *Ophiceras* cf. *subkyoticum* and *Subinyoites kashmiricus* more precisely limit the age of the sediments in the bore from 2,405 feet to 2,812 feet to the Otoceratan Zone, lowest division of the Scythian. The vertebrate skull was found near the centre of this section in core 28 (2,614-2,624 feet).

Occurrence and preservation of the Blina vertebrate fossils

Vertebrate fossils are rare in the formation and are concentrated in a few productive localities. Most of the extensive exposures on the flanks of the Erskine Range are barren. Many small outcrops and rubble heaps in the Fitzroy Valley were prospected but failed to produce any material. Several localities contain only scattered and isolated pieces of bone. A few small pockets of bone were found in the quarries at the Erskine Range but no bone beds or extensive concentrations were discovered.

The condition of the vertebrate fossils suggests that they had been transported by water, but perhaps for no great distance. Most of the fossils are broken and some show worn surfaces which may have been caused by abrasion during transport. No articulated skeletal elements were found. Only the larger and more massive structures such as dipnoan teeth, ethmoidal bones of *Saurichthys* and skulls, lower jaws, dermal shoulder elements and atlases of amphibians occur as common fossils. It is probable that the skeletons were broken up and scattered either prior to or during transport and that the smaller and more delicate pieces of bone were macerated or otherwise destroyed. Perhaps some of the broken and scattered occurrence of the specimens and the scarcity of the smaller, more fragile bones is due to predator action but no tooth marks or other evidence of predation were found on any of the specimens.

Surface material from the localities consists principally of the internal cores and external impressions of amphibian skulls and lower jaws; the original bone has been completely eroded from most of those. The cores retain impressions of the inner surfaces of the dermal bones and also casts of the vacuities and foramina. It has been possible in many instances to reconstruct the original specimens from these casts and impressions with reasonable certainty.

The preservation of bone in specimens from the Erskine Range quarries is generally poor. The bone is splintery, porous and extremely friable. The permineralizing substance, obviously rich in iron compounds, is purple, dark red and brown. In many instances the bone was both too poorly preserved and too delicate to save. In such cases the bone was carefully removed from the internal and external impressions of the specimens and latex peels were taken from these impressions. Preparation of quarry specimens was further complicated by the frequent presence of hard lumps of hematite that adhered to the surfaces.

Fossil vertebrate localities in the Blina Formation

The University of California Museum of Paleontology locality and Bureau of Mineral Resources locality designations in the following text are substituted for the locality designations used by McKenzie 1961 as follows:

- U.C.M.P. locality V 6040 = McKenzie, fig. 1, p.70, locality 4 (quarries 1, 2 and 3);
- U.C.M.P. locality V 6042 = McKenzie, fig. 1, p.70, locality 7;
- U.C.M.P. locality V 6043 = McKenzie, fig. 1, p.70, locality 8;
- U.C.M.P. locality V 6044 = McKenzie, TABLE II, p.73, ninth entry ("Bore 6, Noonkanbah Station. 124° 45' E., 18° 20' S.");
- B.M.R. locality = McKenzie, TABLE 11, p.73, eighth entry ("Dry Corner area, Nerrima Station. 124° 05' 30" E., 18° 21' S.").

U.C.M.P. localities V 6040 and V 6042 are just south of the Great North Highway, 69 miles southeast of Derby, on the south slopes of the small butte which is an outlier of the Erskine

Range. Locality V 6043 is on the southern slope of the main body of the Range north of the highway. To reach locality V 6044, drive car 25 miles north from Noonkanbah Homestead on the station road leading to Calwynyardah Homestead; the locality is a low rounded hill 1½ miles ENE of Noonkanbah Bore no. 20. The B.M.R. locality produced the material noted by Brunnschweiler (1954). Unfortunately the original field notes were destroyed in a fire at the Bureau of Mineral Resources offices in Canberra and the exact location of the site was thereby lost. Dr. Ride corresponded with two members of the B.M.R. field party and in their recollection the locality was on a rise close to a gate on a road between Dry Corner Bore and Tutu Bore. Although the Dry Corner area was searched on two separate occasions by the W.A.M.-U.C.M.P. field party the locality could not be re-established. To reach the approximate area in which the fossils were found turn south from Luluigui Homestead and drive 4 miles to Moore's Bore and 8 more miles to Waterford's Bore. Turn east and drive 10 miles to Dry Corner Bore. The only fence gate on this latter section of road, 1 mile east of Dry Corner Bore, is astride a small sand dune. No other roads between Dry Corner Bore and Tutu Bore could be found. It is possible that the sand accumulation at the gate is recent and has thoroughly covered the site.

Abbreviations for all figures

a.p.v.	....	....	anterior palatal vacuity
Ang	....	....	Angular
c. bo	....	....	basioccipital space
c. so	....	....	supraoccipital space
ca. ct	....	....	chorda tympani canal
Co	....	....	Coronoid
d	....	....	denticle
d. t	....	....	dentary teeth
Den	....	....	Dentary
Ecpt	....	....	Ectopterygoid
Eo	....	....	Exoccipital
f	....	....	foramen
f.c.t.	....	....	chorda tympani foramen
f. m	....	....	foramen magnum
f.m.p.	....	....	posterior meckelian foramen
f. p	....	....	parietal foramen
fa. a	....	....	articular facet
fe. po	....	....	pterooccipital fenestra
fi. pq	....	....	palatoquadrate fissure
fo. ad	....	....	adductor fossa
fo. pt	....	....	posttemporal fossa
fo. st	....	....	subtemporal fossa
Fr	....	....	Frontal
Ico	....	....	Intercoronoid
ip. v	....	....	interpterygoid vacuity
Ju	....	....	Jugal
m. t	....	....	maxillary, teeth
Mx	....	....	Maxillary
n. e	....	....	external naris
n. i	....	....	internal naris, choana
Na	....	....	Nasal
or	....	....	orbit
P	....	....	Parietal
p. c	....	....	cultriform process
p. h	....	....	hamate process
p. l	....	....	lamellosus process
p. po	....	....	paraoccipital process
p. poc	....	....	postcondylar process
p. prec	....	....	precondylar process
p. pt	....	....	ascending process of the pterygoid
p. quj	....	....	descending process of the quadratojugal
p. ra	....	....	retroarticular process
p. sq	....	....	descending process of the squamosal
p. st	....	....	subotic process
p. v	....	....	vertical process
Pa	....	....	Prearticular

Pco	....	....	Precoronoid
Pf	....	....	Postfrontal
Pl	....	....	Palatine
Pm	....	....	Premaxillary
Po	....	....	Postorbital
Pos	....	....	Postsplenial
Pp	....	....	Postparietal
Prf	....	....	Prefrontal
Ps	....	....	Parasphenoid
Pt	....	....	Pterygoid
Qu	....	....	Quadrate
Quj	....	....	Quadratojugal
r. pl	....	....	palatal ramus of the pterygoid
r. qu	....	....	quadrate ramus of the pterygoid
s. io	....	....	infraorbital groove
s. j	....	....	jugal groove
s. m	....	....	mandibular groove
s.o.	....	....	occipital groove
s. so	....	....	supraorbital groove
s. t	....	....	temporal groove
Sa	....	....	Surangular
Sp	....	....	Splenial
Sq	....	....	Squamosal
St	....	....	Supratemporal
sym	....	....	symphyseal region of lower jaw or symphyseal surface
sym. t	....	....	symphyseal tusk
t	....	....	Tusk or tusk pit
Tab	....	....	Tabular
Vo	....	....	Vomer

Superfamily Rhytidosteoidea, n, superf.
Family Rhytidosteoidea, von Huene, 1920,
pp. 212 and 458

The family Rhytidosteoidea, with *Rhytidosteus* as type genus, is revived and amended to include *Peltostega* and the new genus from Western Australia. The unity of this group was realized through comparison of the African and Spitzbergen genera with the new genus.

Peltostega and *Rhytidosteus* both have laterally placed orbits and broad cultriform processes of the parasphenoids. Further direct comparisons, however, were not possible as the only illustrated portions of *R. capensis* were the antorbital portion and the exoccipital, and the *Peltostega* specimens are all posterior skull portions.

The definitive characters of the Rhytidosteoidea cited by von Huene (1920, p. 458) are: broad, triangular skull; orbit laterally placed; probably a short broad interpterygoid vacuity. Woodward (1932, p. 217), Kuhn (1933, p. 101) and Case (1946, p. 400), followed von Huene in placing *Rhytidosteus* in its own family. Romer (1947, p. 314; 1950, p. 590), and Kuhn (1960, p. 70) included *Rhytidosteus* in the Trematosauridae. Von Huene (1948, p. 69) revised his original classification and placed the genus in a new family, Lyrocephalidae with *Lyrocephalus* and *Peltostega*.

Romer (1945, p. 590; 1947, p. 314), Case (1946, p. 406), and Kuhn (1933, p. 75; 1960, p. 70), have included *Peltostega* in the Trematosauridae. Jaekel (1922, p. 5) regarded the genus as a Triassic survival of the Sclerocephalidae, a referral based on the short triangular skull and the central location of the orbit on the skull roof. The superficial appearance of Wiman's reconstruction led Woodward (1932, p. 216) to include *Peltostega* in the Metoposauridae.

Säve-Söderbergh (1935, pp. 87-88), erected a new family, Peltostegidae. The familial characters were: a broad triangular skull with a very

growth on the skull roof; the very lateral position of the orbit, situated close behind the sagittal midpoint of the skull; and the broad and dorsoventrally thin cultriform process which lacks a ventral longitudinal ridge.

Nilsson (1946, pp. 47-48) erected a new superfamily, Peltostegoidea, to emphasize the distinction of *Peltostega* from the Trematosaurioidea. He greatly expanded the characterization of the Peltostegidae. Most of his characters are diagnostic only of the genus and are not germane to this discussion. Several of his observations on the occiput and posterior part of the palate, however, are also applicable to the new genus and may prove to be rhytidosteid characters if new genera of this family are found or if more material of *Rhytidosteus* is recovered: the posterior border of the interpterygoid vacuity is broad; the pteroccipital foramen is large and is visible in posterior view; the ascending process of the pterygoid is partly separated from the descending process of the squamosal by a palatoquadrate fissure.

The family characters of von Huene (1920), for the Rhytidosteidae and of Säve-Söderbergh (1935) for the Peltostegidae which have been quoted in the above discussion are incorporated into the definitions.

Features of the Blina genus which are shared by each of the other two genera are discussed in later passages of this report. These support the concept of the family but there is no certainty that any of them occur in all members of the family and they cannot be regarded as definitive.

It is quite likely that the Rhytidosteidae originated among the Rhinesuchoidea of the late Permian. The Capitosauridae also had their origins within this group. As the rhytidosteids are as fully distinct as the capitosaurids from this basal superfamily, consistency within the classification is best served by placing the family in a new superfamily.

Definition and diagnosis of the superfamily and family

Triassic temnospondyls with broad, triangular skulls and very wide occiputs. Orbits near centres of lateral margins, facing dorsolaterally. Cultriform processes of parasphenoids exceptionally broad. Sculpture of dermal bones dominated by radiating ridges which bear prominent nodes at points of junction and bifurcation. Otic notches and tabular horns triangular and proportionately small.

Quadrates on same hinge line as exoccipital condyles rather than posterior to them as in rhinesuchids, lydekkerinids and uranocentrodontids. Skulls lack: parabolic outlines, rudimentary otic notches, U-shaped palates and modifications of occipital processes of squamosals and pterygoids characteristic of brachyopids; elongate postorbital regions of skull roofs, high, narrow occiputs and extensive parasphenoid bones, underplating exoccipitals, of trematosaurids; posterior slope of occiputs, as viewed from above, and anterior positions of orbits of metoposaurids; posterior, closely spaced orbits of capitosaurids: peculiar con-

struction of occiput and "closed" otic notch of *Laidleria*; Lamellosus crest present, absent in *Laidleria*.

Deltasaurus, gen. nov.

Type species. Deltasaurus kimberleyensis

Distribution. Blina Shale and Kockatea Shale, Western Australia.

Definition and diagnosis of the genus. Skull short and triangular. Orbit oval with an indented anterolateral margin.

Snout broader and more rounded, external nares closer to snout tip, dermal bone structure finer and more regular, radiating ridges of sculpture straighter, lower jaw shallower than in *Rhytidosteus*. Orbits over centers of interpterygoid vacuities, over anterior edges of interpterygoid vacuities in *Rhytidosteus*. Retroarticular process of lower jaw pointed, notched in *Rhytidosteus*.

Pits of sculpture on dermal bones of skull roof less pronounced, grooves of lateral line system more continuous, parasphenoid-pterygoid suture relatively longer, quadrate ramus of pterygoid longer and narrower, (?) palatal shagreen better developed than in *Peltostega*. Exoccipital-pterygoid suture present, absent in *Peltostega*.

Deltasaurus kimberleyensis, sp. nov.

(figs. 1-9)

Holotype. W.A.M. no. 62.1.44, a partial skull roof with associated palate fragment.

Type locality. U.C.M.P. locality V 6040, Blina Formation, West Kimberley District, Western Australia.

Paratypes. Incomplete skulls, U.C.M.P. nos. 61063 and 61064, from U.C.M.P. locality V 6040; incomplete skull, U.C.M.P. no. 61062, from U.C.M.P. locality V 6042; skull fragments, U.C.M.P. nos. 61061, 61135, 61142, 61232, 61277, 61306, 61308, 61309, 61310, 61313, 61314, 61380, 61381, 61383, 61384, 61385, 61386, 61387, 61390 and 62156, all from U.C.M.P. locality V 6040; incomplete articulated lower jaws, U.C.M.P. no. 61098, from U.C.M.P. locality V 6043; lower jaw fragments, W.A.M. nos. 60.9.16 and 64.7.17 and U.C.M.P. nos. 61068, 61071, 61072, 61073, 61100, 61101, 61102, 61103, 61104, 61105, 61106, 61107, 61108, 61110, 61111, 61112, 61114, 61116, 61118, 61119, 61120, 61122, 61123 and 61126, all from U.C.M.P. locality V 6040; lower jaw fragments, U.C.M.P. nos. 61099, 61117, 61121, 61127, and 64972, all from U.C.M.P. locality V 6042; lower jaw fragment, U.C.M.P. no. 62158, from U.C.M.P. locality V 6044; lower jaw fragments, B.M.R. nos. F21794, F21805, F21807 and F21817 from B.M.R. locality; clavicles and clavicular fragments, U.C.M.P. nos. 61080, 61082, 61083, 61084, 61085, 61087, 61137 and 61307, all from U.C.M.P. locality V 6040; clavicular fragments, U.C.M.P. nos. 61092 and 61237, from U.C.M.P. locality V 6043; interclavicular fragments, U.C.M.P. nos. 61124, 61130, 61131, 61139, 61322, 61325, 61326 and 61327, all from U.C.M.P. locality V 6040; interclavicular fragment, U.C.M.P. no. 61319, from U.C.M.P. locality V 6043.

Diagnosis of the species. A *Deltasaurus* with punctate sculpture, dominated by straight, broad occiput; the lack of zones of intense

narrow ridges radiating out from bone centers. Posterior border of external naris straight. Width across posterior borders of orbits relatively greater than in *Kockatea* species.

Description

Skull roof (figs. 1a, 2d, 3a and 4a). The dimensions and most of the restoration of the skull roof (fig. 4a) are taken from the holotype, W.A.M. no. 62.1.44 (fig. 1a). This speci-

men preserves the internarial region and most of the left side. The shape and position of the orbit and external naris, most of the borders of the individual bones and the character of the surface ornament are all clearly established by this specimen. U.C.M.P. no. 61064 (fig. 3a), the left posterolateral corner of a much smaller skull, has contributed the otic notch, several sutures and much of the occipital border.



Fig. 1.—*Deltasaurus kimberleyensis* gen. et sp. nov., holotype W.A.M. no. 62.1.44 (U.C.M.P. locality V 6040); skull: a, dorsal view; b, ventral view. x 0.58.

The holotype was found ventral side up and close to the surface at V 6040. It was completely encased in concretionary iron. It includes the anterior portion of the palate in addition to the incomplete skull roof. The actual bone of the specimen was too badly preserved and the enclosing matrix too hard to allow normal preparation. The concretionary

iron of the palate fragment was ground away until the tiny tips of the denticles of the palate were exposed at a level of 1mm. above the palate. The palate portion was then carefully removed from the specimen. The powdery remnants of skull roof bone were cleaned from the external mold of the dorsal surface with the aid of a 10X microscope. A latex positive

was then taken from this mold. Plaster molds of the latex were made and then plaster positives were taken from the plaster molds.

The distinctive skull shape, which approaches an equilateral triangle, has been restored from the angle between the median suture between the premaxillaries and nasals and the intact left lateral border of the holotype. The snout is bluntly rounded and the posterolateral corner is angular. U.C.M.P. no. 61064 shows an

angular otic notch and tabular horn. The occipital border of this specimen is slightly convex anteriorly about the midline.

The position of the orbit is one of the most striking features of the skull roof. It is widely removed from the midline and lies close to the midpoint of the lateral margin. It faces outward and somewhat upward. It has rounded medial and posterior borders, a flattened lateral border and an angular anterior border. The

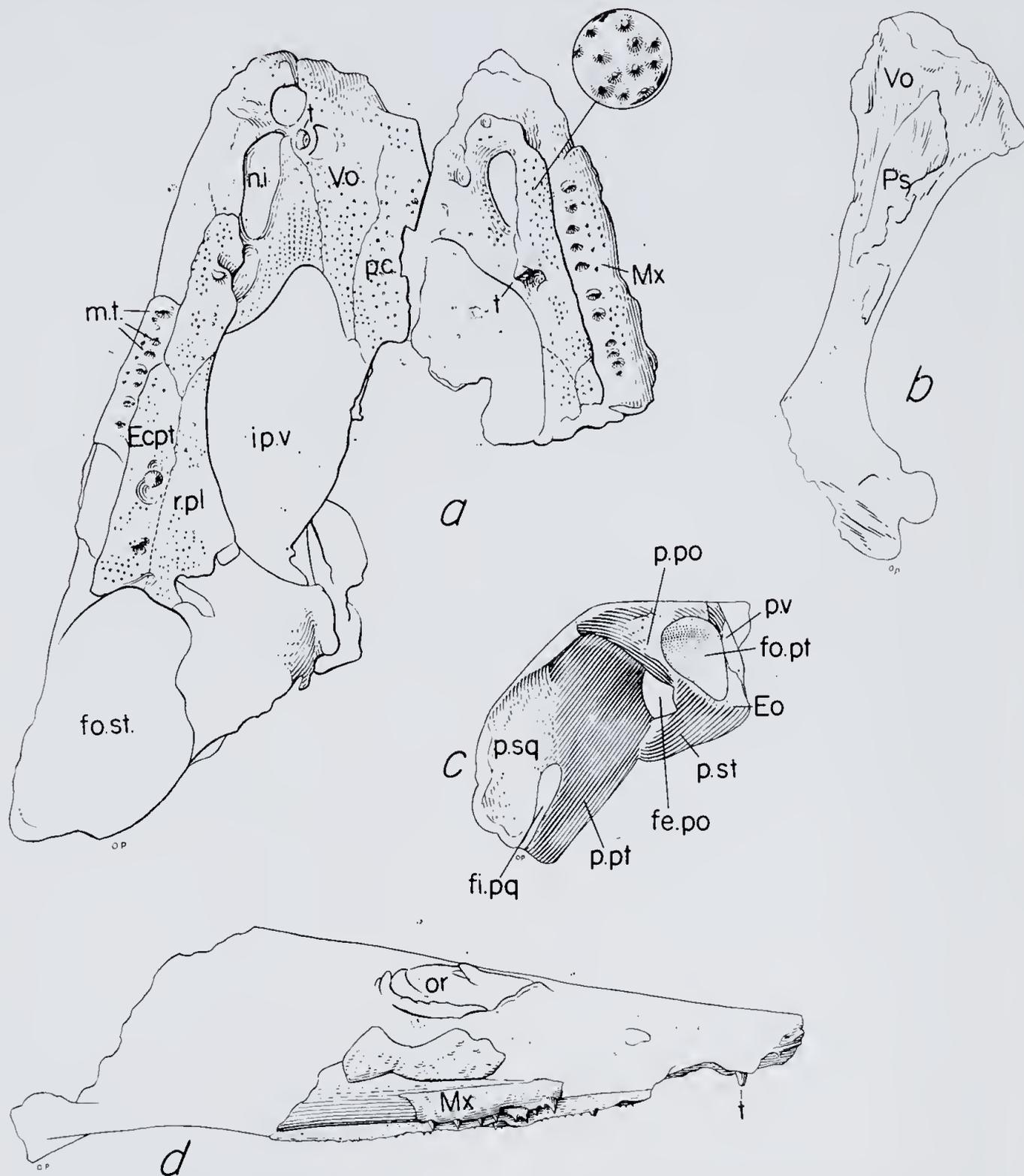


Fig. 2.—*Deltasaurus kimberleyensis* gen. et sp. nov., paratypes: a, U.C.M.P. no. 61063 (U.C.M.P. locality V 6040), skull, palatal surface; b, U.C.M.P. no. 61061 (U.C.M.P. locality V 6040), palatal fragment, ventral view; c, U.C.M.P. no. 61062 (U.C.M.P. locality V 6042), skull fragment, occipital view; d, U.C.M.P. no. 61063 (U.C.M.P. locality V 6040), skull, lateral view. All x 0.63.

orbit is small relative to the skull area. The borders of the orbit are flush with the surrounding skull surface.

The external naris also lies far laterally. The naris is longer than broad, has rounded anterior and medial borders and a flattened lateral border.

The angular otic notch of U.C.M.P. no. 61064 is rather small and shallow compared with those of most other labyrinthodonts.

The dorsal surface of U.C.M.P. no. 61062 shows that the quadratojugal was produced posteriorly into a horn-like process.

The skull probably had a parietal foramen. Its position on the midline suture of the parietal bone is hypothetical.

The broad central area of the skull roof between the nares, orbits and otic notches is either flat or slightly convex. The lateral region between the naris and orbit curves sharply down from the flat skull table to the posterolateral corner of the skull.

There is no lacrimal bone, and the prefrontal and maxillary are in contact. Otherwise the bones of the skull roof have the standard labyrinthodont arrangement.

The paired median roofing bones are broad and occupy most of the broad skull table. The front of the premaxillary is missing; its anterior border is restored from the trend of the marginal tooth row of the palate fragment. The nasal and frontal, quite similar in shape, are broad and quadrangular. They have convex anterior and lateral borders and concave posterior borders. The posterolateral corner of the frontal indents the anterior margin of the parietal bone. The parietal is the largest bone of the skull roof. It has irregular anterior and lateral borders and a straight posterior border on the postparietal. The postparietal is only half the length of the parietal. It has an angular lateral border, anterolaterally bounded by the supratemporal and posterolaterally by the tabular.

The prefrontal, postfrontal, postorbital and supratemporal are roughly equivalent in area and are slightly curved in section. They are considerably smaller than the elements of the paramedian series. The prefrontal forms the anterior border of the orbit and, anteriorly, it projects between the maxillary and nasal; medially it is bordered by the nasal and frontal. The postfrontal forms most of the medial margin of the orbit; it projects between the prefrontal and frontal and has a medial border on the frontal and parietal. The anteromedial projection of the supratemporal lies between the postfrontal and parietal. The supratemporal is bordered medially by the parietal and postparietal and has a posterior border on the tabular. The staggered positions of the prefrontal, postfrontal and supratemporal relative to the midline series insure the structural strength of the skull. The postorbital is elongate and oval. It forms the posterior border of the orbit and has a sigmoid suture with the squamosal.

The maxillary and the anterior part of the jugal are curved in transverse section. The posterior part of the jugal gradually

flattens out and the quadratojugal is flat in section. The maxillary forms the posterolateral margin of the external naris. Behind the naris, the maxillary is strongly indented by the nasal and shallowly indented by the prefrontal. The course of the maxillary-jugal suture is not entirely certain. The sculpture pattern of the holotype suggests that the jugal formed the entire lateral border of the orbit and extended forward to a suture with the prefrontal, excluding the maxillary from the orbit. The jugal extends far back of the orbit to a short suture with the quadratojugal and has a concave medial border on the postorbital. The exact location of the quadratojugal-squamosal suture is not known.

The squamosal is small compared with those of most other labyrinthodonts. It has two anterior projections, one between the jugal and postorbital and one between the postorbital and supratemporal.

The shape and sutural relations of the tabular are preserved on U.C.M.P. no. 61064. The tabular has a lateral border on the squamosal, an anterior border on the supratemporal and a medial border on the postparietal.

The lateral line system is inclosed in well-defined, shallow grooves about 2 mm. in width. The positions of all of the grooves with the exception of the transverse occipital groove are taken from the holotype. The supraorbital groove originates in the premaxillary, trends posterolaterally through the nasal and makes a right angle bend in the prefrontal. It then proceeds posteromedially into the frontal and makes another right angle bend and trends again posterolaterally. It joins the infraorbital and supratemporal grooves in the centre of the postorbital bone. The infraorbital groove begins near the premaxillary-maxillary suture and makes a slight medial bend in the anterior part of the maxillary. It then follows close to the lateral edge of the skull through the remainder of the maxillary and the anterior part of the jugal. In the centre of the postorbital portion of the jugal it turns upward sharply and runs transversely to the junction with the supraorbital and supratemporal grooves. The jugal groove begins at the sharp bend of the infraorbital groove and runs posteriorly to end just behind the jugal-squamosal suture. The supratemporal groove curves through the supratemporal bone and ends near the anterior edge of the tabular bone.

U.C.M.P. no. 61313, an impression of a posterolateral skull portion, is obviously derived from a very small individual of *D. kimberleyensis*; the cheek region lies at an angle to the skull table and the sutures of the tabular and postparietal bones are similar to those on the holotype. A distinct occipital groove runs transversely across the postparietal and tabular just within the occipital margin of the skull roof. The lateral terminations of the groove are not preserved.

A distinctive surface ornament covers the bones of the skull roof. It differs from both the pitted and the coarsely reticulate types of sculpture found on the skulls of most labyrinthodonts. The *Deltasaurus* pattern consists of a finely meshed web radiating from the centre of

each bone. The individual ridges are small and low in relief. The radial ridges are higher in relief than the concentrically arranged ridges, extend to the peripheries of each bone and tend

to bifurcate distally. Rounded nodes on the radial ridges occur at points of bifurcation and at the points of junction with the concentric ridges. The concentric ridges divide the grooves between the radial ridges into small pits. Most of the bones of the skull roof are uniformly pitted over their entire surfaces. Certain small areas, especially the posterior portion of the nasal and the postero-lateral corner of the jugal, have only the radial ridges and lack the concentric ridges; the ridges of these areas are larger, better defined and more widely spaced than those of other parts of the skull.

The sculpture pattern of *Deltasaurus kimberleyensis* is basically similar to that of other members of the Rhytidosteidae. It is probably derived from the normal reticulate pattern by diminution of the ridges and by emphasis on the radial components of sculpture.

The pits at the centre of each bone on the skull roof of the type specimen are larger than those near the edges, indicating that the original ossifications lay at the bone centres. Otherwise, there are no features on the sculpture pattern which are indicative of the growth of each bone. The bones are pitted over most of their surfaces, showing that the radial and concentric ridges were formed concomitantly in the growth of each bone. Similar pitting up to the margins of the tabular, postparietal and squamosal on the fragment of a very small skull, U.C.M.P. no. 61313, shows that this pattern characterizes early ontogenetic stages of *Deltasaurus kimberleyensis*.

This uniformity in the development of the sculpture pattern during growth is quite unlike the development of the reticulate type of sculpture as described by Bystrov (1935). In this type, the central pitted area of each bone represents the original ossification. With further growth a radiating pattern of ridges is formed about the original central pitted area. Transverse bars of ornament then develop between the ridges and gradually expand the central pitted area. Eventually the ridges and grooves will occupy only small rings with the bone peripheries.

Palatal surface of the skull (figs. 1b, 2a, 2b, 3b and 4b). The palate restoration (fig. 4b) is principally based on U.C.M.P. no 61063 (fig. 2a), a partial skull slightly smaller than the holotype. It consists of two fragments. The natural contact between the fragments is lacking but they are certainly derived from the same individual. They were found close together on the hill slope below V 6040 and the choanae and the anterior orbital borders are of identical size.

The bone of the dorsal surfaces is mostly weathered away, leaving an impression of its internal surface. A few scraps of bone remain in the region of the lateral border of the right orbit. The orbits resemble the holotype orbit in shape and position.

The palate surfaces were encased in hard matrix and are fairly well preserved. The larger fragment consists of the right side of the palate from the vomerine tusk to the quadrate region. It includes the internal naris and the sub-

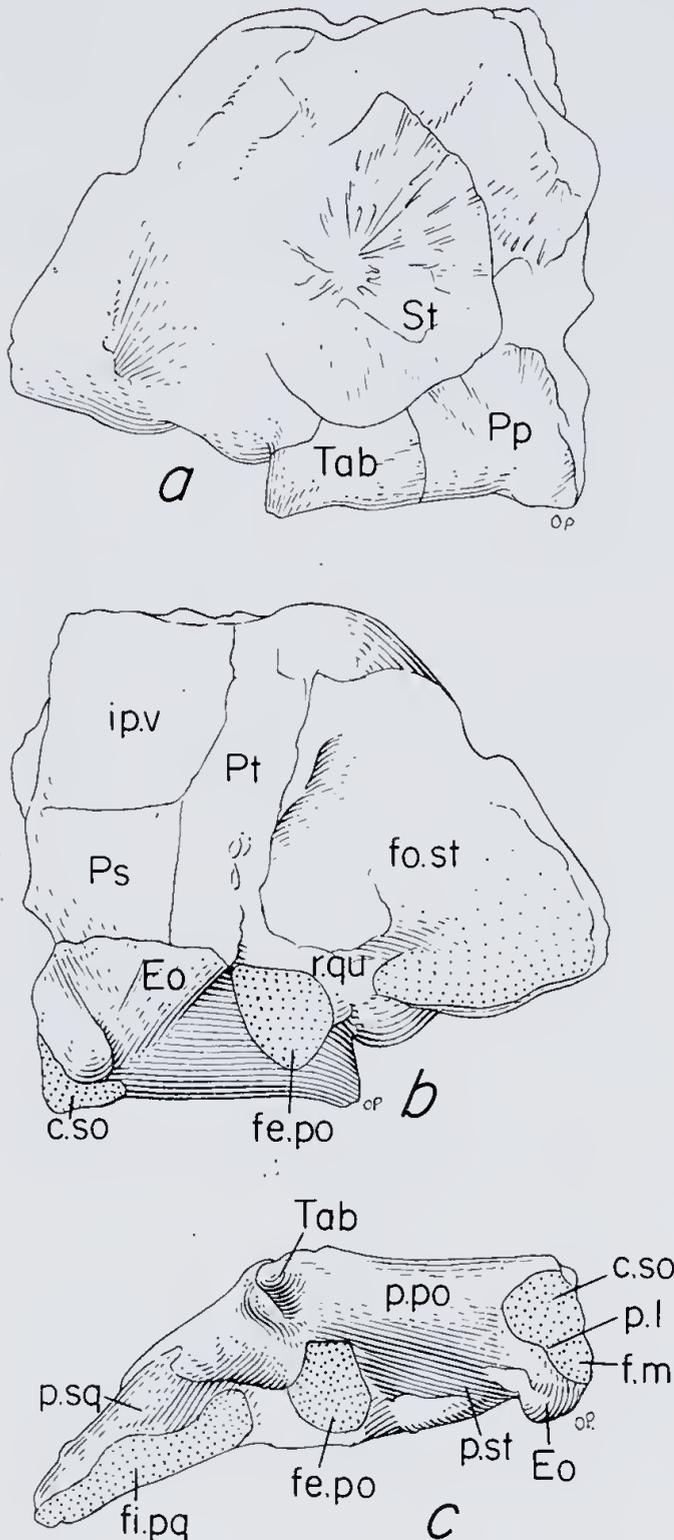


Fig. 3.—*Deltasaurus kimberleyensis* gen. et sp. nov., paratype U.C.M.P. no. 61064 (U.C.M.P. locality V 6040); skull fragment: a, dorsal view; b, palatal view; c, occipital view. All x 0.65.

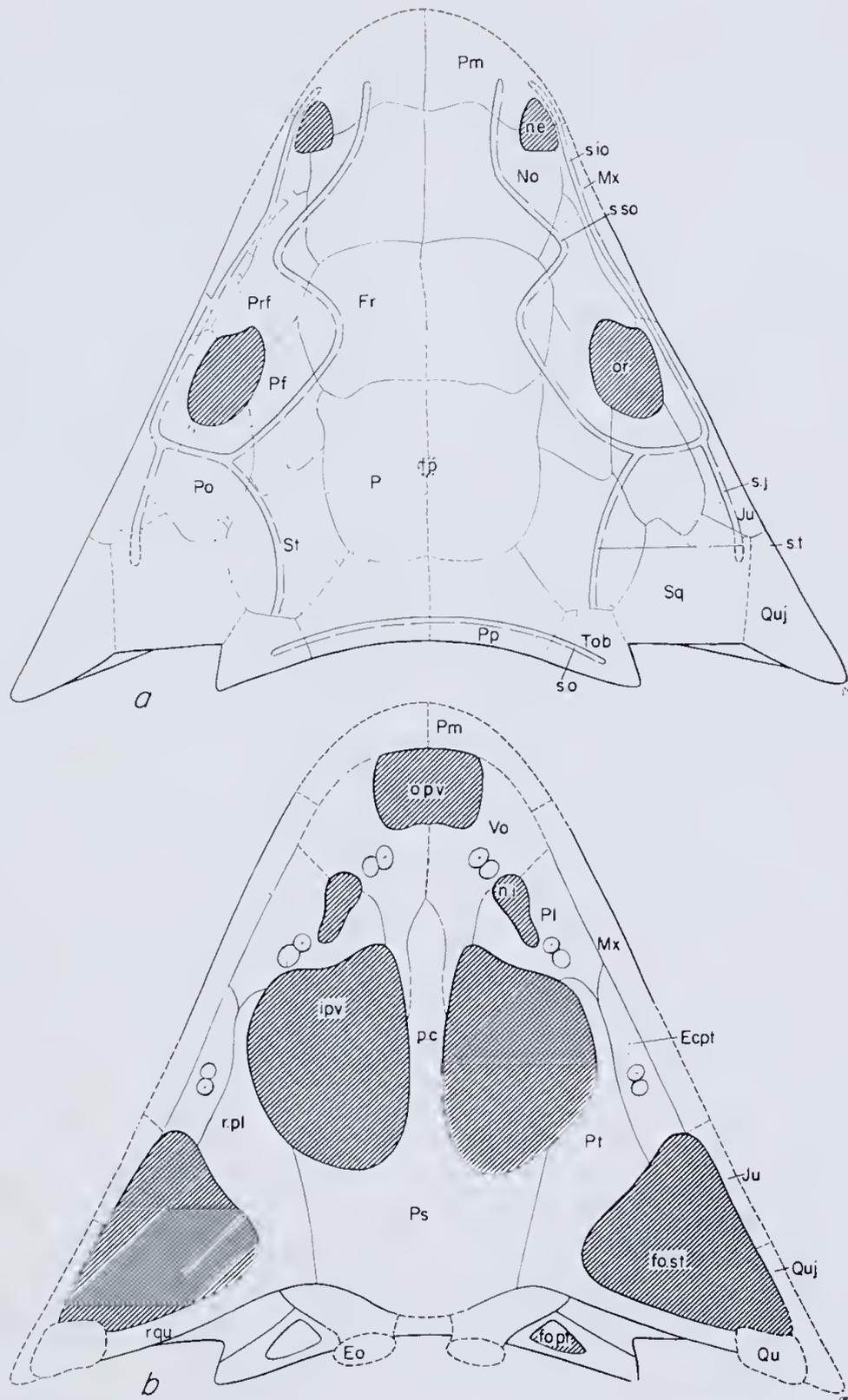


Fig. 4.—*Deltasaurus kimberleyensis* gen. et sp. nov., reconstruction of the skull, based mainly on W.A.M. no. 62.1.44, supplementary data from U.C.M.P. nos. 61062, 61064 and 61313: a, dorsal view; b, palatal view. x 0.33.

temporal fossa and also the anterior and lateral borders of the interpterygoid vacuity; some of the lateral edge is intact. The smaller left fragment has only the region about the internal naris and the anterior edge of the interpterygoid vacuity.

Four other specimens contributed the remainder of the palate restoration. The region anterior to the interpterygoid vacuity is based on the palate fragment of the holotype (fig. 1b). The orientation of the two fragments of U.C.M.P. no. 61063 indicates a broad, flat

cultriform process of the parasphenoid; this is confirmed by U.C.M.P. no 61061 (fig. 2b), an isolated parasphenoid with scraps of the vomers still adhering to its anterior portion. The shape of the anterior part of pterygoid bone and the location of the pterygoid-parasphenoid suture are taken from the palate surface of the small posterolateral skull fragment, U.C.M.P. no. 61064 (fig. 3b). The quadrato ramus of the pterygoid is preserved on U.C.M.P. no 61062.

The various openings of the palate surface are relatively small compared with those of other Triassic labyrinthodonts.

The anterior palatal vacuity, preserved on the type, is unpaired and similar in shape to that found in most capitosaurids. It is twice as broad as long. The anterior and lateral borders are straight. The posterior border is bow-shaped with a median indentation.

The internal naris, best preserved on the left side of the U.C.M.P. no 61063, is pear-shaped with the apex at the posterior margin and the long axis is oblique both to the lateral edge of the skull and to the midline. It is farther from the lateral edge of the palate than in most other Triassic labyrinthodonts.

The short, broad interpterygoid vacuity occupies the central third of each side of the palate. The posterior and posterolateral borders are rounded. The medial border on the cultriform process is straight. The anterolateral border is indented by the palatine bone.

The subtemporal fossa is broader than long. Its anterior border is nearly on a level with the posterior border of the interpterygoid vacuity. The posterolateral corner against the quadrate and quadratojugal bones is angular. The antero-medial border is indented by the usual "elbow" of the pterygoid.

The palatal surfaces of the premaxillary and maxillary bones are a few millimeters above the central palatal surface. The position of the premaxillary-maxillary suture and the posterior boundaries of the maxillary bone on the overplating jugal bone are unknown.

Both fragments of U.C.M.P. no. 61063 bear a portion of the marginal tooth row. The actual teeth have been leached away, leaving only hard cores of matrix that retain the shapes of the pulp cavities. Each core has a central pillar surrounded by radially arranged spokes that represent the hollow spaces within the labyrinthine folds of the original dentine. The internal cores reflect the shapes of the original teeth. They are of uniform height, about 4mm. Some lie close together and others are separated by empty sockets. They are anteroposteriorly compressed and resemble the teeth of other labyrinthodonts in this respect.

The quadratojugal-jugal suture is placed with reference to the course of this suture on the dorsal surface of the holotype. The quadratojugal of the holotype extends to the posterolateral skull corner and obviously covered the lateral surface of the quadrate; the quadratojugal-quadrato suture is placed accordingly on the palate reconstruction.

Internal to the premaxillary and maxillary lie the vomer, palatine and ectopterygoid, each

bearing a large tusk flanked by a replacement pit. There are no rows of smaller teeth running between the large tusks parallel to the marginal tooth row.

The vomer extends from the posterior and lateral borders of the anterior palatal vacuity to the anteromedial border of the interpterygoid vacuity. U.C.M.P. no. 61061 (fig. 2b) shows that the vomer sheathed the anterolateral edge of the cultriform process at least as far posteriorly as indicated in figure 4b. Part of the vomer-parasphenoid suture and part of the intervomer suture are preserved on U.C.M.P. no. 61063. Anterolaterally the vomer borders the maxillary and probably also had a short suture with the premaxillary. The vomer-palatine suture of U.C.M.P. no 61063 runs anterolaterally from the forward edge of the interpterygoid vacuity and becomes indistinct between the choana and the vomerine tusk. It probably curves laterally to end at the forward edge of the choana.

The palatine separates the maxillary from the internal naris and meets the vomer lateral as well as medial to the naris. In other labyrinthodonts the maxillary has a medial extension which forms the lateral border of the internal naris and which has a posterior suture with the palatine and an anterior suture with the vomer. The palatine is bordered by the pterygoid and ectopterygoid posteriorly. The palatine tusk and replacement pit are immediately behind the internal naris.

The ectopterygoid is an elongate bone. The tusk and replacement pit are near the centre of its length.

The anterior part of the pterygoid is strongly developed and the sutural contact with the palatine is extensive for a Triassic genus. The central portion between the parasphenoid bone and the subtemporal fossa is unusually narrow. The quadrate ramus is long and slender.

The body of the parasphenoid is exceptionally broad compared with the width of the central portion of the pterygoid bone. It is bounded posteriorly by oblique sutures with the exoccipitals and probably had a short free margin between the condyles.

The broad flat cultriform process of the parasphenoid extends forward between the interpterygoid vacuities and terminates between the vomers as a conical projection. It is slightly constricted in width opposite the centres of the interpterygoid vacuities.

A few scraps of the right exoccipital adhere to the posterior edge of the palate of U.C.M.P. no. 61064. The exoccipital-parasphenoid suture is not preserved but the bone grain indicates that the exoccipital contribution to the palatal surface must have been small. The condyles are restored after *Peltostega erici* (Nilsson, 1946, fig. 6).

The quadrate condyle of the reconstruction is completely conjectural.

A dense shagreen of small teeth completely covers most of the palate. The original dentine of these teeth has been leached away leaving only labyrinthine casts of the pulp cavities. The

shagreen covers all of the bone surface anterior and lateral to the interpterygoid vacuities. It even extends over the palatal surfaces of the maxillary bone, both medial and lateral to the marginal tooth row. U.C.M.P. no. 61061 shows that the shagreen covered the surface of the cultriform process of the parasphenoid close to its base. It probably extended onto the corpi of the parasphenoid and pterygoid.

The denticles vary in size over the palate. Those on the anterior part of the cultriform process are twice as large as those on the palatine and vomer at the anterior edge of the interpterygoid vacuity.

Occipital surface of the skull (figs. 2c, 3c and 5). U.C.M.P. nos. 61062 (fig. 2c) and 61064 (fig. 3c) are left posterolateral skull corners broken off slightly lateral to the midlines. The first, derived from a skull comparable in size to the holotype, is uncrushed and retains much of the actual shape of the occiput. The second, derived from a smaller skull, has undergone considerable dorsoventral compression. The restoration of the occiput (fig. 5) is a composite of both of these. Both are fairly complete in the central and lateral portions of the occiput but lack the occipital and quadrate condyles. The occipital structures are preserved mainly as internal impressions with a few scraps of bone adhering in places.

The angular occipital margin of the skull roof of U.C.M.P. no. 61062 closely matches that of the holotype. The skull table is flat. The cheek margin descends ventrolaterally, forming a 40 degree outside angle with the skull table at the otic notch. The lower half of the cheek margin is set at a 25 degree outside angle with the upper half. The ventral margin of the occiput of this specimen is slightly convex upward and the missing quadrate region was below the level of the parasphenoid bone.

The postparietal, tabular and squamosal of U.C.M.P. no. 61062 are produced backward into a short ledge overhanging the occipital structures. The quadratojugal probably had a similar ledge but this is not preserved. The postparietal-tabular and the tabular-squamosal sutures are placed on the ledge according to their positions on the skull roofs of the holotype and U.C.M.P. no. 61064.

The paraoccipital process of the tabular is preserved as internal impression on both occipital fragments. The pattern of bone grain on U.C.M.P. no. 61064 shows the approximate position of the tabular-exoccipital suture.

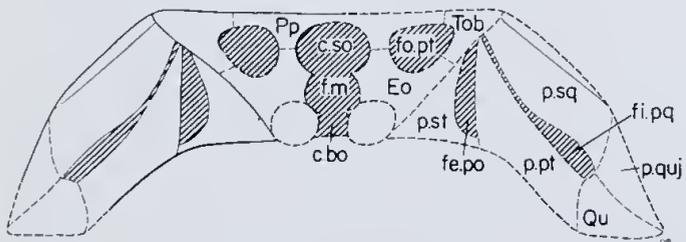


Fig. 5.—*Deltasaurus kimberleyensis* gen. et sp. nov., reconstruction of the occipital surface of the skull, based on U.C.M.P. nos. 61062 and 61064; size based on no. 61062. x 0.38.

The supraoccipital process of the postparietal was a short cylindrical structure. A vertical groove filled with splintery bone is all that remains of this process on the occiput of U.C.M.P. no. 61064. The position of the suture with the underlying exoccipital bone is unknown.

The exoccipitals of both specimens are badly damaged but each contributes some information. The paraoccipital and vertical processes of both diverge in the usual manner from the upper part of the main body of the bone. The broken bases of the condyles are marked by radiating bone grain. The condylar base of U.C.M.P. no. 61062 is just above the level of the parasphenoid bone. U.C.M.P. no. 61064 retains a processus lamellosus on the medial side of the vertical process. A long palatal process of the exoccipital is present on both specimens. It remains in natural position on U.C.M.P. no. 61062 where it runs ventrolaterally to a contact with the pterygoid bone. The processus basalis and vagus foramen are not present on either specimen.

The impression of a large triangular plate of bone is laterally continuous with the edge of the paraoccipital process of U.C.M.P. no. 61064. The apex of this plate lies near the exoccipital-tabular suture and the broad base rests on the upper surface of the palatal process of the exoccipital. It has a flat posterior surface and a straight lateral edge. It slopes downward, inward and forward on this specimen; a few scraps of impression remaining on the inner side of the paraoccipital process of U.C.M.P. no. 61062 indicates that the plate of bone originally lay in a more dorsoventrally orientated plane as its ventrolateral corner lies near the exoccipital-ptyergoid suture. This plate has the morphologic position of a subotic process of the exoccipital. The fenestra ovalis of cyclotosaurids is situated just anterior to and just medial to the posterior edge of the exoccipital-ptyergoid suture; the posterior and ventral margins of this foramen are formed by the subotic process. If the identification is correct, the subotic process of *D. kimberleyensis* is peculiar. In all other Triassic labyrinthodonts for which it has been reported it is a short cylindrical process just ventrolateral to the condyle.

The posttemporal fossa of U.C.M.P. no. 61062 is an oval depression, enclosed by the paraoccipital bar, the vertical process of the exoccipital and the overhanging ledge of the skull roof. The dorsal, medial and lateral margins are well-defined; the ventral margin is less distinct.

The large opening in the center of the occiput was undoubtedly tripartite as in other labyrinthodonts. The lateral borders of the supraoccipital foramen and the foramen magnum, divided by the processus lamellosus lamellosus, are present on U.C.M.P. no. 61064. The shape of the basioccipital foramen is unknown because the processus basalis which delimits the lower edge of the foramen magnum is not preserved. The large supraoccipital foramen is broader and perhaps higher than the foramen magnum. The supraoccipital and basioccipital were probably cartilaginous as in other late

labyrinthodonts; no traces of ossification were found in the supraoccipital foramen.

The ascending process of the pterygoid, preserved as an internal impression on the occipital surface of U.C.M.P. no. 61062, is perpendicular to the quadrate ramus and is broken off just medial to the missing quadrate bone. The flat external surface extends anteromedially from the broken lateral edge and ends with an indistinct medial margin under the otic notch. The process is highest in its most medial portions and gradually decreases in height laterally.

The descending process of the squamosal and quadratojugal are poorly preserved on both specimens. The sinuous ventral margin on the processes, shown in the reconstruction, is principally based on U.C.M.P. no. 61064. The suture between the squamosal and quadratojugal is hypothetical.

U.C.M.P. no. 61062 retains the very indistinct outlines of a narrow palatoquadrate fissure between the lateral portions of the occipital processes of the squamosal and pterygoid. The smooth lower margin of the squamosal on U.C.M.P. no. 61064 indicates that this bone was not in sutural contact with the pterygoid for most of its length and that the palatoquadrate fissure was even more extensive than is indicated by U.C.M.P. no. 61062.

The pteroccipital fenestra is a large opening between the ascending process of the pterygoid and the lateral edge of the subotic process of the exoccipital. The shape of the fenestra is reconstructed from both occipital surfaces.

Measurements. Estimates of the original dimensions of the type skull are:

Skull roof	
Median length	22.2 cm.
Median length from the snout tip to the level of the posterior borders of the external nares	5.2 cm.
Median length from the level of the posterior borders of the external nares to the level of the anterior borders of the orbits	6.0 cm.
Median length from the level of the anterior borders of the orbits to the level of the posterior borders of the orbits	3.6 cm.
Median length from the level of the posterior borders of the orbits to the posterior edge of the skull roof	7.6 cm.
Width across the posterior borders of the external nares	10.8 cm.
Width across the posterior borders of the orbits	20.0 cm.
Width across the posterolateral skull corners	29.4 cm.
Least interorbital width	11.3 cm.
Palatal surface	
Median length	21.4 cm.
Median length from the snout tip to the level of the anterior borders of the interpterygoid vacuities	8.4 cm.
Median length from the level of the posterior borders of the interpterygoid vacuities to the posterior edge of the palate	5.0 cm.
Greatest length of the left interpterygoid vacuity	8.0 cm.
Greatest width normal to the length of the left interpterygoid vacuity	5.7 cm.
Length of the anterior palatal vacuity	2.7 cm.

Width of the anterior palatal vacuity	3.8 cm.
Length of the left internal naris	2.7 cm.
Greatest width normal to the length of the left internal naris	1.2 cm.

The lower jaw (figs. 6-8). Lower jaw fragments of *Deltasaurus kimberleyensis* are the most abundant fossils in the Blina collection. Most of these were found in the quarries and about the slopes at V 6040. One was collected at the Noonkanbah locality, V 6044 and four are from the B.M.R. locality (Dry Corner). A pair of articulated rami, U.C.M.P. no. 61098 (fig. 6a), was found in the quarry at V 6043 only a few feet from articulated jaws of a brachyopid. This specimen closely matches the skull outline of *D. kimberleyensis* and is certain to pertain to the same species; the numerous fragmentary jaws are referred through comparison with this specimen.

The articulated jaws and many of the partial jaws are largely internal casts of the region anterior to the glenoid fossa. They compositely show the shape of the adductor fossa and of the meckelian space anterior to it. A comparative review of the more promising of the internal casts has revealed the courses of many of the deep sutures of the dermal bones. In many instances fossae and fenestrae are preserved as infillings of matrix that project from the surfaces of the casts. Scraps of the original enclosing cylinders of dermal bone adhere to a few of the casts.

Four of the jaw fragments, U.C.M.P. nos. 61100, 61114, 61119 (fig. 6c) and 61122 (fig. 6k) preserve portions of the retroarticular processes. The surface bone has been leached from the dorsal, lingual and labial sides of these, exposing the cores of the surangular bones in the retroarticular processes and of the articular bones beneath the glenoid fossae.

W.A.M. no. 60.9.16 retains part of the external labial surface and five additional specimens, U.C.M.P. nos. 61071 (fig. 6h), 61104, and 61125, and B. M. R. nos. F21805 and F21807 include impressions of parts of this surface. These show the character of the external ornament and the positions of several of the sutures. A portion of the external lingual surface is preserved on U.C.M.P. no. 61121 (fig. 6b).

The restoration technique is that developed by Nilsson (1943). A composite restoration was made of each aspect of the internal cast of the lower jaw (figs. 7a, b and c), utilizing the internal cast specimens and the retroarticular cores. The gross outlines and proportions are based on U.C.M.P. no. 61096. A second series of restorations (figs. 8a, b and c), built about the first series, shows the external surfaces of the lower jaw. Approximately 2.0 mm. have been added to all surfaces to allow for the thickness of the dermal bone. The symphyseal region of the articulated jaws, the labial impressions and the lingual fragment have contributed to the external restorations. Unknown external sutures are placed according to the general labyrinthodont arrangement of the dermal bones of the lower jaw described by Nilsson (1943). The composite internal cast will be considered first and will be followed by a description of the restored external surfaces.

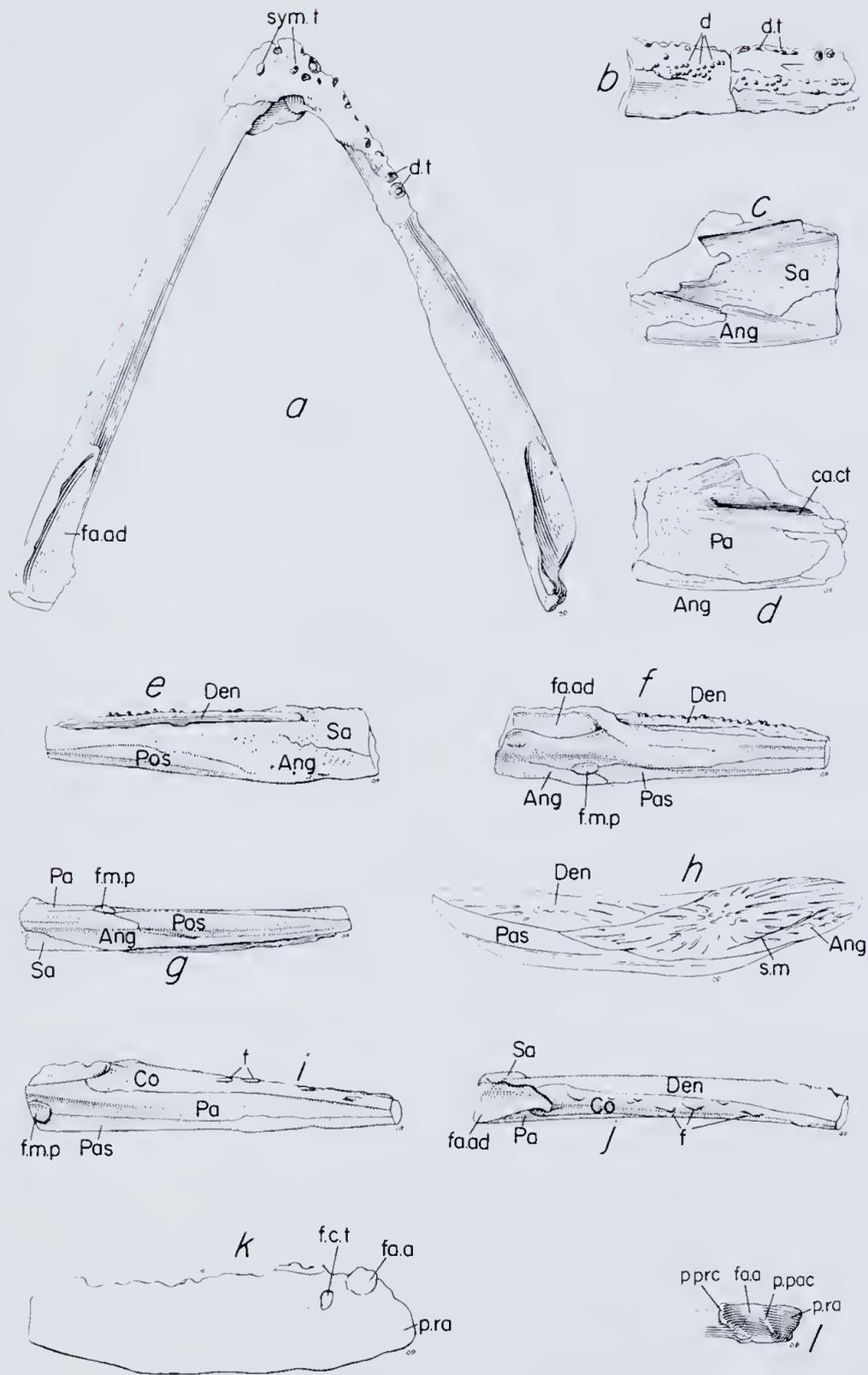


Fig. 6.—*Deltasaurus kimberleyensis* gen. et sp. nov., paratypes: a, U.C.M.P. no. 61098 (U.C.M.P. locality V 6043), lower jaw, dorsal view; b, U.C.M.P. no. 61121 (U.C.M.P. locality V 6042), lower jaw fragment, lingual view; c, U.C.M.P. no. 61119 (U.C.M.P. locality V 6040), lower jaw fragment, labial view; d, the same, lingual view; e, U.C.M.P. no. 61101 (U.C.M.P. locality V 6040), lower jaw fragment, labial view; f, the same, lingual view; g, the same, ventral view; h, U.C.M.P. no. 61071 (U.C.M.P. locality V 6040), latex peel of the external impression of the labial surface of a lower jaw fragment; i, U.C.M.P. no. 61099 (U.C.M.P. locality V 6042), lower jaw fragment, lingual view; j, the same, dorsal view; k, U.C.M.P. no. 61122 (U.C.M.P. locality V 6040), lower jaw fragment, lingual view; l, U.C.M.P. no. 61068 (U.C.M.P. locality V 6040), articular facet of a lower jaw, dorsal view. All x 0.43.

In dorsal view (fig. 7a) each internal cast is slightly convex labially. It is narrowest at the symphysis and gradually increases in width back to the glenoid fossa. The retroarticular process tapers to a pointed apex. The upper surface, anterior to the adductor fossa, is occupied by the internal impressions of the dentary and coronoid bones. There are presumably three bones in the coronoid series as in other labyrinthodonts but the sutures dividing these were not found in the collection. The dentary-coronoid suture runs obliquely across the upper surface from a lingual point just behind the symphysis to a labial point lateral to the anterior edge of the adductor fossa. The coronoid ends at the adductor fossa; the dentary continues back to overlap a portion of the surangular impression on the labial surface of the jaw. The dentary impression on the dorsal surface is flat; the coronoid impression is convex. U.C.M.P. nos. 61099 (figs. 6i and j) and 61088 are cylindrical projections on the coronoid internal impressions; these are probably infillings of foramina that carried blood and nerve supply to the bone and teeth.

The adductor fossa has a flattened posterior border against the articular and a bluntly pointed anterior border.

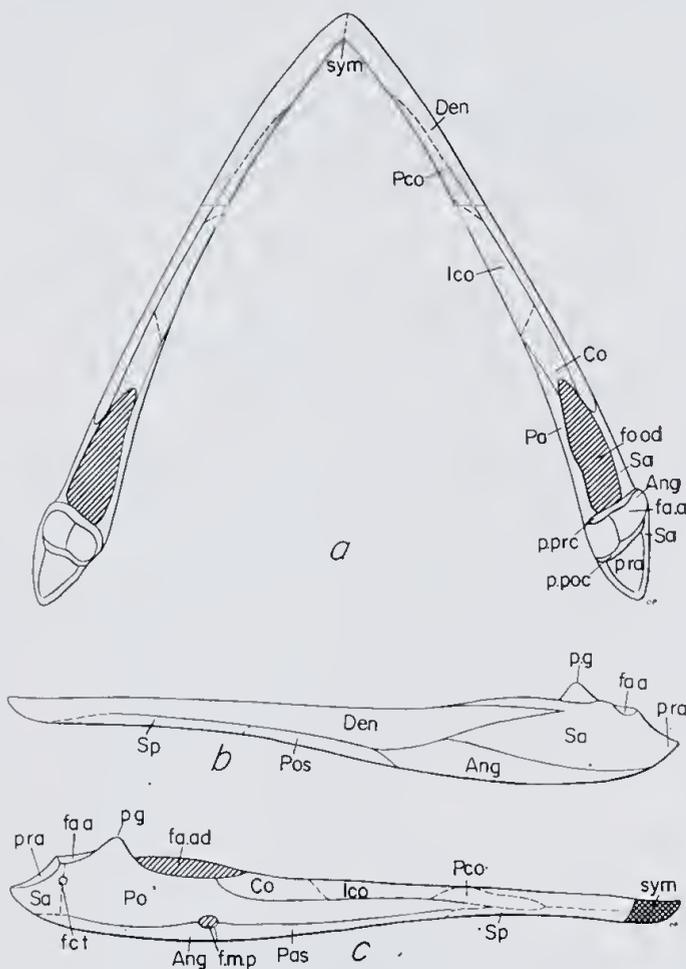


Fig. 7.—*Deltasaurus kimberleyensis* gen. et sp. nov., reconstruction of the internal surfaces of the dermal bone of the lower jaw; size based on U.C.M.P. no. 61098; a, dorsal view, based principally on U.C.M.P. nos. 61068, 61098, 61099, 61101 and 61122; b, labial view, based principally on U.C.M.P. nos. 61068, 61101, 61119 and 61122; c, lingual view, based principally on U.C.M.P. nos. 61099, 61101, 61119 and 61122. All x 0.38.

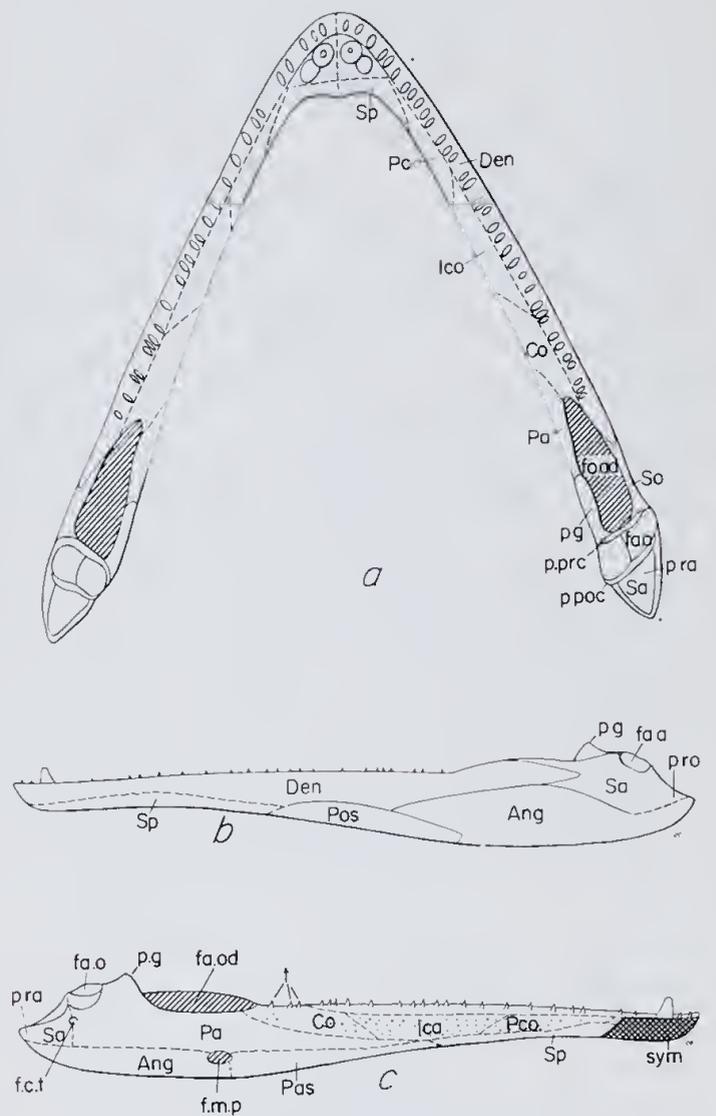


Fig. 8.—*Deltasaurus kimberleyensis* gen. et sp. nov., reconstruction of the external surfaces of the dermal bones of the lower jaw; size based on U.C.M.P. no. 61098; outlines based on the reconstructed internal cast, with compensation for the thickness of the dermal bones: a, dorsal view, supplementary data from U.C.M.P. nos. 61068 and 61121; b, labial view, supplementary data from U.C.M.P. nos. 61068 and 61071; c, lingual view, supplementary data from U.C.M.P. nos. 61068 and 61121. All x 0.34.

The glenoid facet (fig. 6l) is formed by the articular bone encased by the surrounding surangular. It is divided by a low longitudinal crest. Precondylar and postcondylar processes bound the facet fore and aft. The precondylar process is lingually continuous with the high rounded hamate process of the prearticular bone. The hamate process lies along the posterior lingual border of the adductor fossa and perhaps served as an insertion area for part of the adductor muscle mass.

The dorsal aspect of the retroarticular process is triangular. It is occupied by the shallow insertion area of the m. depressor mandibulae.

In labial aspect (fig. 7b), the internal cast gradually deepens posteriorly from the symphyseal region. The upper surface, anterior to the adductor fossa, is flat. The labial wall of the adductor fossa is high and rounded. The anterior half of the lower border is flat; the posterior half is convex ventrally.

The impressions of the surangular, angular, dentary and splenial bones cover the labial surface. Several specimens have contributed portions of the angular-surangular and angular-dentary sutures. The surangular covers a large area on the dorsoposterior portion of the jaw and includes all of the retroarticular process. Anterodorsally the surangular bears a longitudinal groove for the splinter-shaped posterior process of the dentary. The dentary covers most of the lingual surface anterior to the adductor fossa. It is bordered ventrally by the splenial and postsplenial. The angular fills the area below the surangular and the dentary and behind the postsplenial.

The lingual surface of the internal cast of the lower jaw (fig. 7c) is similar to the labial surface in outline except around the border of the adductor fossa, which is produced into the high, rounded hamate process posteriorly and is lower than the lateral border anteriorly.

The prearticular extends far forward on the lingual surface between the splenials and coronoids, tapering to a fine point not far behind the symphyseal region. The suture between the prearticular and surangular is unknown; it probably descends more or less vertically from the glenoid facet as in other labyrinthodonts.

The most anterior portions of the lingual surface of the internal cast are not represented in the collection. The coronoid series tapers forward and probably terminates as a sharp point just behind the symphysis. The internal cast within the symphyseal region was probably covered by dentary impression above and splenial impression below.

The posterior meckelian foramen, well defined on several internal casts, is unusually small for a Triassic genus. It is only 7mm wide and 4mm deep on U.C.M.P. no. 61101 (fig. 6f), a jaw fragment slightly larger than U.C.M.P. no. 61068. The prearticular forms its upper border and the angular and postsplenial its ventral border.

The lingual surface of U.C.M.P. no. 61119 (fig. 6d) retains the deeper layers of the prearticular bone. These contain a shallow longitudinal groove just below the glenoid facet which is probably the internal wall of the chorda tympani canal. Near the center of the adductor fossa this groove becomes indistinct. The chorda tympani canal probably opened through a foramen into the adductor fossa and the nerve probably continued forward from this foramen through the meckelian space.

In ventral view the internal cast of the lower jaw is sharply keeled from the retroarticular process to the posterior part of the postsplenial. The central part of the lower surface is rounded. The ventral surface of the symphyseal region is flat.

The shapes of the reconstructed external surfaces closely resemble those of the internal cast except in the symphyseal region.

The symphyseal region is nearly complete on U.C.M.P. no. 61098. The dentaries and splenials expand inwardly into a broad triangular plate. The dentaries form the dorsal surface of this plate and the splenials the ventral surface. The dentary surface of this plate carries sym-

physeal tusks internal to the marginal tooth row. The surface surrounding the tusks is covered with a shagreen of small denticles identical with those of the palate.

Remnants of dermal bone adhere to the dorsal surfaces of U.C.M.P. nos. 61101 (figs. 6e and f) and 61121 (fig. 6b). These carry a few internal cores of the marginal teeth of the dentary which resemble those of the maxillary row in size, shape and spacing. Remnants of the coronoid series of W.A.M. no. 60.9.16, U.C.M.P. nos. 61121 and 64972 and B.M.R. no. F21817 display a shagreen of denticles which are identical with those of the palatal surface of the skull and those of the symphyseal plate. A reasonable interpretation from these specimens is that the coronoid series was completely covered with shagreen.

No suture between the dentary and the coronoid could be distinguished on the shagreened areas of the specimens mentioned above, which suggests that the dorsal surface of the dentary is confined to the narrow strip which carries the dentary tooth row. If this interpretation is correct the coronoid bones have a considerably larger area on the external surface than they have on the internal cast and must overlap the dentary with a squamous suture. This condition is the reverse of the situation in *Aphaneramma rostratum* (Nilsson, 1943, figs. 4A and 4B) where the dentary overlaps the coronoid series and the superficial surface of this bone is larger than its internal impression.

Impressions of the external surfaces of the angular and postsplenial are preserved on latex positives of U.C.M.P. nos. 61104, 61071 (fig. 6h) and 61125 and B.M.R. no. F21807. The superficial surfaces of these bones are considerably larger than their deep surfaces. The angular must overlap extensively on the external surface of the surangular and slightly on the external surface of the dentary and the postsplenial must overlap extensively on the external surfaces of both the angular and the dentary. The postsplenial terminates posteriorly as a sharp projection over the angular. These squamous relationships are consistent with the observation of Nilsson (1943) on the Spitzbergen trematosaur. The splenial bone of *D. kimberleyensis*, not preserved in the collection, probably also had a larger superficial than deep surface.

The ornament pattern of the angulars and postsplenials, as displayed on the latex impressions, is identical with that of the skull roof.

U.C.M.P. no. 61071 shows the diagonal course of the mandibular lateral line groove on the angular bone. It descends anteroventrally from the glenoid region. The oral and accessory grooves of the lower jaw, if present, are not preserved.

The superficial sutures of the lingual surface (fig. 8c) are hypothetical. The reconstruction is based on the squamous relationships of the dermal bones of this surface described by Nilsson. If the same relationships maintain in *D. kimberleyensis*, the angular, postsplenial, splenial and coronoid bones all have larger superficial than deep surfaces and all extensively

overlap the external surface of the prearticular bone.

The lower jaw of *D. kimberleyensis* has the basic temnospondyl construction. It shares a well developed retroarticular process with most other Triassic genera of this group. The strong development of the hamate process parallels the Cyclotosauridae. The distinctive feature of the lower jaw of *D. kimberleyensis* are the expanded symphyseal plate, the small size of the posterior meckelian foramen and the shagreen of denticles which covers the coronoid bones and the symphyseal portion of the dentary bone.

Measurements. Estimates of the original dimensions of the lower jaw, U.C.M.P. no. 61098 are:

Length (outside curvature) from the symphysis to the tip of the retroarticular process	.....	21.7 cm.
Length (outside curvature) from the symphysis to the forward edge of the adductor fossa	.....	13.9 cm.
Length of the symphysis	.....	2.6 cm.
Length of the adductor fossa	.....	4.2 cm.

Dermal shoulder elements (fig. 9). Ten clavicular and nine interclavicular fragments are referred to *D. kimberleyensis*. All but one of these are external surfaces which bear delicate sculpture patterns identical to that of the holotype. The odd fragment is a detached cleithral process of the clavicle; the base of this process closely matches the broken bases of two of the clavicular fragments. The visceral surfaces of the dermal shoulder girdle are not known.

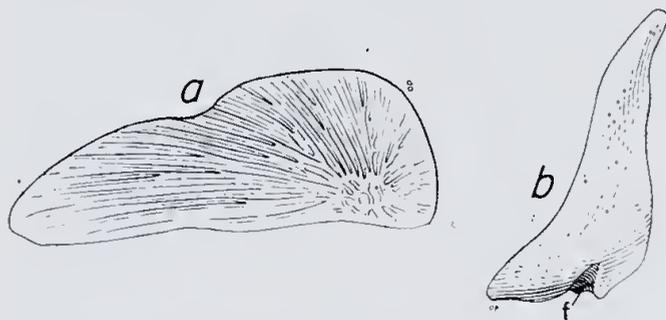


Fig. 9.—*Deltasaurus kimberleyensis* gen. et sp. nov., paratypes; a, U.C.M.P. no. 61092 (U.C.M.P., locality V 6043) right clavicle, ventral view; b, U.C.M.P. no. 61082 (U.C.M.P. locality V 6040), left cleithral process of clavicle, lateral view. x 0.77.

U.C.M.P. no. 61092 (fig. 9a), the external impression of the ventral surface of a left clavicle, is about 7.0 cm. in greatest length (along the lateral edge). The outlines are complete except for a small piece broken from the medial edge. The medial and posterior borders are convex. The lateral border is sinuous. The sculpture pattern is reflected on a latex peel of this impression; the centre of ossification, marked by a few small pits, lies just medial to the shallow notch near the posterior end of the lateral edge; the remainder of the surface is covered with a spiral pattern of fine bifurcating ridges which curve out from the ossification centre in a counter-clockwise direction.

The cleithral process (U.C.M.P. no. 61082, fig. 9b) rests on the postero-lateral corner of the ventral surface. The tip of the process is

inclined posteriorly. The upper edge of a foramen, probably for circulatory supply, is present on the base.

The interclavicular specimens are all too fragmentary for accurate description. Several of these, however, suggest that the posterior portion of the bone was a broad, diamond-shaped plate as in other Triassic labyrinthodonts.

***Deltasaurus pustulatus*, sp. nov.**

(figs. 10 and 11)

Holotype. B.M.R. no. F21775, a partial skull roof with a small fragment of the palate surface and matching impression of the skull roof.

Type locality. Beagle Ridge Bore (B.M.R. 10), Kockatea Formation, South-West Division, Western Australia. The skull roof and its impression are preserved on the two surfaces of a break through core no. 28 (2614'-2624'). The core is 8.6 cm in diameter and composed of a uniform grey-green shale.

Diagnosis of the species. A *Deltasaurus* with bone sculpture composed principally of rows of pustules which radiate out from bone centers, with no pitting or concentric ridges. External naris with angular posterior border. Skull relatively narrower than that of *Deltasaurus kimberleyensis*.

Description. The ventral surface of the break carries the skull roof. A large piece is missing,

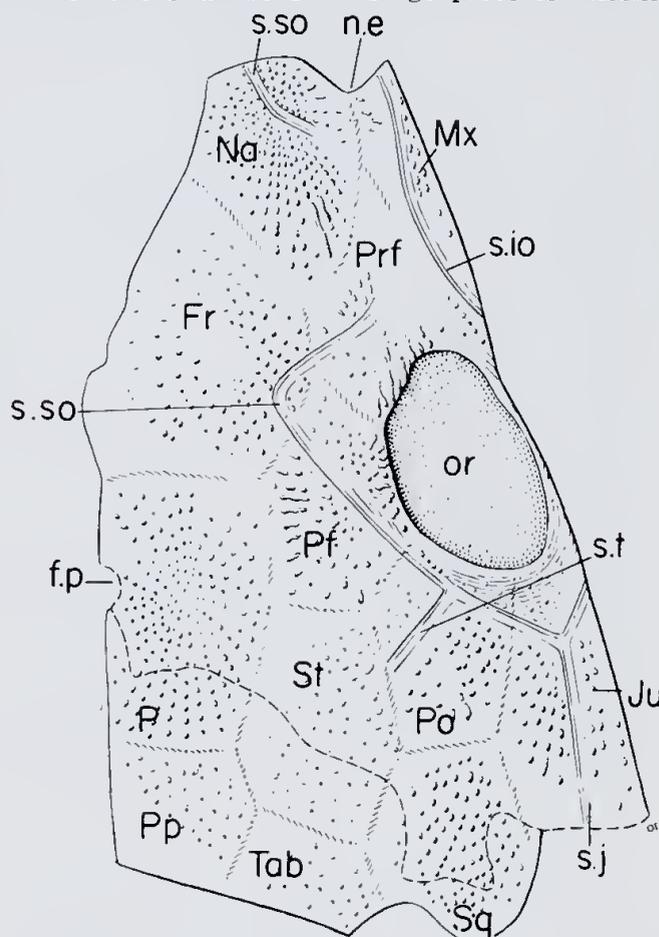


Fig. 10.—*Deltasaurus pustulatus* sp. nov., holotype, B.M.R. no. F 21775 (Beagle Ridge Bore); composite illustration of the skull roof and its external impression; the dashed line across the posterior part of the illustration is the edge of the actual specimen; the areas behind this dashed line are preserved only as impression. x 1.3.

probably spalled away during drilling operations, and the specimen was originally more complete medially and posteriorly. On the medial side the broken edge of the skull coincides with the median side of the parietal bone and the posterior half of the frontal bone; the broken edge then bends laterally and passes through the frontal and nasal bones. The broken posterior edge of the skull roof runs irregularly through the center of the postorbital region. A portion of the internal cast of the skull roof is preserved behind the broken posterior edge. Sutural impressions could not be identified on this internal cast. The specimen terminates anteriorly near the posterior border of the external naris against the rim of the core. The lateral edge of the skull roof is intact from the external naris to the posterior edge of the jugal bone.

An X-ray photograph shows a section of the alveolar border of the maxillary bone along the lateral edge of the skull roof. It is only a few

millimetres broad and extends from a point 1.8 cm posterior to the orbit to a point 1.3 cm anterior to the orbit. The anterior part of the process had broken loose from the edge of the skull and shifted medially. A row of maxillary teeth, faintly discernable on the X-ray, runs the length of the process. Preparation of the palatal surface through the base of the core is not advisable as this small piece of maxillary is the only part of the palatal structures preserved and as the skull roof is exceedingly thin and fragile.

The polished edge of the core shows two anterior teeth in cross-section. The lateral one is a marginal tooth of the maxillary row and the medial one appears to be a vomerine tusk. The presence of this latter tusk implies a piece of vomer bone to underlie and support it but such a fragment was not observed on the X-ray.

The upper surface of the split core carries the external impression of the skull roof with a few scraps of bone adhering to it. It includes

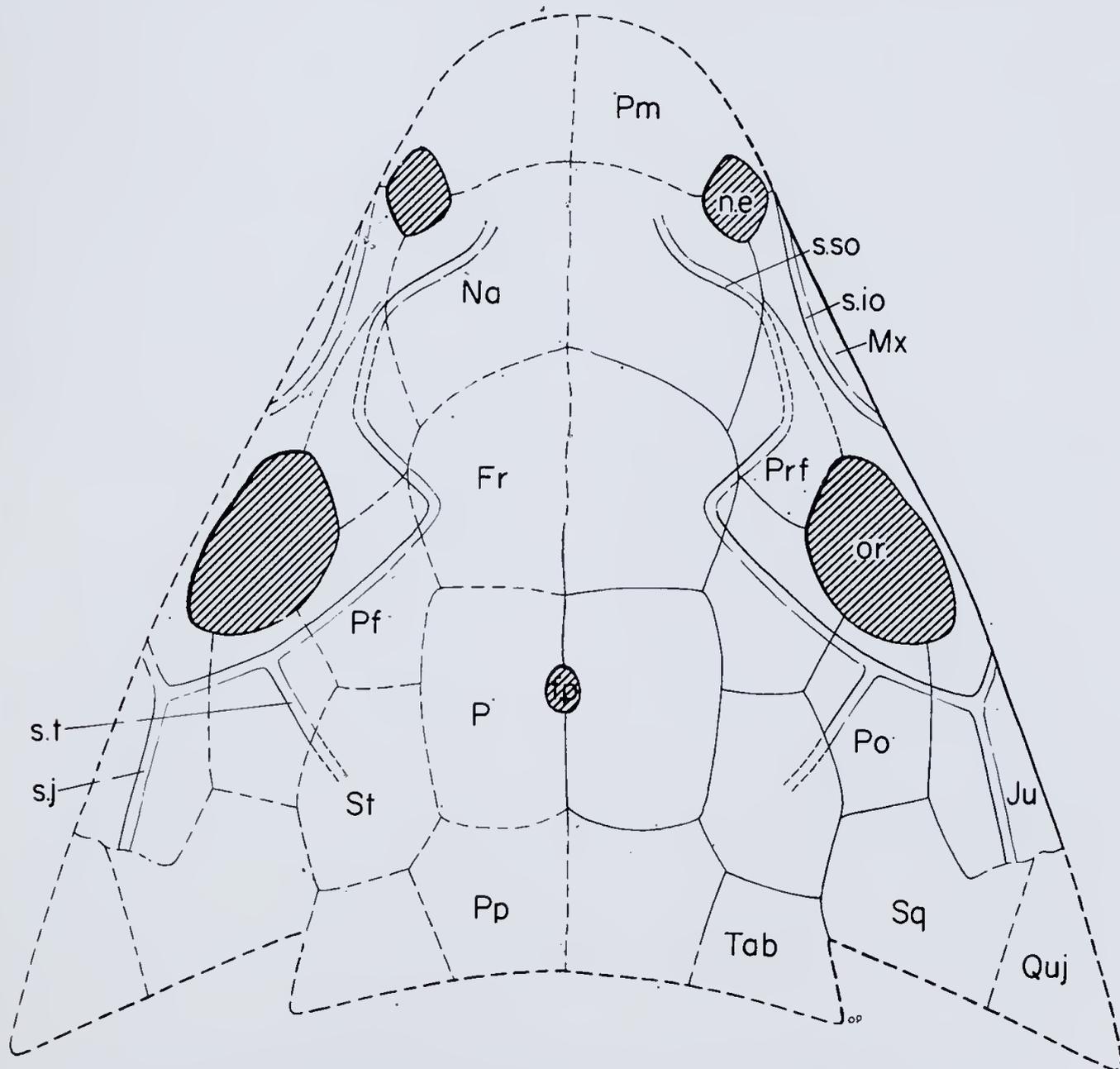


Fig. 11.—*Deltasaurus pustulatus* sp. nov., composite reconstruction of the dorsal surface of the skull based on the skull roof, B.M.R. no. F 21775, and its external impression x 1.33.

the impression of a posteromedial portion of the skull roof which has been lost from the actual specimen.

The orbital margins and portions of the borders of the external naris and parietal foramen are clearly marked on both surfaces. The surface sculpture and the grooves of the lateral line system are well preserved on the skull roof. The sutures are more clearly indicated on the impression.

The orbit has a flattened lateral border, an angular anterior border and rounded medial and posterior borders. It lies close to the lateral edge, level with midline center of the reconstructed skull.

The posterior border of the external naris is angular.

The parietal foramen, unknown in *D. kimberleyensis*, lies within the anterior half of the medial suture of the parietal bones.

The external impression includes the complete parietal, supratemporal, postorbital, postfrontal and jugal bones and portions of the nasal, frontal, postparietal, squamosal, maxillary and tabular bones. The premaxillary and quadratojugal are entirely lacking. The arrangement of the bones on the skull roof is quite similar to the arrangement in *D. kimberleyensis*. Further description at this point is not necessary as minor variations will be considered in the following comparative section.

The sculpture is delicate and regular. Rows of small round pustules radiate out from the center of each bone. The pustules are small and indistinct at the center of each bone and become progressively larger and more sharply defined towards the peripheries. There are no pits and rudimentary ridges can be observed only in the posterior part of the nasal bone.

The portions of the supraorbital, infraorbital, jugal and supratemporal grooves which are preserved on the specimen are similar to those of *D. kimberleyensis* in shape and position. They are concentrated in the lateral part of the skull roof. The entire course of the supraorbital groove, with the exception of the part lying on the prefrontal, may be traced. The infraorbital groove is present on the maxillary anterior to the orbit and on the jugal and postorbital posterior to the orbit. The anterior part of the jugal groove is well-marked. The supratemporal groove is distinct on the postorbital and ends abruptly at the postorbital-supratemporal suture. The portions of the tabular and postparietal which would carry the occipital groove if present, are not preserved.

Measurements. Estimates of the original dimensions of the skull roof are:

Median length	....	....	....	....	9.3 cm.
Median length from the snout tip to the level of the posterior borders of the external nares	....	....	....	....	2.1 cm.
Median length from the level of the posterior borders of the external nares to the level of the anterior borders of the orbits	....	....	....	....	2.1 cm.
Median length from the level of the anterior borders of the orbits to the level of the posterior borders of the orbits	....	....	....	....	1.9 cm.

Median length from the level of the posterior borders of the orbits to the posterior edge of the skull roof	....	....	....	....	3.2 cm.
Width across the posterior borders of the external nares	....	....	....	....	4.4 cm.
Width across the posterior borders of the orbits	....	....	....	....	7.8 cm.
Width across the posterolateral skull corners	....	....	....	....	10.8 cm.
Least interorbital width	....	....	....	....	4.6 cm.
Diameter of the parietal foramen	....	....	....	....	0.5 cm.

Comparison of *Deltasaurus pustulatus* with *Deltasaurus kimberleyensis*

The well core specimen is congeneric with *D. kimberleyensis* of the Blina Shale. The bones of the skull roof and the system of sensory grooves are generally similar to those of the Blina species. There is no lacrimal bone. The bones bordering the median suture are considerably larger than those of the lateral portions of the skull. The orbit has a somewhat flattened lateral border and a pointed anterior border and is placed close to the lateral edge of the skull.

The most important distinction of the Kockatea skull roof and the one which clearly necessitates a specific separation from the Blina form lies in the character of the surface sculpture. The sculpture pattern of *D. pustulatus* is comparatively simple. There are no concentric ridges, and, consequently, no pits. Only a few radiating ridges are present. The pustules apparently correspond to the nodes along the radiating ridges of *D. kimberleyensis* pattern in which the radiating and concentric ridges have been suppressed and the nodes have been emphasized. The difference is not ontogenetic. The sculpture on a fragment of a very small skull of *D. kimberleyensis* (U.C.M.P. no. 61313) from V 6040 is recognizable as an early stage of the sculpture found on the holotype of *D. kimberleyensis*. The pits are well-developed but small and the radiating ridges, although present, are not as pronounced as those on the holotype.

The skull of *D. pustulatus* is narrower than that of *D. kimberleyensis*. The width across the posterior borders of the orbits of the restored skull roof of *D. pustulatus* is 0.839 of the estimated median length. The same index in *D. kimberleyensis* is 0.901. As with the previous difference it is not likely that this is an ontogenetic feature. Juvenile skulls of other labyrinthodonts are always shorter and broader than the larger skulls.

The posterior border of the external naris is angular in *D. pustulatus*. It is straight across in *D. kimberleyensis*.

The bones of the skull roofs show minor differences which in themselves would not justify the erection of a new species. However, they tend to support the separation based on the above characters. The supratemporal of *D. pustulatus* is narrower and has a less extensive suture with the postparietal. The anterolateral corner of the parietal does not project forward between the frontal and postfrontal as is the case in *D. kimberleyensis*. The posterior border of the postorbital is straight in *D. pustulatus* and sigmoid on *D. kimberleyensis*. In *D. kim-*

berleyensis the nasal-frontal suture is roughly perpendicular to the median suture; in *D. pustulatus* it is oblique.

Comparison of Deltasaurus with related genera

The holotype and only material of *Rhytidosteus capensis* Owen includes three portions of the skull, several parts of the lower jaw rami

and a clavicular fragment. The largest skull portion consists of the dorsal and palatal surfaces of the entire antorbital region. The second portion is the interotic part of the skull roof which includes most of the tabular horns. The third portion is a piece of the right exoccipital which includes the condyle.

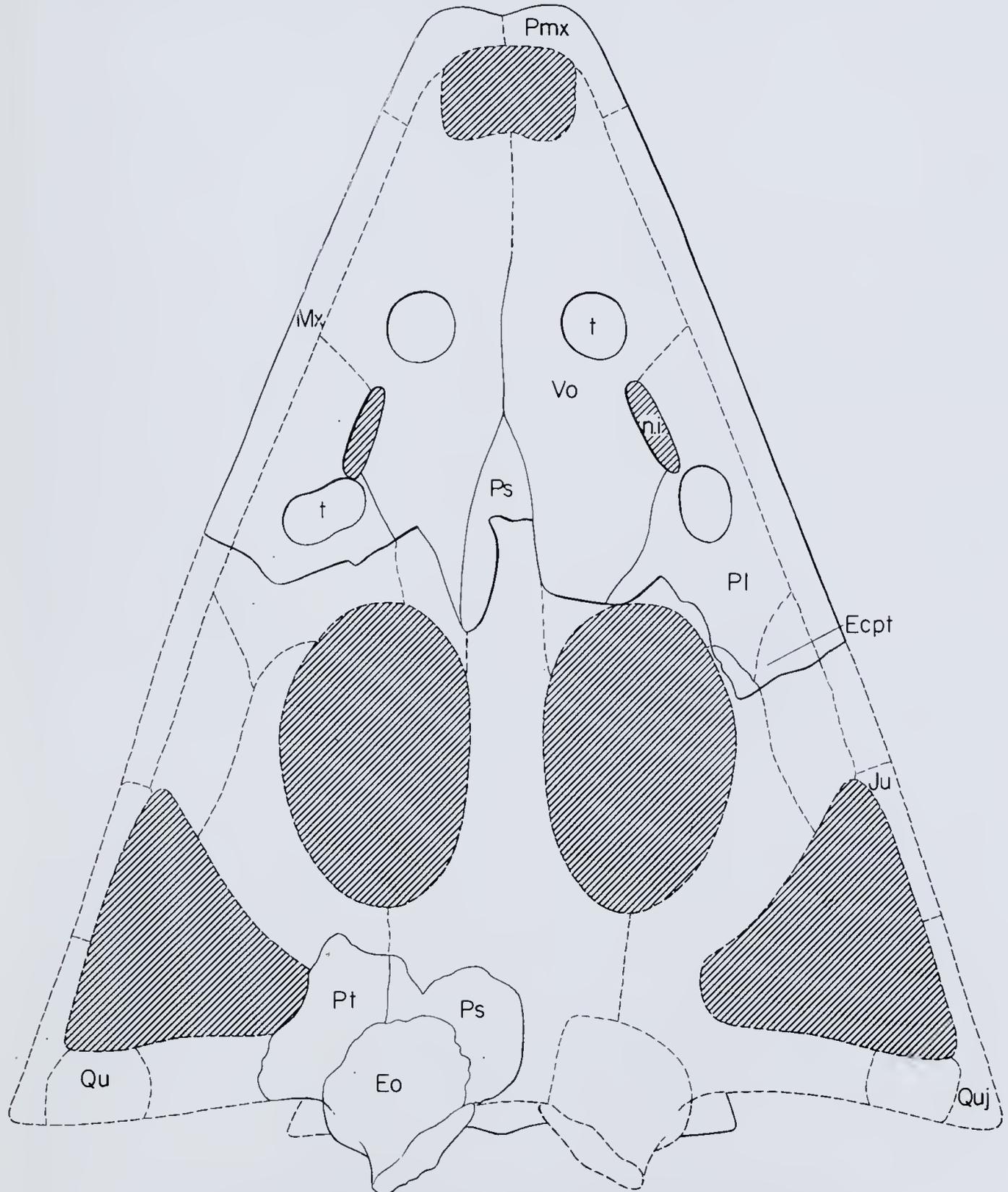


Fig. 12.—*Rhytidosteus capensis* Owen, reconstruction of the dorsal surface of type specimen; antorbital fragment from Owen (1884, pl. XVI); interotic fragment from a plaster replica in U.C.M.P. collection of Brit. Mus. (Nat. Hist.) no. R 503. x 0.58.

R. capensis was collected nearly a century ago near Beersheba, Orange Free State. Owen (1884, pp. 333-338, pls. XVI and XVII) described and figured the antorbital portion and the lower jaws. A central piece of the left lower jaw is missing and the contact shown by Owen (pl. XVII) is obviously not the natural one. As

Romer (1947, p. 190) has pointed out, the distance from the glenoid fossa to the symphysis in Owen's reconstruction is far too short for the length of the antorbital region of the skull. Owen neglected the interotic and exoccipital portions. The exoccipital was described and figured by Watson (1919, pp. 35-36, fig. 21).

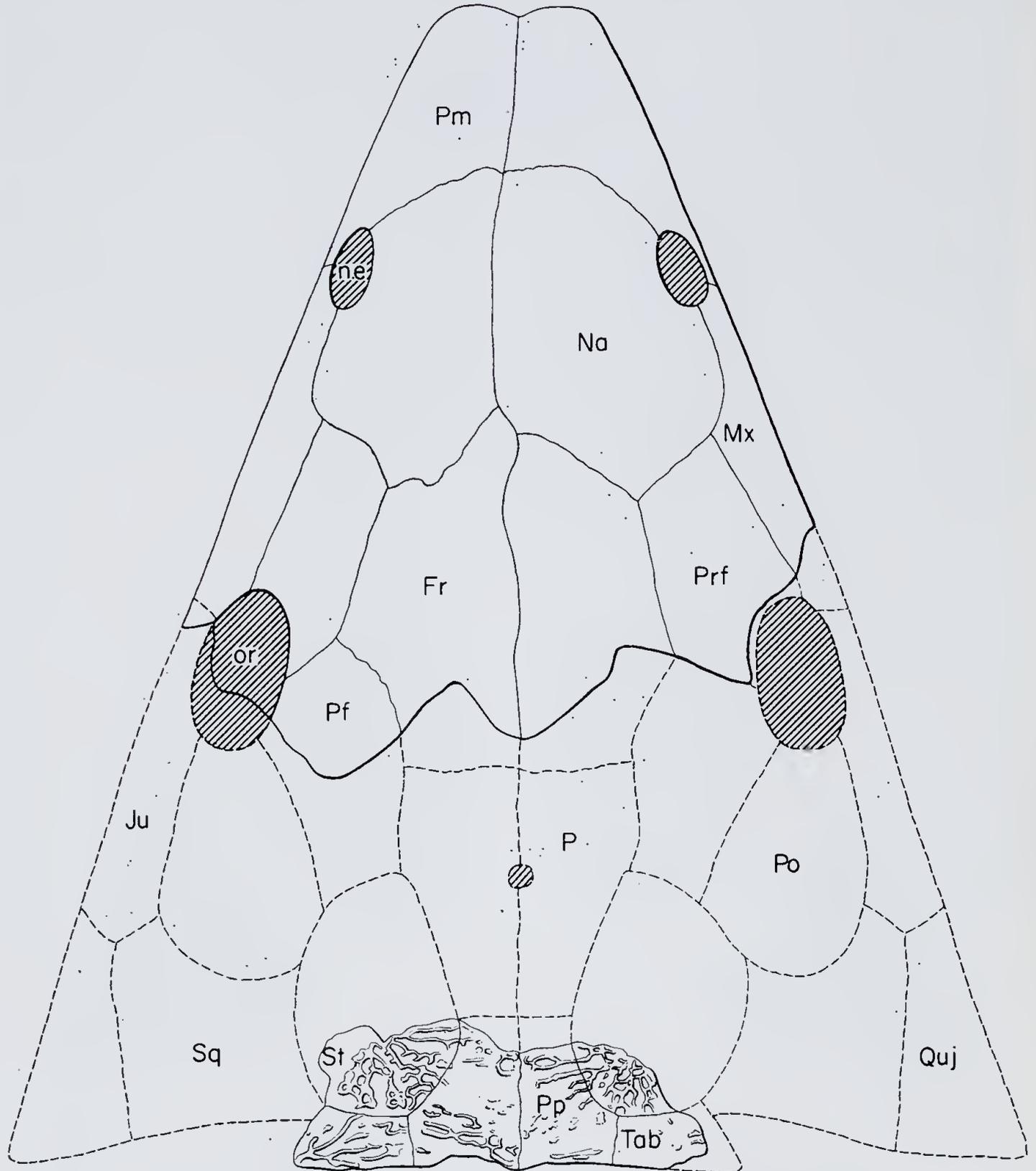


Fig. 13.—*Rhytidosteus capensis* Owen, reconstruction of the palatal surface of the type specimen; antorbital fragment from Owen (1884, pl. XVII); basicranial fragment from a plaster replica in the U.C.M.P. collection of Brit. Mus. (Nat. Hist.) no. R 503. x 0.58.

The British Museum responded generously to a request for further information and loaned plaster replicas of the exoccipital and unillustrated fragments to the University of California Museum of Paleontology.

Comparisons with *D. kimberleyensis* show that the interotic and exoccipital fragments are comparable in size with the antorbital portion of the skull. They were undoubtedly derived from the same individual. New restorations of the dorsal and palatal surfaces are attempted (figs. 12 and 13). The interotic portion has most of the postparietals and tabulars and the posterior edges of the supratemporals. The position of this fragment in the restoration was determined by roughly estimating the size of the missing parietal bones and the distance of the tabular horn from the missing posterolateral skull corner. Owen's plate XVI shows that the left half of the antorbital portion is crushed; it has been restored to correspond in shape with the right side.

Many details of the *R. capensis* fragments relate this form to *D. kimberleyensis*. The orbit and naris lie close to the lateral edge of the skull. The orbit faces outward as well as upward. There is no lacrimal bone. The supra-orbital groove has a similar course in the antorbital region. The skull table is nearly flat between the tabular horns and the cheek probably descended steeply to the quadrate region. The tabular horn is small and sharply angular. The surface ornament of *R. capensis*, although coarser in texture, has the fundamental structure of *D. kimberleyensis*: the bifurcating radial ridges have a higher relief than the concentric ridges; nodes along each radial ridge mark conjunctions with the concentric ridges; pitted and grooved areas are irregularly arranged on each bone.

The palate surface is completely covered with a dense shagreen of tiny denticles. The cultriform process is broad and has a conical termination between the vomers. The choana, although more regularly oval than that of *D. kimberleyensis*, is also set well in from the lateral margin of the skull. The fossae for the vomerine and palatine tusks are similarly placed relative to the choana.

The conjoined lower jaw rami form a bulbous symphyseal shelf which fits within the margins of the upper jaw. The ventral borders of the rami are sharply keeled posteriorly. The retro-articular processes are similar in relative size to those of *D. kimberleyensis* and the outlines of the glenoid facet and the adductor fossa correspond closely. These characters of the lower jaws also indicate a close relationship of the African and Australian genera.

A number of characters of the skull and lower jaw distinguish *R. capensis* from *D. kimberleyensis*. *R. capensis* has a longer and narrower antorbital region of the skull. The external naris is set further back from the snout tip. The anterior part of the postparietal is indented by the posterior margin of the supratemporal. The supraorbital groove is less well defined.

The left side of the antorbital fragment of *R. capensis* appears to be broken off just anterior to the forward edge of the interpterygoid vacuity.

The portion of the palate anterior to the vacuity is relatively much longer than it is in *D. kimberleyensis*. As restored, the interpterygoid vacuities of *R. capensis* are proportionately much smaller than those of *D. kimberleyensis*. In *R. capensis* the orbit lies above and lateral to the anterior part of the interpterygoid vacuity; in *D. kimberleyensis* the orbit is above and lateral to the center of the vacuity.

The lower jaw of *R. capensis* is deeper and more massive than that of *D. kimberleyensis*. The posterior edge of the retroarticular process is notched whereas it is pointed in *D. kimberleyensis*.

Romer (1947, p. 190, fig. 34) referred *Microposaurus casei* (Haughton, 1925, pp. 253-256, figs. 17-18) to *R. capensis* and made a composite restoration of the two skulls. He considered the common horizon and the similarity of the skull shape and size to be indicative of identity and the lateral orbit and naris of *R. capensis* and the posteriorly placed quadrates of *M. casei* to be the results of differential distortion.

By including the interotic fragment of *R. capensis*, a restoration of the dorsal surface which differs materially from Romer's composite has been produced. The broad cultriform process and the extensive exoccipital-pterygoid suture suggest that *R. capensis*, unlike *Microposaurus casei*, is unrelated to the trematosaurus.

M. casei displays such typical trematosaur characters as a greatly extended postorbital region, a very long parasphenoid-pterygoid suture, a narrow cultriform process and a double anterior palatal vacuity. The parasphenoid probably extensively underplates the exoccipitals as in other trematosaurus.

"*Trematosaurus*" *kannemeyeri* (Broom, 1909, pp. 270-271) has tentatively been referred to *R. capensis* by Kitching (1957, p. 81). Broom did not illustrate the specimen but von Huene (1920, fig. 8) contributed an interpretation restored from the measurements cited by Broom. The skull is very narrow in the orbital region. This fact alone suggests that "*T.*" *kannemeyeri* should be retained in the Trematosauridae. The generic designation, however, is probably not correct.

Plaster and rubber replicas of the holotype skulls of *P. erici* and *P. wimani*, generously donated by the Paleontological Institute, University of Uppsala, have augmented the excellent review of the genus by Nilsson (1946) and have made direct comparisons with the Australian genus possible. Nilsson's careful reconstructions have been of great value in this work.

Peltostega has long been a problematic genus. It has been variously classified in the Trematosauridae, the Metoposauridae, the Sclerocephalidae and in its own family, Peltostegidae. Wiman (1916, pp. 210-216, text figs. 1-3, pl. XV, figs. 1-3, pl. XVI, fig. 1) first described the type and only specimen of *P. erici*. It was recovered from the Triassic Posidonomya beds of Mt. Anderson, Spitzbergen with *Aphaneramma rostratum* and *Lyrocephalus euri* by the third Swedish Spitzbergen expedition in 1915.

The specimen is the posterior half of a large skull (33-34cm. in median length as restored by

Nilsson, 1946). The postorbital part of the skull roof, the entire occipital surface and part of the palate are preserved. The original restorations of the missing portions of the skull by Wiman are too foreshortened in the antorbital region. The battered condition of the palate (Wiman, pl. XV, fig. 2) led Romer (1947, p. 189) to the conclusion that the structure identified by Wiman as the cultriform process of the parasphenoid was actually the ventral surface of the overlying sphenethmoid. He suggested that the cultriform process had been a narrow structure as in trematosaurids. Nilsson, however, identified the structure as a cultriform process and it is probable that this interpretation is correct.

Nilsson (pp. 4-34) described a second species, *P. wimani*, from the same horizon in Spitzbergen. The holotype, another occipital portion, was found at Mt. Wallenberg. A referred skull roof fragment was found at Mt. Congress. The holotype of *P. wimani* is even larger than that of *P. erici* and differs from it in its comparatively delicate ornament of the dorsal surface, proportionately greater exoccipital condyles and in details of the bones of the skull roof.

Many characters relate *Peltostega* to *Deltasaurus*. Both genera have broad triangular skulls and lateral orbits facing outward as well as upward near the middle of the lateral margins. The parietal foramen of *P. erici* is close behind a line between the posterior borders of the orbits as in *D. pustulatus*. Angular otic notches are present in *D. kimberleyensis* and in both species of *Peltostega*. The frontal bone is excluded from the orbital border in *P. erici* and in both species of *Deltasaurus*.

The dermal sculpture of *Peltostega* corresponds closely to that of *D. kimberleyensis*. The resemblance of sculpture to that of *D. pustulatus* is less obvious, but as noted above, the sculpture of this species is reasonably regarded as a modification of that of *D. kimberleyensis*. The skull roof bones of the *Peltostega* specimens are uniformly pitted over most of their surfaces. These pits are small and equidimensional as in *D. kimberleyensis* but are somewhat more distinct as the concentric ridges of sculpture have a higher relief than in the Australian form. As in *D. kimberleyensis* there is a basic pattern of radiating ridges which carries small rounded nodes at points of bifurcation and at points of junction with the concentric ridges. The peripheries of certain bones of *P. wimani*, notably the anterior edges of the left squamosal and left quadratojugal, have exceptional development of the radiating ridges and the pits are poorly developed or lacking due to imperfect development of the concentric ridges; similar unpitted areas also occur on the type skull of *D. kimberleyensis* as noted in the descriptive section.

Common characters of the posterior part of the palatal surface include broad cultriform processes and broad corpi of the parasphenoid bones and broad posterior margins of the interpterygoid vacuities.

The occipital surfaces of *P. erici* and *D. kimberleyensis* are somewhat similar. The supra-

occipital fenestrae are round and are larger than the foramina magni. The cheeks slope down sharply from the flat skull table. The descending processes of the squamosal are separated from the ascending processes of the pterygoids by long, narrow palatoquadrate fissures.

Peltostega has a longer and narrower antorbital region (as reconstructed by Nilsson), and the posterior margin of the skull table is more strongly excavated. The lateral line system is not as conspicuously developed in *Peltostega*; the supraorbital groove is not continuous medial to the orbit of *P. erici*; and the supratemporal groove of this species is shorter; *P. wimani* seemingly lacks an occipital groove while that of *P. erici* is discontinuous. Both species of *Peltostega* have a posterior bifurcation of the jugal groove not present in *D. kimberleyensis*.

The palatal shagreen of *P. erici* is apparently quite rudimentary although this may be the result of incomplete preservation. The skull has a few small denticles on the pterygoid bone and a row of larger teeth on the posterior part of the left ectopterygoid; these latter are probably also part of the shagreen as they are too irregularly orientated and too medial to be part of a palatal tooth row.

The basicranial regions of *Peltostega erici* and *D. kimberleyensis* show minor differences in construction. The parasphenoid-ptyergoid suture is more lateral in *D. kimberleyensis*. The quadrate ramus of the pterygoid is broader and shorter in *P. erici*. The Australian species lacks the large rounded excavation of the posterior margin of the palate between the exoccipital and quadrate condyles. *P. erici* has a small projection of the pterygoid on the posterior margin of the interpterygoid vacuity; this is not present on the outline of the pterygoid which is well-preserved on U.C.M.P. no. 61063.

The only notable difference of the occipital surface is the construction of the subotic process of the exoccipital. This is a broad, flat, obliquely orientated structure in *D. kimberleyensis*. It is a short vertical bar just ventrolateral to the condyle in *P. erici* and *P. wimani*.

The incompleteness of the *Peltostega* and *Rhytidosteus* material has made it impossible to determine if either is more closely related to *Deltasaurus* than the other. *Deltasaurus* and *Rhytidosteus* share a great intensification of the shagreen of the palate, but this may also have been true of *Peltostega*. The dermal sculpture is basically similar in the three genera; that of *Rhytidosteus* is somewhat coarser than that of *Deltasaurus* and that of *Peltostega* is somewhat finer. *Peltostega* is perhaps the most primitive genus in one respect: it lacks a suture between the exoccipital and the pterygoid on the palate. *Deltasaurus* has a short exoccipital-ptyergoid suture and *Rhytidosteus* has an extensive one. If the Rhytidosteidae follow the trend found in the Capitosauridae and Brachyopidae described by Watson (1919, 1951, 1956), this sutural contract would be progressively enlarged through evolution.

Comparisons of the Rhytidosteidae with other families

The Rhytidosteidae superficially resemble several genera of the Trematosauridae, particularly *Lyrocephalus*, in the triangular shape of the skull, in the relatively small interpterygoid vacuities and in the positions of the orbits near the levels of the sagittal midpoints. Nilsson (1946) distinguished the Trematosauridae from *Peltostega* by the elongation of the skull between the orbits and the parietal foramen, by the deeper occiput, by the exceedingly high narrow cultriform process and by the great length of the corpus of the parasphenoid, which reaches back to underplate the exoccipital condyles. These characters distinguish the Trematosauridae from the Rhytidosteidae. The double anterior palatal vacuities of trematosaurids is an additional difference.

Nilsson noted the following characters of the Capitosaurids which distinguish this family from *Peltostega*: the otic notch is deeper and narrower; the orbits are placed in the posterior portion of the skull roof; the cultriform process is not wide and it often has a keeled ventral surface; the pteroccipital foramen is not as well defined; and there is a high sharp oblique ridge on the ascending process of the pterygoid (lacking, however, in *Paracyclotosaurus*). These are also valid differences of this family from the Rhytidosteidae.

Capitosaurids and Rhytidosteids share vertical occiputs and differ from the trematosaurids and metoposaurids in this respect. The retroarticular process is similar in shape in the two families. Some of the rhytidosteid genera parallel characters found in certain capitosaurids. *Deltasaurus* has a single anterior palatal vacuity, similar in shape to that of *Parotosaurus* and *Cyclotosaurus*. There is a palatoquadrate fissure between the squamosal and the pterygoid on the occiputs of *Deltasaurus*, *Peltostega* and *Parotosaurus*. *Deltasaurus* and *Rhytidosteus* have an exoccipital-ptyerygoid suture as do *Cyclotosaurus* and *Paracyclotosaurus*.

Nilsson remarked on the superficial similarities of *Peltostega* and the metoposaurids in the lateral positions of the orbits and the broad cultriform processes. The metoposaurid orbit, however, does not face dorsolaterally as is the case in *Peltostega* and the cultriform process is narrow between the vomers in metoposaurids. The metoposaurid cultriform process passes broadly and evenly into the corpus of the parasphenoid; the corpus expands suddenly in *Peltostega*.

Nilsson distinguished the metoposaurids from *Peltostega* by the anterior positions of the orbits, by the enlarged postorbital regions, by the enlarged paraquadrate foramina and by the reduced posttemporal fossae of this family. These distinctions are also valid for the other rhytidosteid genera.

Additional metoposaurid characters not found in the rhytidosteid genera are occiputs which slope down and back from the skull roof and complex (and poorly understood) relations of the pterygoids and squamosals on the cheek portions of the occiputs.

The Brachyopidae share only general labyrinthodont characters with the Rhytidosteidae.

The Rhytidosteidae are a conservative family and retain many primitive rhinesuchid-lydekkerinid conditions. The palatal shagreen, the locations of the orbits near the centre of the skull, the broad cultriform processes, the short parasphenoid-pterygoid sutures and the locations of the parietal foramina close behind the orbits distinguish the Rhytidosteidae from contemporary early Triassic families and also suggest derivation of this family from the Rhinesuchidae, Lydekkerinidae or Uranocentrodontidae. The undivided anterior palatal vacuity of *Deltasaurus kimberleyensis* and the palatoquadrate fissure of both *D. kimberleyensis* and *Peltostega erici* are probably also conservative features. All late Permian rhinesuchoids in which the snout region is preserved have a single anterior palatal vacuity. *Lydekkerina huxleyi* (Watson, 1919, fig. 4) and *Limnoiketes palundinatans* (Parrington, 1948, fig. 6B), show palatoquadrate fissures.

The specialized characters of the skull readily distinguish the Rhytidosteidae from the Rhinesuchidae and the Lydekkerinidae and necessitate a superfamilial separation. The rhytidosteids have narrower snouts and broader occiputs. The orbits lie near the lateral edge of the skull roof. The sculpture pattern is modified. The quadrate condyles have moved forward relative to the exoccipital condyles. *Deltasaurus*, *Peltostega* and *Rhytidosteus* have smaller and more angular otic notches than those found in members of the late Permian families. The palatal exposures of the cultriform processes of the parasphenoids of rhinesuchids and lydekkerinids terminate in sharp angles between the vomers. In most genera of these families this termination lies behind the level of the anterior borders of the interpterygoid vacuities. The rhytidosteid cultriform processes reach far forward between the vomers and have broad conical terminations.

Comparison of the Rhytidosteidae with problematic Triassic genera

Laidleria

Laidleria gracilis, recently described by Kitching (1957, pp. 67-82, figs. 16-19), consists of the palatal surface of the skull, the lower jaws and the articulated partial skeleton, and is preserved on a sandstone slab in the Albany Museum, Grahamstown, South Africa. It was found in the Karroo of the eastern Cape Province. The exact stratigraphic provenance is uncertain but it is probably from the Cynognathus zone as it was found just below the Stormberg rocks and as the matrix resembles Cynognathus zone matrix of other localities.

Certain features of the skull and lower jaw are suggestive of the Rhytidosteidae: the skull is triangular and the occiput is very broad; the orbit lies near the lateral border of the skull; the postorbital region is short; the cultriform process is broad; and the symphysis is expanded into a broad plate.

Many details of skull construction prevent an inclusion of *Laidleria* in the Rhytidosteidae.

The cultriform process of the parasphenoid, although broad, tapers to a sharp point anteriorly in contrast to the broad and conical terminations found in *Deltasaurus* and *Rhytidosteus*. The snout is slender and pointed. In Kitching's interpretation, an otic foramen replaces the otic notch (a condition paralleled by *Tertrema* of the Trematosauridae and by *Cyclotosaurus* and *Paracyclotosaurus* of the Capitosauridae). The frontal forms part of the orbital border; palatal shagreen is either absent or is greatly reduced (a small pitted area on each pterygoid may represent shagreen); there is a palatal tooth row (definitely absent in *Deltasaurus*); and the choana lies close to the lateral edge of the skull.

The most profound differences of *Laidleria* from the Rhytidosteidae occur on the occipital surface. The *Laidleria* occiput is very low and is of uniform height from corner to corner. The descending process of the squamosal has sutural contact with the ascending process of the pterygoid. The exoccipital apparently lacks the processes lamellosus and basalis (a condition also found in *Indobrachyops panchetensis* (von Huene and Sahni, 1958) and the foramen magnum cannot be distinguished from the supraoccipital and basioccipital foramina.

Three characters of *Laidleria* are unique among the Labyrinthodontia: the dentary teeth are very large, few in number and widely spaced; the contact of the pterygoid and ectopterygoid in the palate is peculiar—a rounded posterior lapet of the ectopterygoid underlies the anterior extent of the palatal ramus of the pterygoid; the tabular has two sutures with the exoccipital—the usual suture on the paraoccipital bar and an additional suture medial to the posttemporal fossa.

Useful characters for systematic purposes are perhaps present on the skull roof of *Laidleria gracilis* which is still embedded in matrix. The nature of the lateral line system, the position of the parietal foramen and most of the sutural relations of this surface are unknown.

Kitching (fig. 19B) shows sculpture on the skull peripheries and on the labial surfaces of the lower jaws. The illustration does not depict this sculpture clearly, and comparisons with the sculpture of the rhytidosteid genera cannot be made.

The lower jaw symphysis covers the region of the anterior palatal vacuity and the shape of this structure is not known.

Laidleria superficially resembles *Lyrocephalus* in skull shape but the cultriform process of the parasphenoid is too broad for a trematosaur and the parasphenoid lacks the posterior extension which is characteristic of the Trematosauridae. The numerous peculiarities of skull construction exclude this African genus from the other Permian and Triassic families. *Laidleria* is best placed in its own family, Laidleriidae as Kitching has suggested. However, there is greater resemblance to the Rhytidosteidae than to other families and it may be provisionally included in the Rhytidosteidae.

Lastiscopos

Wilson (1948, pp. 359-361, pl. 59) described the only known specimen of *Lastiscopos disjunctus*, a poorly preserved skull from the late Triassic Dockum Formation of Texas, and provisionally placed it in a new family, Lastiscopidae. Little could be said of its construction. As Wilson noted (p. 360), the high vault of the skull and the large interpterygoid vacuity suggest the Trematosauridae. He also stated: "The extreme posterior edge of the parasphenoid is missing but there is good evidence in the broken edges of the bone that it at one time covered the ventral surface of the exoccipitals." This condition would also tend to relate *Lastiscopos* to the Trematosauridae.

Two characters of the skull suggest the Rhytidosteidae rather than the Trematosauridae. These are the extreme lateral position of the orbit and the short distance between the orbits and the parietal foramen.

It is to be hoped that more evidence establishing the systematic position of this animal will be found. It is the only non-metoposaurid labyrinthodont of the North American late Triassic and if it proves to be either a trematosaurid or a rhytidosteid, it will be the latest known occurrence of its family. For the present the family, Lastiscopidae should be placed as *incertae sedis* among the superfamilies of the Triassic Tennoispondyli.

Age relationships

The entire collection of fossil vertebrates from the Blina Shale may be considered as a faunal unit through the occurrence of *Deltasaurus kimberleyensis*. Skull and lower jaw fragments of this animal were found at all the Erskine Range localities although these are spaced over two square miles of area and more than 70 vertical feet of section. Four jaws of *D. kimberleyensis* were collected at the B.M.R. Dry Corner locality and one at U.C.M.P. locality V 6044. There is no evidence of evolutionary change or faunal replacement among the collections from the various localities.

The uniform lithology of the Blina Shale exposures in the Erskine Range is consonant with the uniformity of the faunal content. There are no intraformational disconformities within the measured section at V 6040 and there is no other evidence to indicate a major interruption of the depositional cycle. No lateral or vertical changes in the sedimentary facies suggest the presence of more than one depositional environment.

The microfloras from the Blina and Kockatea Shales establish a general time equivalence for these units within the lower part of the Scythian Stage (Balme, 1963). The presence of species of *Deltasaurus* in both formations supports the correlation. Dickins and McTavish (1963) place the portion of Kockatea Shale which contains *Deltasaurus pustulatus* in the Otoceratan zone. Minor differences in bone sculpture and skull proportions are the only features which distinguish *D. kimberleyensis* from the Kockatea species and it is not likely that the stratigraphic position of the Blina fauna is far removed from the Otoceratan zone.

Although detailed considerations of the age relationships of the Blina fauna are deferred to a subsequent paper certain conclusions should be stated here.

The similarity between *Deltasaurus*, *Rhytidosteus* and *Peltostega* indicates that the Blina Shale, the Cynognathus zone and the Posidonomya beds are close in time to one another. These correlations are supported by the occurrence in the Blina Shale of a brachyopid which is close to *Batrachosuchus* of the Cynognathus zone and of trematosaurids which are perhaps congeneric with *Aphaneramma* and *Tertrema* of the Posidonomya beds. The Cynognathus zone, in turn, may be equated with the Bunter Formation of Germany, and with Zone VI of the Cis-Uralian region of the U.S.S.R. through the occurrence in these three units of *Parotosaurus* and *Trematosaurus*. The Posidonomya beds contain ammonites and other invertebrates as well as fish and amphibians and the ammonites place the level in the upper part of the Scythian Stage (Spath, 1930 and Frebold, 1939). In all probability, therefore, the time range represented by the Posidonomya beds, the Blina Shale, the Cynognathus zone, the Bunter Formation and Zone VI is contained by the Scythian Stage.

Watson (1942 and 1957) and Romer (1947) considered the Lystrosaurus zone to be the earliest Triassic level in the Beaufort Formation of South Africa. The temnospondyls of this zone, however, are rhinesuchoids, a group which probably contains the ancestors of the younger capitosauroids (Watson, 1962) and rhytidosteoids. The cranial structure of the rhinesuchoids is notably more primitive than that found in the younger superfamilies, indicating an appreciable time lapse from the Lystrosaurus zone to the Cynognathus zone and the Blina Shale. The position of the Blina fauna in the lower part of the Scythian stage and of *Deltasaurus pustulatus* in the basal Otoceratan zone suggests that Cynognathus zone is the earliest Triassic level in the Beaufort Formation and that the Lystrosaurus zone is of late Permian age.

Acknowledgments

The field program in northwestern Australia was sponsored by the Museum of Paleontology, University of California and the Western Australian Museum. Dr. R. A. Stirton, Director of the Museum of Paleontology, arranged financial support and guided the preliminary planning. Dr. W. D. L. Ride, Director of the Western Australian Museum, supervised the procurement and transport of vehicles and supplies and later arranged the shipment of the fossil collections to the University of California. Each institution provided the use of a vehicle and trailer. The Museum of Paleontology defrayed costs of food and equipment and provided funds for travel. The Western Australian Museum provided salaries for two members of the party.

The field party is indebted to British Petroleum Kwinana Ltd. and in particular to Mr. L. R. Gascoine for the provision of fuel and all service costs at BP garages for the vehicles and to Western Australian Petroleum Pty. Ltd. for the use of a storage building in Derby.

It is a pleasure to acknowledge the kind hospitality of Mr. and Mrs. P. Slater of Derby, Mr. and Mrs. W. W. Henwood of Calwinyardah Station, Mr. W. W. Henwood Jr. of Blina Station, and Mr. and Mrs. K. C. Rose of Liveringa Station.

The success of the field program is largely a reflection of the experience and leadership of Dr. C. L. Camp. Mr. Duncan Merrilees, Dr. Kenneth G. McKenzie and Dr. W. D. L. Ride aided greatly in the collection of fossil vertebrates.

I wish to thank: Dr. W. D. L. Ride, Director of the Western Australian Museum and Mr. J. M. Rayner, Director and Dr. N. H. Fisher, Chief Geologist of the Bureau of Mineral Resources, Geology and Geophysics for the loan of fossil collections, and the British Museum of Natural History and the Uppsala University Paleontology Institute for providing replicas of type specimens.

I appreciate the many helpful suggestions made by Drs. Joseph T. Gregory, Ruben A. Stirton, Robert C. Stebbins and Samuel P. Welles who critically read this manuscript. Mrs. Mary McDonald accomplished the difficult preparation of much of the collection. Drawings of the fossil specimens are the work of Mr. Owen J. Poe.

I am particularly grateful for the advice, assistance and encouragement offered by Dr. Joseph T. Gregory under whose direction this research was conducted.

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9.—The identity of *Mus burtoni* Ramsay, 1887 (Rodentia, Muridae, *Melomys*) from the neighbourhood of Derby, Western Australia

by J. A. Mahoney*

Manuscript received 16th February 1965; accepted 27th April 1965

Abstract

The identity of *Mus burtoni* has remained obscure following its erection by Ramsay in 1887. The type skull and mandible of this species have now been found in the Australian Museum, Sydney. *Mus burtoni* is placed in *Melomys* Thomas, 1922 where it is predated by *Melomys cervinipes* (Gould, 1852) and *Melomys rufescens* (Alston, 1877). It is doubtfully conspecific with the former species and distinct from the latter. *Melomys burtoni* (Ramsay, 1887) is tentatively accepted as a valid species pending more satisfactory knowledge of the genus.

Introduction

Mus burtoni was erected by Ramsay (1887b) for a single rodent specimen received from Derby, north Western Australia. The fragmentary skull and mandible and the feet are illustrated in the original description and skin (or flesh) dimensions listed. The sex is not stated nor is a catalogue number or depository noted. No further specimens have been recorded for *Mus burtoni* and subsequent authors have accepted Ramsay's name for it without comment (Ogilby, 1892 p. 107), indicated that its identity is obscure (Longman, 1916 p. 34; Iredale and Troughton, 1934 p. 75; Ellerman, 1941 p. 214), or ignored it (Tate, 1951). The type skull and mandible of *Mus burtoni* have now been found in the Australian Museum, Sydney. These have been examined and *Mus burtoni* is placed in *Melomys* Thomas, 1922.

Melomys burtoni (Ramsay, 1887)

Holotype: Australian Museum No. S427, fragmentary skull and mandible. The skin of the holotype is not registered under this number and has not been found. The holotype was received from T. H. Bowyer-Bower Esq.,† from Derby, north Western Australia. Ramsay does not clearly indicate that the specimen was collected at Derby consequently its locality is recorded here as the neighbourhood of Derby, Western Australia. The moderate wear on the molars of the holotype suggests that it is a young adult.

The holotype skull and mandible are registered in the Australian Museum "S" catalogue as "Rat Skull of". Prior to registration this specimen belonged in the Museum's "old collection". Collector, date of collection, and locality data are not recorded in the catalogue

for it, nor is any indication given there that it is a type. Mr. G. P. Whitley, recently retired Curator of Fishes, Australian Museum, has examined the catalogue entry for the holotype and believes it to have been made by Mr. E. R. Waite (personal communication). Registration of this specimen, dated August 12, 1893, was made during Dr. E. P. Ramsay's Curatorship of the Australian Museum (September 22, 1874 to December 31, 1894). The skull and mandible are accompanied by an unattached label (pill-box top), shown in figure 2, M. The initials "G. H. B." at the top of the label are the same as those of G. H. Barrow, the artist who produced the illustrations for Ramsay's paper on *Mus burtoni*. The words following "6" at the bottom of the label are difficult to read but may be "times abt."—Ramsay's published figures of the skull and lower molars of the holotype of *M. burtoni* are noted by him as being 6 times natural size. "B Bower" and "Derby" are written in pencil on the right hand side of the label. Two Australian Museum numbers, S427

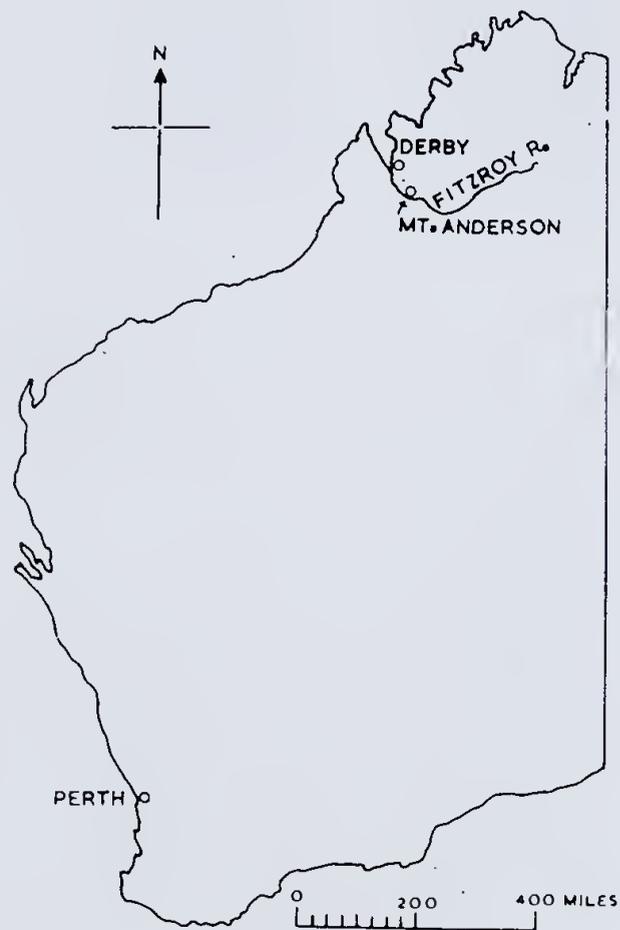


Figure 1—Locality map; Western Australia.

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† Thomas Henry Bowyer-Bower accompanied by a taxidermist, Walter Burton, left Sydney early in 1886, and collected in north-western Australia, up the Fitzroy River as far as Mount Anderson (see fig. 1). He then collected on Thursday Island, off Cape York, and at Palmerston in Northern Territory, where he died of typhoid fever on December 22, 1886. (auth. Whittell, 1954, Pt. 2, p. 71).



A



B



C



D



E



F



G



H



J



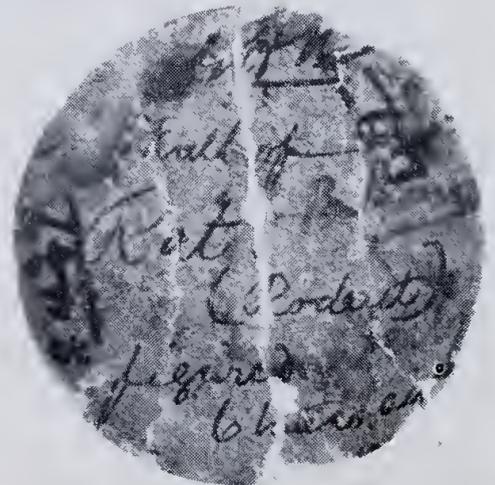
I



K



L



M

and 427, are also included on it. One, at least, of these numbers was apparently written on the label by Waite at the time of registration while the second number may have been added later. Other writing on the label agrees with that of Ramsay (see Whittell, 1954 Pt. 1 Pls. 29, 30 for a sample of Ramsay's handwriting).

The Australian Museum skull and mandible (S427) agree well with Ramsay's figures of *Mus burtoni* if allowance is made for some latitude in their production, and if the illustration of the skull is a mirror image of the original. Ramsay's figure 2 shows the presence of a left third molar but this is the only tooth now missing from S427. This must have been missing from the skull when Ramsay had it, otherwise Ramsay could not have described it as having a portion of the dentition.

One further rodent, the holotype of *Hapalotis boweri* Ramsay, 1887 from "North West Australia", is recorded by Ramsay (1887a) as having been received by him from Bowyer-Bower. The skull of this specimen cannot be found and may not have been sent to Ramsay (see Ramsay, 1887a p. 1154). It is not figured in his paper on *H. boweri* and does not comply with data on the label accompanying S427.

The above details, considered together, justify recognition of S427 as the holotype skull and mandible of *Mus burtoni* Ramsay.

Specimens examined: Holotype.

External characters: Ramsay notes that the chief characteristic in this species is its remarkably woolly and soft fur, and uniform colour. His account of the external characters is reiterated below but with the measurements, given by him in inches, converted to millimetres:

General colour of a uniform dull ashy-grey or mouse-colour, fur dense, close, thick and soft, of one kind, almost woolly, slightly browner above than on the under surface, which is of a light grey tint; head rather short; ears moderate; tail naked, not quite the length of the body; whiskers black reaching to behind the ears; from snout to eye, 17.8 mm; from snout to ear, 30.5 mm; length of ear 16.5 mm, greatest width 11.4 mm; forearm, 17.8 mm; hand, 11.4 mm; hind foot, 25.4 mm; tail, 104 mm; total length from snout to tip of tail, 226 mm.

Ramsay's figures of the hind and fore feet of the holotype are reproduced in figure 2, K and L.

Skull and mandible: Ramsay did not describe the skull and mandible of the holotype. However, he noted that the former is broken and that only the anterior parts of it with a portion of the dentition is left. M^3 is missing from the left molar row of S427 and the posterior portion of the palate is badly damaged:

Antero-internal angles of nasals broken but fronts of nasals about level with premaxillae; posterior ends of nasals level with backs of nasal processes of premaxillae. Nasals with maximum width subterminal then tapering

Figure 2 (opposite)—*Melomys burtoni* (Ramsay). A—S427 (Holotype), dorsal view of cranium; B—ventral view of cranium; C—right lateral view of cranium; D—left lateral view of cranium; E—occlusal view of right upper molar row; F—occlusal view of left lower molar row; G—dorsal view of left mandibular ramus; H—lingual view of left mandibular ramus; I—labial view of left mandibular ramus; J—lingual view of right mandibular ramus; K—Holotype, hind foot; L—Holotype, fore foot; M—Australian Museum label accompanying holotype of *Melomys burtoni* (Ramsay). A—D and G—J x2.6 approx.; E & F x8.0 approx.; H, K & L x2 (reproduced from Ramsay, 1887b Pl. 17 figs. 4-5); M x1.3.

to their junction with the frontals. Rostrum short, broad, and deep. Lacrymals small. Postorbital ridges present. Dorso-anterior angles of zygomatic plates rounded, about level with anterior edges of bottom halves of plates (anterior edge of left zygomatic plate damaged). Incisive foramina elliptical with rounded ends and with greater part contained in maxillae; left incisive foramen extending to anterior extremity of M^1 . Left posterior palatal foramen small, opposite anterior end of M^2 . Incisors opisthodont. Molars moderately worn, without accessory cusps.

Angular processes and coronoid regions of mandibular rami broken. Molars without accessory cusps.

Measurements for the holotype are tabulated in table 1. The skull, mandible, and dentition of this individual are illustrated in figure 2, A to J.

TABLE 1

Measurements (in millimetres) for holotype skull and mandible (Australian Museum No. S427) of *Melomys burtoni* (Ramsay).

Length from anterior extremity of nasal to posterior extremity of inter-frontal suture	19.0 approx.
Nasal length measured from anterior extremity of nasal to posterior extremity of internasal suture	8.8 approx.
Maximum width across nasals	3.3
Width across nasals between nasofrontopremaxillary points	1.9
Width of rostrum at anterior end of incisive foramina	4.6
Maximum width of rostrum	5.1 approx.
Interorbital width	5.0
Height of skull at anterior extremity of M^1	7.2
Minimum width across zygomatic plate	3.3
Length of incisive foramen	5.2*
Width across incisive foramina	2.0 approx.
Length of diastema	7.7
Width of palate between alveoli of antero-internal roots of M^1	2.9 approx.
M^1 Length x width	3.1 x 1.6
M^2 Length x width	2.2 x 1.6
M^3 Length x width	1.1 x 1.1
M^{1-3} Length	5.8
Length of mandibular ramus from tip of incisor to posterior extremity of condyle measured with ventral surface of ramus horizontal	19.4
Height of condyle above ventral surface of mandibular ramus measured with ventral surface of ramus horizontal	7.5 approx.*
M_1 Length x width	2.6 x 1.5
M_2 Length x width	2.1 x 1.7
M_3 Length x width	1.4 x 1.3
M_{1-3} Length	6.0

Notes: The length and height marked by asterisks were measured on the left side of the skull and mandible; measurements of the other paired structures were taken on the right side of the skull and mandible. Measurements taken by vernier callipers graduated to read to 0.05 mm; tooth measurements do not include roots.

Discussion

Twelve species of *Melomys*, including *M. burtoni* (Ramsay), have been recorded from Australia. Except for the Queensland form, *Melomys callopes* Finlayson, 1942, these were erected prior to 1938 when Rümmler published on the New Guinea Muridae. In that work, Rümmler (1938 p. 100) reduced the Australian species to two, *Melomys cervinipes* (Gould, 1852) from Queensland, Northern Territory, and

New South Wales¹, and *Melomys lutillus* (Thomas, 1913) from Queensland (and New Guinea). Both Ellerman (1941 pp. 230-231 & 1949 pp. 87-88) and Tate (1951 p. 292) concur with Rümmler in listing only *M. cervinipes* and *M. lutillus* as the Australian species; but, while Ellerman agrees closely with Rümmler (1938 pp. 116 & 130) in his allocation of the various Australian populations of *Melomys* under these two names, Tate's arrangement is rather different, and it is clear that further work will be required before boundaries can be placed with any certainty about these taxa.

At the time that these authors revised *Melomys*, *M. burtoni* was not recognized as a species of that genus and since it is an older name than all available names of *Melomys* (excluding *Pogonomelomys*—see under) except *M. cervinipes* (Gould, 1852) and *M. rufescens* (Alston, 1877), the identification of its biological status and affinities is nomenclaturally important. *M. burtoni* is distinct from *M. rufescens*, which is only known to occur in the Bismarck Archipelago, New Guinea, and the Solomon Islands (Laurie and Hill, 1954). Unfortunately, so little is known of the morphological ranges of both *M. cervinipes* and *M. lutillus* that the relationships of *M. burtoni* to either of these Australian species cannot be determined at present. It can only doubtfully be placed within *M. cervinipes* (Gould); therefore I tentatively accept it here as a valid species of *Melomys* but recognize that further material and more detailed studies will probably result in its identification with one or more of the extra-Western Australian populations of *Melomys*. Until now, *Melomys* was not known to occur in Western Australia.

While no species of *Pogonomelomys* are known to occur in Australia this genus is closely related to *Melomys* and should be taken into consideration in discussing the status of *M. burtoni*. *Pogonomelomys* (type species *Melomys mayeri* Rothschild and Dollman, 1932) was first introduced, as a subgenus of *Melomys*, by Rümmler (1936 p. 248) but was later elevated to full generic rank by Tate and Archbold (1941 p. 5). In doing this, they drew particular attention to the prehensile dorsal tip of the tail, provided with tactile skin, in *Pogonomelomys*; but Harrison (1962 p. 59) has recently noted that the tail tips are partly prehensile in Australian *Melomys* identified by him (1962 p. 57) as *M. cervinipes eboreus* Thomas and *M. lutillus littoralis* (Lönnerberg) and the

¹*Melomys cervinipes* (and *Melomys*) has not been known to extend further south than the Hunter River, New South Wales where Gould reported it in 1852. A number of maxillae and mandibular rami, indistinguishable from *Melomys cervinipes* (Gould), are included in the Quaternary red bone deposit of the Pyramid Cave, Buchan district, eastern Victoria (see Wakefield 1960a & 1960b for an account of the bone deposits in the Buchan District) and, if this material is correctly placed here, this rodent has apparently undergone a recent shrinkage in range in south-eastern Australia. These specimens were identified by me subsequent to publication of Wakefield's second paper (1960b) and are not included among the rodent remains recorded therein for the Pyramid Cave deposit. They have now been placed in the palaeontological collections of the National Museum of Victoria and are registered specimens no. P 20673.

distinction may not be as useful as Tate and Archbold supposed. Unfortunately, the nature of the skin on the dorsal tip of the tail of *M. burtoni* is not mentioned by Ramsay so there is no justification in placing it within *Pogonomelomys*; nevertheless, such characters as it is known to possess do not exclude this possibility, but it should here be noted that of all the species currently placed in *Pogonomelomys* (Ellerman, 1949; Tate, 1951; Laurie and Hill, 1954) only the name *Uromys bruijnii* Peters and Doria, 1876 predates *M. burtoni*, and *U. bruijnii* and *M. burtoni* are certainly not con-specific.

Acknowledgments

I wish to thank Mr. B. J. Marlow, Curator of Mammals, Australian Museum, Sydney for permission to examine the Museum's rodent collection. A preliminary examination of the label accompanying S427 was carried out by Constable B. J. Fitzgerald, Handwriting Section, Scientific Investigation Bureau, Criminal Investigation Branch, N.S.W. Police Force. Mr. Marlow and Mrs. J. Anderson, Curator of the Macleay Museum, University of Sydney have provided valuable assistance in the elucidation of data on this label. Mr. G. P. Whitley, recently retired Curator of Fishes, Australian Museum has identified the handwriting of the Australian Museum catalogue entry for S427 as that of Mr. E. R. Waite. Mr. N. A. Wakefield, Melbourne Teacher's College, Victoria has kindly permitted me to examine his Buchan district rodent collection. Mr. R. C. Taylor, Department of Illustration, University of Sydney has provided the photographs for figure 2. The manuscript has been read and criticised by Dr. W. D. L. Ride, Director, Western Australian Museum, Perth.

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Editor: A. F. Trendall

Assistant Editor: A. S. George

The Royal Society of Western Australia, Western Australian Museum, Perth

JOURNAL OF

THE ROYAL SOCIETY

OF

WESTERN AUSTRALIA

VOLUME 48

PART 4

PUBLISHED 31ST DECEMBER, 1965

REGISTERED AT THE G.P.O., PERTH FOR TRANSMISSION BY POST AS A PERIODICAL

THE
ROYAL SOCIETY
OF
WESTERN AUSTRALIA

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**Journal
of the
Royal Society of Western Australia**

Vol. 48

Part 4

10.—The Porcellanidae (Crustacea, Anomura) of Western Australia with descriptions of four new Australian species

by Janet Haig*

Manuscript received and accepted 16th February, 1965

Abstract

Twenty-eight species of Porcellanidae are reported for Western Australia. Three are new species: *Pachycheles johnsoni*, *Porcellana furcillata*, and *Polyonyx maccullochi*. Fifteen previously known species are new records for Western Australia, and seven of those fifteen are new records for Australia. A new species, *Pachychicles granti*, from Queensland and New South Wales, is also described.

Introduction

Until now very little attention has been given to Western Australian crabs of family Porcellanidae. Only two papers have been published, dealing specifically with the Western Australian fauna, in which Porcellanidae were treated: these were Rathbun (1924) and Hale (1929). Porcellanids were mentioned incidentally in three additional works. Only ten species of the family have been recorded from Western Australia.

The incentive for the present study was provided by a large collection of crustaceans dredged off the coast of Western Australia by an expedition sponsored by the Bernice P. Bishop Museum of Honolulu, and donated to the Western Australian Museum (George, 1961). The Porcellanidae from that expedition, together with other members of the family in the collections of the Western Australian Museum, were turned over to me for study. I have also been able to borrow numerous Western Australian porcellanids from the Australian Museum; the Porcellanidae collected by the Hamburg Southwest-Australia Expedition, 1905, and housed in the Zoologisches Museum, Hamburg; and a small group of specimens in the U.S. National Museum, comprising a portion of the Porcellanidae collected during Dr. E. Mjöberg's Swedish scientific expeditions to Australia 1910-1913 and reported by Rathbun (1924). During a visit to the British Museum (Natural History) I examined a small collection of Western Australian Porcellanidae housed in that institution.

In the synonymy of each species I have tried to include all references to its occurrence anywhere in Australia.

Discussion of zoogeographical implications will be included in a future report, which will treat the other anomuran families (hermit crabs excepted) represented in Western Australia.

The following abbreviations are used in the text: W.A.M.—Western Australian Museum; A.M.—Australian Museum; B.M.N.H.—British Museum (Natural History); Z.M.H.—Zoologisches Museum, Hamburg; U.S.N.M.—United States National Museum.

**Key to Western Australian genera
of Porcellanidae**

- | | | | |
|--------|---|---|----------------------|
| 1. | Movable segments of antennal peduncle with free access to orbit | 2 | |
| | Movable segments of antennal peduncle excluded from orbit by a forward projection of basal segment, which meets anterior margin of carapace | 4 | |
| 2. (1) | Posterior portion of lateral walls of carapace consists of one or more pieces separated by membranous interspaces from anterior portion | 3 | <i>Pachycheles</i> |
| | Lateral walls of carapace entire | 3 | |
| 3. (2) | Front a strongly produced, triangular rostrum, armed with a row of strong spines; telson of abdomen five-plated | 4 | <i>Petrocheles</i> |
| | Front various, usually rather prominent but never produced into a strongly armed rostrum; telson seven-plated | 4 | <i>Petrolisthes</i> |
| 4. (1) | Carapace broader than long | 5 | |
| | Carapace as long as, or longer than, broad | 6 | |
| 5. (4) | Dactyl of walking legs with at least two well-developed fixed claws, and often with accessory spinules on lower margin | 5 | <i>Polyonyx</i> |
| | Dactyl of walking legs a straight, slender spine with no accessory spinules | 6 | <i>Raphidopus</i> |
| 6. (4) | Carapace markedly longer than broad; dactyl of walking legs very short and stout, with four strong, fixed claws | 6 | <i>Porcellanella</i> |
| | Carapace at most only slightly longer than broad; dactyl of walking legs slender, with one or two fixed claws and a few movable spinules | 7 | |

* Allan Hancock Foundation, University of Southern California, Los Angeles, California, U.S.A. Contribution no. 274 from the Allan Hancock Foundation.

7. (6) One cheliped distinctly larger than the other, particularly in males; dactyl of small cheliped twisted out of plane with manus; dactyl of walking legs with a single terminal claw *Pisidia*
 Chelipeds subequal or one distinctly larger than the other; dactyl not twisted out of plane with manus (except in occasional large specimens of *gravelei*); dactyl of walking legs bifurcate or with a single terminal claw *Porcellana*

Genus PETROCHELES Miers

Diagnosis. Basal antennal segment short, not produced forward to meet anterior margin of carapace; movable segments with free access to orbit. Carapace conversely cordate, broader posteriorly than anteriorly and with a strongly produced, triangular rostrum. Lateral margins of carapace and rostrum armed with a row of strong spines. Chelipeds subequal; chelae long, slender, flattened; carpi armed with strong spines on margins and on dorsal surface. Telson of abdomen five-plated.

Petrocheles australiensis (Miers)

Petrolisthes (Petrocheles) australiensis Miers 1876a, p. 222 (Australia); 1876b, p. 61. Haswell 1882b, p. 147 (Mordialloc). Baker 1905, p. 264, pl. 36, figs 1, 1a (St. Vincent Gulf; Port MacDonnell).

Petrocheles australiensis, Hale 1927a, p. 81, text-fig. 78 (South Australia).

Diagnosis. Protogastric region of carapace with a pair of spines. Rostral spines four on either side. Inner margin of carpus of cheliped armed with six or seven strong spines.

Material examined. 3♀, Great Australian Bight, S. of Nullarbor Station, 5.i.1958, R. Hardie, W.A.M. 171-60. "Swims backwards like crayfish."

Remarks. Largest specimen 18.4 mm in carapace length.

Distribution. Australia (Victoria and South Australia). Now recorded from Western Australia.

Genus PETROLISTHES Stimpson

Diagnosis. Basal antennal segment short, not produced forward to meet anterior margin of carapace; movable segments with free access to orbit. Carapace rounded or subquadrate, usually about as broad as long; armature various. Front triangular or trilobate, often rather prominent, not strongly armed except near base (minutely denticulate in some species). Chelipeds subequal; chelae flattened; armature of carpi various. Telson of abdomen almost invariably seven-plated.

Key to Western Australian species of *Petrolisthes*

1. Supraocular spine present; spines on lateral margins of carapace posterior to epibranchial spine 2
 No supraocular spine, nor spines on lateral margins of carapace posterior to epibranchial spine 3

2. (1) Front broad, sinuously triangular; inner orbital angle not distinct, but marked by a large spinule *scabriculus*
 Front narrow, with distinctly marked but unarmed inner orbital angle *militaris*
3. (1) Epibranchial spine present 4
 No epibranchial spine *teres*
4. (3) Carapace strongly to faintly rugose, not much longer than broad 5
 Carapace smooth, distinctly longer than broad *ohshimai*
5. (4) Merus of walking legs unarmed on anterior margin 6
 Merus of walking legs armed on anterior margin *moluccensis*
6. (5) Dorsal surface of chela with rugae and flattened tubercles; inner side of fingers pubescent *boscii*
 Dorsal surface of chela with small, up standing, well-separated granules; no pubescence, or at most only a fine trace, in gape of fingers *haswelli*

Petrolisthes scabriculus (Dana)

Porcellana scabricula Dana 1852, p. 424 (Sulu Sea); 1855, pl. 26, fig. 13.

Petrolisthes scabriculus, Stimpson 1858, p. 227. Haig 1964, p. 358, text-fig. 2.

Diagnosis. Carapace transversely rugose. Supraocular spine present. Front broad, triangular, forming a nearly even curve from tip to supraocular spine; inner orbital angle marked by a distinct spinule. Epibranchial region with two spines; midbranchial margin with a few spinules. Inner margin of carpus of chelipeds with four or five broad teeth; outer margin with row of strong spines. Chela with a median longitudinal crest; dorsal surface to outside of this crest covered with hairs, which form a heavy fringe along outer margin. Merus of walking legs armed on anterior margin with a row of spines.

Material examined. 1♀, W. of Flat I. off Onslow (near Long I.), 6-10 fm, 9.vi.1960, B. R. Wilson on "Davena", W.A.M. 36-62. 1♂, 2 miles S.W. of Peak I., 10 fm, 18.vi.1960, B. R. Wilson on "Davena", W.A.M. 136-60.

Remarks. For a discussion of differences between this species and *P. militaris*, see Haig (1964). Male 7.5 mm; ovigerous female 7.6 mm.

Distribution. Philippine Islands; East Indian Archipelago. Heller's (1865) record from the Nicobars needs confirmation because of possible confusion with *P. militaris*. Now recorded from Australia.

Petrolisthes militaris (Heller)

Porcellana annulipes White 1847, p. 63 (*nomen nudum*; Corregidor, Philippine Islands).

Porcellana militaris Heller 1862, p. 523 (Nicobars).

Petrolisthes annulipes, Miers 1884, p. 270, pl. 29, fig. B (Port Denison; Port Molle; Prince of Wales Channel; Thursday Island; Cape Capricorn). Henderson 1888, p. 106 (Flinders Passage).

Petrolisthes militaris, Ortmann 1892, pp. 259, 265. Rathbun 1924, p. 29 (Cape Jaubert). Miyake 1943, p. 56, text-figs. 1-2 (Bathurst Island). Haig 1964, p. 357, text-fig. 1 (Queensland).

Diagnosis. Carapace transversely rugose. Supraocular spine present. Front narrow, triangular, with a distinctly marked but unarmed inner orbital angle. Epibranchial region with two spines; mid-branchial margin with a few spinules. Inner margin of carpus of chelipeds

with four or five broad teeth; outer margin with a row of strong spines. Chela with a median longitudinal crest, outer margin often with a scanty fringe of hairs. Merus of walking legs armed on anterior margin with a row of spines.

Material examined. 1♂, 12♀, Broome, June 1932, A.M. P.10256. 1♂, 10♀, entrance to Roebuck Bay, 9 fm, 15.viii.1929, A. A. Livingstone, A.M. P.14072. 1♂, 4♀, near entrance to Roebuck Bay, 5-8 fm, 26.ix.1929, A. A. Livingstone, A.M. P.14085. 2♂, 1♀, Roebuck Bay, 1932, Mrs. B. Grey, B.M.N.H. 1♂, 10 miles W. of Gordon Bay, 15 fm, W.A.M. 335-62. 3♂, 6♀, 10-20 miles W. of Lagrange Bay, 12-25 fm, W.A.M. 346-62. 1♂, 1♀, 40 miles W. of Cape Jaubert, 23 fm, W.A.M. 325-62. 1♂, 1♀, 45 miles W.S.W. of Cape Jaubert, 72 ft, 7.vii.1911, E. Mjöberg, U.S.N.M. 56408. 1♀, 45 miles W.S.W. of Cape Jaubert, 66 ft, 15.vii.1911, E. Mjöberg, U.S.N.M. 56409. 1♂, 45 miles W.S.W. of Cape Jaubert, 66 ft, 16.vii.1911, E. Mjöberg, U.S.N.M. 56407. 1♂, between Broome and Wallal on Ninety Mile Beach, c. 8 fm, 1930, Capt. R. Bourne, A.M. P.9923. 5♂, 5♀, off Ninety Mile Beach between Cape Jaubert and Wallal, 5 fm, Sept. 1929, A. A. Livingstone, A.M. P.14111. 4♂, 4♀, 2 juv., 72 miles W. x N. of Bedout I., 25 fm, W.A.M. 356-62. 5♂, 2♀, 60 miles W. x N. of Bedout I., 25 fm, W.A.M. 341-62. 1♂, 2♀, Port Walcott, 8 fm, W.A.M. 175-60. 1♂, Anchorage Bay, Rosemary I., Dampier Archipel., W.A.M. 352-62. 3♂, 6♀, 3-4 miles off E. end Delambre I., Dampier Archipel., 10 fm, W.A.M. 118-60. 1♂, Gidley I., Dampier Archipel., 10 fm, W.A.M. 129-60. 2♀, 25 miles N.W. of Angel I., Dampier Archipel., 37 fm, W.A.M. 151-60. 2♂, 2♀, between Malus and Gidley Is., Dampier Archipel., 10 fm, W.A.M. 137-60. 1♂, 3♀, Malus I., Dampier Archipel., 10 fm, W.A.M. 180-60. 1♂, 2♀, W. approaches to Mermaid Strait, Dampier Archipel., 20 fm, W.A.M. 117-60. 1♂, 1♀, 7-8 miles N. of Long I. near Onslow, 28 fm, W.A.M. 121-60. 2♂, 4♀, 3 juv., off Shark Bay, 121 m, "Umitaka Maru", W.A.M. 356-60.

Remarks. The ground colour on most of the specimens tended to be light, usually with the striations of carapace and chelipeds marked out in red, although this colouration was reduced to red flecks in some cases. In a few specimens the carapace and chelipeds were solid red. Most of the material showed a characteristic pattern on the walking legs, consisting of two narrow red bands on the merus and one broad band each on the carpus and propodus. Males to 8.4 mm; non-ovigerous females to 6.7 mm; ovigerous females to 10.1 mm. Ovigerous females in May at Dampier Archipelago; June at Broome, Port Walcott, Dampier Archipelago, and Onslow; July at Cape Jaubert; August at Roebuck Bay; September at Roebuck Bay and between Cape Jaubert and Wallal; October at Lagrange Bay, Cape Jaubert, and Bedout I.; December at Shark Bay.

Distribution. Indian Ocean (Seychelles; Cargados; Chagos; southern India and Ceylon; Nicobars); Japan southward through China Sea to Philippine Islands, East Indian Archipelago and Australia (Western Australia; Northern Territory; Queensland).

Petrolisthes moluccensis (de Man)

Porcellana (Petrolisthes) moluccensis de Man 1888, p. 411, pl. 18, fig. 5 (Amboina).

Petrolisthes moluccensis, Ortman 1894, p. 26. Miyake 1942, pp. 334, 337, text-figs. 3-4.

Petrolisthes bosci, Nobili 1906a, p. 66; 1906b, pp. 129, 130 (part).

Diagnosis. Carapace transversely rugose. No supraocular spine. Front broad, sinuously triangular, with distinct inner orbital angle. A single epibranchial spine. Inner margin of carpus of chelipeds with five (occasionally six) broad teeth; outer margin with a row of spines, increasing in size distally. Chela without longitudinal crest; covered with rugae or laterally elongate granules. Gape of fingers without pubescence. Merus of walking legs armed on anterior margin with a row of spines.

Material examined. 8♂, 6♀, Abrolhos Is., southern group, March-August 1960, J. Allchin via P. Barrett Lennard, W.A.M. 174-60.

Remarks. The material agrees well with the descriptions given by de Man and Miyake, who however indicated that the carapace is weakly rugose. In the Western Australian specimens the rugae on the carapace are strong. Examination of considerable additional material (including Paris Museum specimens from the Persian Gulf and Red Sea, reported by Nobili as *P. boscii*) has shown that, among specimens otherwise identical, there is variation in this character: in some specimens the transverse rugae are very fine, so that the carapace appears almost smooth in places, and in others they are very strong and distinct, particularly on the anterior half of the carapace.

Chelipeds and carapace dark red, with narrow, yellowish transverse bands. Under side of chelipeds dark reddish purple. Abdomen and posterior portion of carapace red with white mottlings. Merus of walking legs mottled; carpus red with a few white dots; propodus light with a very broad, median red band; dactyl similarly banded, but red area narrower. Males to 12.4 mm; non-ovigerous females to 11.7 mm; ovigerous females to 9.8 mm.

Distribution. Red Sea and Persian Gulf (Nobili, as *P. boscii*); Ryukyu Islands; Palau Islands; East Indian Archipelago (Amboina; Misool). Now recorded from Australia.

Petrolisthes boscii (Audouin)

Porcellana boscii Audouin 1826, p. 89 (Red Sea).

?*Porcellana rugosa*?, White 1847, p. 63 (Torres Straits).

Petrolisthes boscii, Stimpson 1858, p. 227. Henderson 1893, p. 427 (North Australia). McCulloch 1913, p. 353, text-fig. 53 (Port Hedland). Hale 1929, p. 68 (Dirk Hartog Island).

Petrolisthes rugosus, Miers 1884, p. 270 (North Australia).

Diagnosis. Carapace with small, broken rugae over most of surface. No supraocular spine. Front rather narrow, sinuously triangular. A single epibranchial spine. Inner margin of carpus of chelipeds with four broad teeth; outer margin with three strong spines or teeth near distal end. Chela with elongate striae, low short rugae, and flattened tubercles. Gape of fingers with a short, thick pubescence extending to their tips. Merus of walking legs unarmed on anterior margin.

Material examined. 2♂, Northwest Australia, 1932, Mrs. B. Grey, B.M.N.H. 2 juv., Pender Bay, 1932, Mrs. B. Grey, B.M.N.H. 1♂, Cable Beach, Broome, shore, W.A.M. 349-62. 1♀, Gantheaume Point, between tides, June-Oct. 1929, A. A. Livingstone, A.M. P.14109. 4♀, off Roebuck Bay, 5-9 fm, June-Oct. 1929, A. A. Livingstone, A.M. P.14103. 1♂, 1♀, near entrance to Roebuck Bay, 5-8 fm, 26.ix.1929, A. A. Livingstone, A.M. P.14447. 1♂, 4♀, 3 juv., Port Hedland, W.A.M. 25-62 & 26-62. 2♂, 2♀, Rosemary I., Dampier Archipel., shore under stones, W.A.M. 28-62 & 319-62. 1♀, Eagle Hawk I., Dampier Archipel., under stone at low tide, W.A.M. 22-62. 1♀, S.W. corner Enderby I., Dampier Archipel., on fringing reef, W.A.M. 172-60. 5♂, 5♀, Onslow, July 1905, Gale for Hamburg S.W. Australia Exped., Z.M.H. 11623. 1 juv., Exmouth Gulf, 6 miles N. of Learmouth, W.A.M. 170-60. 2♂, 1♀. Point Gregory, N.W. side Peron Peninsula, Shark Bay, under stones on limestone reef flat just below high tide, W.A.M. 194-60. 1♂, at and near Brown Station, Dirk Hartog I., Shark Bay, ½-3 m, 18.ix.1905, St. 30, Hamburg S.W. Australia Exped., Z.M.H. 11706. 1♀, S.E. end Dirk Hartog I., Shark Bay, among coral, W.A.M. 204-57. 1 juv., Surf Point, outer bar (exit of South Passage), Shark Bay, ½-3½ m, 16.vi.1905, St. 25, Hamburg S.W. Australia Exped., Z.M.H. 11694. 1♂, Port Gregory, sub-littoral in lagoon under stones and coral, W.A.M. 5-63. 1♂, Port Gregory, under stones around coral heads, W.A.M. 3-63. 1♂, 3♀, Port Gregory, under stones on reef flat at low tide, W.A.M. 6-63. 1♂, Western Australia, W.A.M. 48-49. 1♂, no data, W.A.M. 182-60.

Remarks. Ground colour pale; tubercles and anterior margins of rugae on carapace, chelipeds, and merus of walking legs marked with red; a median red ring on propodus of walking legs. Males to 12.4 mm; non-ovigerous females to 8.9 mm; ovigerous females to 11.4 mm. Ovigerous females in June and August at Dampier Archipelago; July at Onslow; September at Port Hedland; December at Shark Bay and Port Gregory.

Distribution. Indian Ocean, from Red Sea to Mergui Archipelago; western Pacific from Japan to Malay Archipelago. Australia (Western Australia; "North Australia"; ? Queensland).

Petrolisthes haswelli Miers

Petrolisthes haswelli Miers 1884, p. 269, pl. 29, fig. A (Thursday Island; Port Curtis, Facing Island; Torres Straits).

Diagnosis. Carapace covered with faint, broken, transverse striae. No supraocular spine. Front rather narrow, sinuously triangular. A single epibranchial spine. Inner margin of carpus of chelipeds with four to six uneven teeth; outer margin with three strong teeth near distal end, one or two additional small ones sometimes developed. Chela covered with small, upstanding, well-separated granules. Gape of fingers bare or with a faint trace of pubescence. Merus of walking legs unarmed on anterior margin.

Material examined. 1♀, Yampi Sound, W.A.M. 157-60. 3♂, 2♀, Cockatoo I., low tide under stones, W.A.M. 353-62. 3♂, 1♀, Gantheaume

Point, W.A.M. 10877. 1♂, S. point of Cable Beach, Broome, W.A.M. 177-60. 2♂, 1♀, Riddell Beach, Broome, under rocks on surface of reef, W.A.M. 340-62. 1♀, Port Hedland, W.A.M. 35-62. 2♀, Rosemary I., Dampier Archipel., shore under stones, W.A.M. 319-62. 2♂, 3♀, S.W. corner Enderby I., Dampier Archipel., on fringing reef, W.A.M. 172-60. 3♂, 1♀, Exmouth Gulf, 6 miles N. of Learmouth, W.A.M. 170-60. 1♀, Exmouth Gulf, Wapet jetty under stone, W.A.M. 331-62. 1♂, Exmouth Gulf, shore, W.A.M. 322-62. 2♂, 1♀, Point Gregory, N.W. side Peron Peninsula, Shark Bay, under stones on limestone reef flat just below high tide, W.A.M. 194-60.

Remarks. Several authors have placed this species in synonymy with *Petrolisthes lamarckii* (Leach), a form found in Australia but not yet reported from Western Australia. *P. haswelli* differs consistently from typical members of that species in the strong granulation of the chelae and the presence of transverse striae on the carapace. It is perhaps even more closely related to *P. boscii*, from which it differs in the ornamentation of the chelae and the lack of a thick pubescence in the gape of the fingers. Very small specimens of *P. haswelli* and *P. boscii* are sometimes difficult to distinguish, for in juveniles of *P. boscii* the amount of pubescence on the inner side of the fingers is reduced and the tubercles on the chela may be more rounded and pronounced than in adults.

Miers (1884) noted a British Museum specimen of *P. haswelli* collected by the "Samarang" at Koo-Keang-San (Majico-shima Group, now known as Sakishima Islands, in the southern Ryukyu Islands). Two "Samarang" specimens from that locality, which I examined at the British Museum (Natural History), disagree in several details with a type from Thursday Island (BMNH) and with other Australian material examined; possibly they are examples of *P. lamarckii* with unusually granulate chelae. The record of Whitelegge (1897, p. 144), who listed *P. haswelli* from Funafuti, needs confirmation.

Carapace, chelipeds, and walking legs covered with small red spots. Propodus of walking legs frequently with a broad, median red ring as in *P. boscii*. Males to 15.4 mm; non-ovigerous females to 10.8 mm; ovigerous females to 9.2 mm. Ovigerous females in April at Exmouth Gulf; October at Cockatoo Island; December at Shark Bay.

Distribution. Possibly an Australian endemic. Queensland (Miers); specimens seen from Northern Territory. Now recorded from Western Australia.

Petrolisthes teres Melin

Petrolisthes inermis Haswell 1882a, p. 757 (Port Denison); 1882b, p. 146. Miyake 1943, p. 80, text-figs. 16-17 (Sandgate, Moreton Bay).

Petrolisthes japonicus var. *inermis*, Miers 1884, p. 268 (Port Moller; Port Curtis; Shark Bay). Grant and McCulloch 1906, p. 38 (Port Curtis).

Petrolisthes japonicus, Hale 1929, p. 68 (Dirk Hartog Island).

Petrolisthes teres Melin 1939, p. 104 (not text-figs. nor Bonin Islands records). Haig 1964, p. 364.

Diagnosis. Carapace nearly smooth, lateral margins subparallel, lateral walls hairy. No supraocular spine. Front rather broad, sinuously

triangular. No epibranchial spine. Inner margin of carpus of chelipeds with a shallow, pointed tooth at proximal end, and often a second, smaller one at about middle of margin; outer margin with two teeth, including the one at posterodistal angle. Chela narrow, nearly smooth, dorsal surface with indistinct, longitudinal crest; outer margin often with fringe of hairs. Gape of fingers with a long, thick tuft of pubescence. Merus of walking legs unarmed on anterior margin.

Material examined. 8 specimens, Northwest Australia, Mrs. B. Grey, B.M.N.H. 1♀, Entrance Point, Broome, between tides on rocky reef, August 1929, A. A. Livingstone, A.M. P.14457. 1 juv., Port Hedland, September 1961, Brown, W.A.M. 25-62. 3♀, Exmouth Gulf, Wapet jetty, under stone, 7.iv.1961, R. W. George, W.A.M. 323-62. 2♂, Dirk Hartog I., Shark Bay, August, 1960, via P. Barrett Lennard, W.A.M. 75-62. 4♂, 1♀, Point Gregory, Shark Bay, 30.xii.1961, D. G. Bathgate, W.A.M. 40-62. 1♀, Monkey Mia, Shark Bay, 25-30.viii.1960, A. Kalnins, W.A.M. 179-60. 1♀, Lagoon Point, saltwater lagoon, Shark Bay, 0- $\frac{1}{3}$ m, 11 and 13.vi.1905, St. 4, Hamburg S.W. Australia Exped., Z.M.H. 11639. 10♂, 14♀, Denham, Shark Bay, shore, 8-9.vi.1905, St. 5, Hamburg S.W. Australia Exped., Z.M.H. 11524. 21♂, 25♀, Denham, Shark Bay, shore, 19-20.ix.1905, St. 5, Hamburg S.W. Australia Exped., Z.M.H. 11582. 3♂, 6♀, N. side of Denham jetty, Shark Bay, under stones on sand flats at low tide, 29.xii.1959, B. R. Wilson, W.A.M. 195-60.

Remarks. For a discussion of the use of the name *tercs*, see Haig (1964). Males to 8.7 mm; non-ovigerous females to 9.0 mm; ovigerous females to 8.1 mm. Ovigerous females in August at Broome and in December at Shark Bay.

Distribution: Recorded only from Gulf of Siam (Haig) and Australia (Western Australia and Queensland).

Petrolisthes ohshimai (Miyake)

Porcellana maculata H. Milne Edwards 1837, p. 253 (New Ireland).

Petrolisthes maculatus, Miers 1884, p. 558. Lenz 1905, p. 375, pl. 47, fig. 1.

Neopetrolisthes ohshimai Miyake 1937, p. 35, text-fig. (Ryukyu Islands); 1942, p. 350, text-fig. 13. McNeill 1953, p. 90 (Hope Island).

Petrolisthes ohshimai, Johnson 1960, p. 164. Gordon 1960, p. 166.

"Small species of erab," Saville-Kent 1897, p. 220, pl. 39 (Roebuck Bay or Laeepede Islands, *vide* Gordon 1960).

"Unidentified erab," McCulloch and McNeill 1923, p. 58 (Great Barrier Reef).

Diagnosis. Carapace smooth, hairless, convex, markedly elongate. No supraocular spine. Front very broad, partly covering and reaching well beyond eyes. Epibranchial spine present. Inner margin of carpus of chelipeds with two or three wide-set teeth, proximal one largest; outer margin unarmed except for a short, blunt tooth at distal end. Chela broad, flat, with strongly curved outer margin. Merus of walking legs unarmed on anterior margin. Red spots on carapace and chelipeds, and usually also on abdomen, maxillipeds, eyestalks, and walking legs. The red colour sometimes takes the form of large, irregularly-shaped blotches.

and sometimes of very regularly and evenly distributed small spots: compare e.g. the illustrations in Lenz 1905 and in Miyake 1942.

Material examined. 1♀, Roebuck Bay, 1932, Mrs. B. Grey, B.M.N.H. 1♂, 1♀, N.E. side Rosemary I., Dampier Archipel., low tide on hypostome of large anemone, 27.viii.1961, B. R. Wilson and G. W. Kendrick, W.A.M. 32-62.

Remarks. Johnson (1960) transferred Miyake's species to genus *Petrolisthes* and reported a specimen from Christmas Island, eastern Indian Ocean, which he considered a westward extension of range. However, Dr. J. Forest (*in litt.*) informs me that *Porcellana maculata* H. Milne Edwards is identical with Miyake's species. There are two dried type specimens in the Paris Museum, labelled "*Porcellana maculata*, Edw./MM. Quoy et Gaimard./Nlle Irlande"; one of them, a male 8.5 by 7 mm, was chosen as lectotype by Dr. Forest. On the basis of this record, and subsequent ones by Miers and Lenz, the range of the species may be extended to the western Indian Ocean. It is a commensal with giant sea anemones of genus *Stoichactis*.

Even though H. Milne Edwards' name antedates Miyake's, the latter must be used for the species because of Article 23b of the International Code of Zoological Nomenclature, which requires that a name unused as a senior synonym for more than 50 years is to be discarded. The name *maculatus* as applied to this species did not appear in print between its use by Lenz (1905) and by Jacquotte (1964).

The red colour in the Rosemary Island specimens is in small, evenly distributed spots as in Lenz's illustration, but there are large areas of unspotted ivory white: most of the frontal region, the fingers, distal and outer part of the palm, proximal and distal ends of carpus of the chelipeds, most of the merus of the walking legs, and the entire carpus, propodus, and dactyl of those appendages. Male 11.2 mm; female 10.0 mm.

Distribution. Indian Ocean: Zanzibar, Mozambique, Madagascar, Gulf of Mannar, Christmas Island. Pacific Ocean: Ryukyu Islands, Palau Islands, Bismarck Archipelago, Marshall Islands, Fiji Islands. Australia (Western Australia and Queensland).

Genus **PACHYCHELES** Stimpson

Diagnosis. Basal antennal segment short, not produced forward to meet anterior margin of carapace; movable segments with free access to orbit. Carapace rounded or subquadrate, usually about as broad as long in males, a little broader than long in females; unarmed except for spine, present in some species, at outer orbital angle. Front not prominent, usually rounded or transverse in dorsal view, trilobate in frontal view. Epimera (lateral walls of carapace) incomplete, the posterior (subbranchial) portion consisting of one or more pieces separated by membranous interspaces from anterior portion. Chelipeds large, thick, and robust, one almost always distinctly larger than the other. Telson of abdomen composed

of either seven or five plates (five in all Indo-West Pacific species). Male lacking pleopods in many species.

Key to Australian species of *Pachycheles*

1. Carapace covered with scattered setae; pleopods present in males *pisoides*
Carapace devoid of hairs; no pleopods in males 2
2. (1) Carpus and chela with longitudinal rows of strong, well-separated tubercles, these tubercles covered with short hairs *granti*
Chelipeds devoid of hairs 3
3. (2) Anterior regions of carapace smooth; chelae smooth, tuberculate, or with four longitudinal ridges *sculptus*
Anterior regions of carapace roughened; carpus and chela with large, scalloped-edged tubercles, latter often with free edges *johnsoni*

Pachycheles sculptus (H. Milne Edwards)

Porcellana sculpta H. Milne Edwards 1837, p. 253 (Java).

Porcellana pisum H. Milne Edwards 1837, p. 254 (China).

Porcellana pulchella Haswell 1882a, p. 758 (Holborn Island; Port Molle); 1882b, p. 148.

Pachycheles pulchellus, Miers 1884, p. 273, pl. 30, fig. A (Port Molle; Albany Island; Thursday Island; Prince of Wales Channel). Henderson 1888, p. 114 (Arafura Sea south of Papua; Flinders Passage). Ortmann 1894, pp. 29, 30 (Thursday Island).

Pachycheles sculptus, Ortmann 1894, p. 29. Haig 1964, p. 368.

Pachycheles pisum, Rathbun 1924, p. 30 (Cape Jaubert). Ward 1928, p. 245 (Capricorn and Bunker Groups).

?*Pachycheles sculptus*, Ward 1928, p. 245 (Capricorn and Bunker Groups).

Diagnosis. Front broad, transverse in dorsal view and trilobate in frontal view; anterior regions of carapace smooth; carapace and chelipeds devoid of hairs. Chelipeds, especially carpus and chela, extremely variable: Chela entirely smooth, or with incipient smooth, longitudinal ridges, or with surface somewhat pitted, or with four smooth, narrow, longitudinal ridges, latter often crossed by slightly oblique grooves to form rows of close-set tubercles; the wide interspaces between these rows smooth, pitted, or with small, wide-set tubercles. Chelae similar in ornamentation, or minor more strongly ridged and tuberculate than major. Carpus completely smooth, or with low, somewhat overlapping tubercles, or with irregular rows of strong, squamate tubercles, some of them transversely elongate. No pleopods in males.

Material examined. 1 ♂, 23 miles S.W. of Troughton I., 25 fm, W.A.M. 336-62. 1 ♂, 2 ♀, Pender Bay, 1932. Mrs. B. Grey, B.M.N.H. 10 ♂, 11 ♀, Broome, June 1932, A.M. P.10222. 1 ♂, off Roebuck Bay, 5-9 fm, June-Oct. 1929, A. A. Livingstone, A.M. P.14124. 2 ♂, entrance to Roebuck Bay, 9 fm, 15.viii.1929, A. A. Livingstone, A.M. P.14100. 1 ♂, 1 ♀, near entrance to Roebuck Bay, 5-8 fm, 26.ix.1929, A. A. Livingstone, A.M. P.14081. 1 ♂, Roebuck Bay, 1932, Mrs. B. Grey, B.M.N.H. 2 ♂, 10-20 miles W. of Lagrange Bay, 12-25 fm, W.A.M. 347-62. 2 ♀, 40 miles W. of Cape Jaubert, 23 fm, W.A.M. 326-62 & 329-62. 1 ♂; 1 ♀, 42 miles W.S.W. of Cape Jaubert, 70 ft, 26.v.1911, E. Mjöberg, U.S.N.M. 56400. 1 ♂, 42 miles W.S.W. of Cape Jaubert, 70 ft, 30.v.1911, E. Mjöberg,

U.S.N.M. 56401. 1 ♀, 42 miles W.S.W. of Cape Jaubert, 48 ft, 16.vii.1911, E. Mjöberg, U.S.N.M. 56399. 1 ♂, off Ninety Mile Beach between Cape Jaubert and Wallal, 5 fm, Sept. 1929, A. A. Livingstone, A.M. P.14106. 3 ♂, 3 ♀, 60 miles W. x N. of Bedout I., 25 fm, W.A.M. 342-62 & 343-62. 1 ♀, N.E. side Rosemary I., Dampier Archipel., under stones at low tide, W.A.M. 358-62. 11 ♂, 9 ♀, 3-4 miles off E. end Delambre I., Dampier Archipel., 10 fm, W.A.M. 125-60 & 126-60. 1 ♂, 1 ♀, 2 miles W. of Legendre I., Dampier Archipel., 23 fm, W.A.M. 128-60. 1 ♂, Malus I., Dampier Archipel., 10 fm, W.A.M. 180-60. 1 ♀, W. approaches to Mermaid Strait, Dampier Archipel., 20 fm, W.A.M. 117-60. 1 ♂, 1 ♀, Exmouth Gulf or Shark Bay, trawled, W.A.M. 76-62. 1 juv., off Shark Bay, 121 m, "Umitaka Maru", W.A.M. 356-60. 1 ♀, Point Gregory, N.W. side Peron Peninsula, Shark Bay, under stones at low tide, W.A.M. 196-60. 3 ♂, 2 ♀, N.E. side Peron Flats, Shark Bay, from sponges and trawl trash, W.A.M. 354-62 & 355-62. 1 ♂, N.W. of Middle Bluff, Shark Bay, 7-8 m, 21.ix.1905, St. 1, Hamburg S.W. Australia Exped., Z.M.H. 11635. 2 ♂, 2 ♀, 1 juv., N.N.E. of N. point Heirisson Prong, Shark Bay, 11-12½ m, 18.vi.1905, St. 15, Hamburg S.W. Australia Exped., Z.M.H. 11667. 2 ♂, W.A.M. 338-62. 5 ♂, 4 ♀, Shark Bay, W.A.M. 321-62, 332-62, 334-62, & 337-62. 1 ♂, 1 ♀, Cottesloe, W.A.M. 21-64

Remarks. See Haig (1964) for a discussion of nomenclature and intraspecific variation in this species. In that paper mention was made of two unnamed species of *Pachycheles*, both of which have been confused with *P. sculptus*. These two species are here described; both of them are Australian forms although only one is known from Western Australia.

The colour pattern has disappeared in most of the material examined. A few specimens show traces of a median longitudinal white stripe on the carapace. Males to 8.2 mm; non-ovigerous females to 3.5 mm; ovigerous females to 11.7 mm (not all material measured). Ovigerous females in January and April at Shark Bay; May at Cape Jaubert and Dampier Archipelago; June at Broome, Dampier Archipelago, and Shark Bay; July at Cape Jaubert and Shark Bay; August at Dampier Archipelago; September at Broome and Shark Bay; October at Cape Jaubert and Bedout Island.

Distribution. Mergui Archipelago, China, Philippines, East Indies, Ryukyu Islands, Loyalty Islands. Australia (Western Australia and Queensland). *Pachycheles sculptus* has been reported from a few localities in the western Indian Ocean, but these records are based on *P. natalensis* (Krauss). Several additional records need confirmation; some may be based on one or the other of the two species described below.

Pachycheles johnsoni, sp. nov.

(Fig. 1)

Description. Carapace strongly convex front to back, its surface smooth in median portion and with a series of transverse grooves along lateral margins, and distinctly roughened by grooves in anterolateral region. Front broad,

transverse in dorsal view and with a median triangular lobe in frontal view; inner orbital angles subrectangular. Orbits concave; outer orbital angle produced into a small, acute tooth. Separated portion of lateral wall of carapace consisting of a single large piece. Carapace devoid of hairs.

First movable antennal segment with a conical tubercle on anterior margin; second lightly granular, without anterior projection; third nearly smooth; flagellum setose.

Chelipeds not greatly differing in size in females, rather more unequal in large males; devoid of hair. Merus rugose to nearly smooth on dorsal surface; inner margin armed with a strongly projecting, subrectangular lobe. Carpus with three (rarely four) broad, strongly projecting teeth on inner margin, in some specimens proximal tooth largest and others successively smaller, in other specimens all teeth subequal in size; these teeth smooth or punctate on their dorsal surfaces, and their

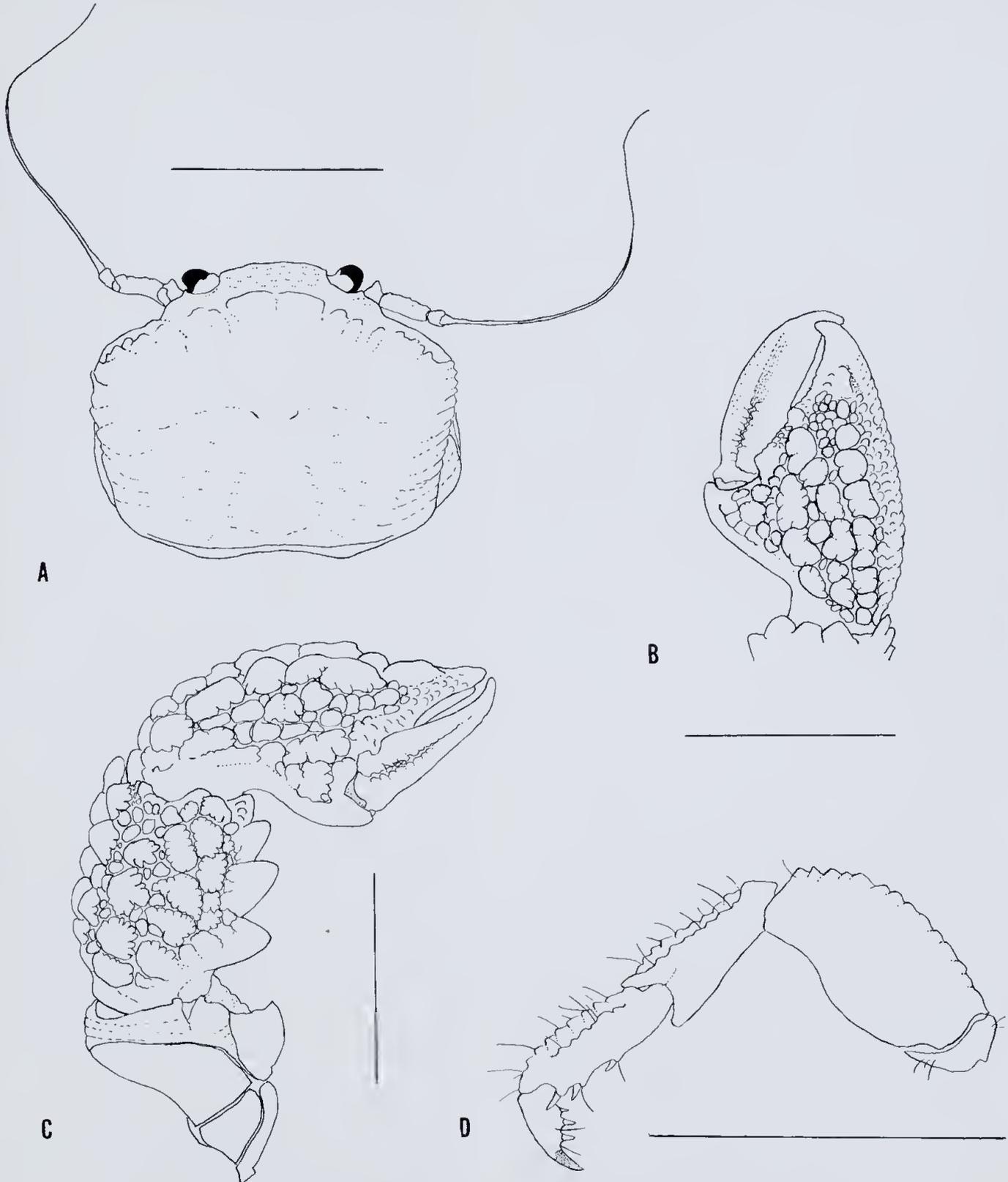


Figure 1.—*Pachycheles johnsoni*. Female paratype. A, dorsal view of carapace; B, right (minor) chela, straight dorsal view; C, left (major) cheliped; D, left walking leg. Scales = 5 mm.

margins entire in all Australian material examined. Upper surface of carpus (except anterior teeth) completely covered with large tubercles, which are rounded or somewhat elongate, high-topped, and with edges scalloped and sometimes free all the way around or at least on their distal side, thus forming mushroom-shaped structures similar to those found in several species of hermit crabs of genus *Pylopagurus*; edges of tubercles generally touching each other, but occasional gaps filled with smaller tubercles which may be less projecting than the large ones. Manus covered with mushroom-shaped tubercles of same size and structure as those of carpus; on manus, however, largest ones tend to be arranged in more or less even, longitudinal rows, spaces between the rows entirely filled with smaller, less projecting tubercles; outer row of tubercles sometimes partially coalesced to form a longitudinal ridge, deeply cut and scalloped along its margins. Dactyl smooth or punctate on upper surface; its proximal half with a deep, longitudinal groove which may be scalloped on its edges and filled with a few low tubercles; proximal portion of pollex tuberculate. Lower surface of chela somewhat punctate, that of carpus obliquely rugose near outer margin, elsewhere nearly smooth.

Walking legs covered with long, stiff, non-plumose hairs. Carpus and propodus roughened and grooved on their upper and outer surfaces. Dactyl with three well-developed, moveable spinules on lower margin, in addition to fixed terminal claw; proximal to these spinules one or two additional, smaller ones sometimes developed.

Telson of abdomen five-plated. No pleopods in males.

Holotype male (6.8 by 7.6 mm), Point Gregory, N.W. side of Peron Peninsula, Shark Bay, under stones on limestone reef flat, 1.i.1960, B. R. Wilson, W.A.M. 197-60.

Paratypes. NORTHERN TERRITORY: Between North and South Shell Is., Port Darwin, 3-7 fm, A. A. Livingstone: 1♂, 1♀, 2.vii.1929, A.M. P.14761; 1♂, 4.vii.1929, A.M. P.14760; 1♀, 5.vii.1929, A.M. P.14084. WESTERN AUSTRALIA: 2♀, Entrance Point, Broome, rocky reef between tides, Aug. 1929, A. A. Livingstone, A.M. P.14086. 1♀, Gantheaume Point, between tide marks, Sept. 1929, A. A. Livingstone, A.M. P.14090. 1♀, between Broome and Cape Bossutt, 5 fm, June-Oct. 1929, A. A. Livingstone, A.M. P.14075. 1♂, Port Hedland, Sept. 1961, Brown, W.A.M. 33-62. 1♀, Point Gregory, N.W. side Peron Peninsula, Shark Bay, under stones on reef flat, 1.i.1960, B. R. Wilson, W.A.M. 197-60. 1♀, at and near Brown Station, Dirk Hartog I., Shark Bay, $\frac{1}{2}$ -3 m, 18.ix.1905, St. 30, Hamburg S.W. Australia Exped., Z.M.H. 11707. 1♀, 3 miles W. of Carnac I., 16 fm on sponge, 13.viii.1962, R. W. George on "Bluefin", W.A.M. 324-62. 1♂, 1♀, Cape Leeuwin, W.A.M. 227/8-30.

Remarks. In a juvenile male (about 2.5 mm) the sculpturing on the margin of the tubercles of the chelipeds is clearly visible, although the roughness of the anterior margin of the carapace is less so. Juvenile *Pachycheles sculptus* of comparable size, while they may have rather

strongly tuberculate chelipeds, lack scalloping on the tubercles and the gaps between the rows of tubercles are smooth. Where the chelipeds differ in size in *P. johnsoni*, the degree of sculpturing is not appreciably different in the two; in *sculptus* it is often very different.

I have examined considerable material of a small *Pachycheles* collected on coral reefs in the Caroline and Marshall Islands. Although these specimens differ in several respects from the Australian material of *P. johnsoni*, I am inclined to believe that they represent no more than a variety of the latter. There tend to be more teeth (usually five) on the inner margin of the carpus, and the margins of these teeth are scalloped or dentate. The scalloped-edged tubercles on the carpus and chela form a flat paving instead of having strongly projecting, convex surfaces. There are usually five rather than three movable spinules on the lower surface of the dactyl of the walking legs. At least a part of the Palau Islands specimens treated by Miyake (1942, p. 374) as *P. sculptus* refer to *P. johnsoni* and show some of the characters just mentioned.

In those specimens still retaining traces of colour pattern, there is a median, longitudinal white stripe on the carapace very much as in *P. sculptus*. In one specimen the edges of the white area begin to diverge just posterior to the protogastric region, until at the posterior margin it occupies about half of the carapace breadth. Males to 6.8 by 7.6 mm; non-ovigerous females to 6.7 by 8.1 mm; ovigerous females to 7.4 by 9.5 mm. Ovigerous females in January of Shark Bay; July at Port Darwin; August at Broome; September at Gantheaume Point and Shark Bay.

I am pleased to dedicate this species to Dr. D. S. Johnson, to whom I am indebted for helpful suggestions concerning its status.

Distribution. Palau, Caroline and Marshall Islands; Australia (Western Australia and Northern Territory), at localities listed above. Other specimens now referred to *P. sculptus* may prove, on reexamination, to belong to *P. johnsoni*.

Pachycheles granti, sp. nov.

Pachycheles sculptus, Grant and McCulloch 1906, p. 40, pl. 2, fig. 1 (Mast Head Island; Cabbage Tree Bay). McNeill and Ward 1930, p. 364 (Collaroy).

Description. Carapace convex front to back; surface more or less smooth except in frontal region and along lateral margins; hepatic and protogastric regions well marked. Front broad, transverse in dorsal view and with a median triangular lobe in frontal view; inner orbital angles subrectangular. Orbits deeply concave; outer orbital angle produced into a strong, narrow, acute tooth. Separated portion of side walls of carapace consisting of a single large piece. Carapace devoid of hairs.

First movable antennal segment with a conical tubercle on anterior margin; second lightly granular, without anterior projection; third nearly smooth; flagellum setose.

Chelipeds markedly unequal in size. Merus nearly smooth or with several small tubercles on dorsal surface; inner margin armed with

a strongly projecting, conical lobe. Carpus with three broad, strongly projecting teeth on inner margin; these teeth smooth, with entire or minutely crenulate margins, and usually subequal in size. Upper surface of carpus (exclusive of marginal teeth) covered with five longitudinal rows of well-separated, strongly projecting tubercles, irregularly rounded or somewhat elongate, and covered except at their apices with very short, close-set hairs. Manus likewise with five rows of tubercles, similar in size, arrangement, and setation to those of carpus. Dactyl covered with tubercles, usually more strongly projecting in proximal portion, and with a deep, longitudinal groove; pollex with small, flattened tubercles. Lower surface of chela nearly smooth except for a row of small tubercles near outer margin.

Carpus and propodus of walking legs with long, stiff, non-plumose setae on their anterior margins.

Telson of abdomen five-plated. No pleopods in males.

Holotype male (6.8 by 7.1 mm). Shelly Beach, Yamba, near mouth of Clarence River, on reef, Jan. 1939, A. A. Cameron, A.M. P.14778.

Paratypes. QUEENSLAND: 1♂, 1♀, Mast Head I., presented by F. E. Grant, B.M.N.H. NEW SOUTH WALES: 1♂, 1♀, Angourie Point, Yamba, mouth of Clarence R., Sept. 1938, A. A. Cameron, A.M. P.11000. 2♀, Angourie Point, Oct. 1939, A. A. Cameron, A.M. P.11193. 1♂, 1♀, Angourie Point, Dec. 1939, A. A. Cameron, A.M. P.11249. 1♂, reef at Shelly Beach, Yamba, near mouth of Clarence R., A. A. Cameron, A.M. P.11027. 1♀, Shelly Beach, reef, Jan. 1939, A. A. Cameron, A.M. P.11017. 1♂, reef at Shelly Beach, Nov. 1939, A. A. Cameron, A.M. P.11190. 1♂, Shelly Beach, Jan. 1939, A. A. Cameron, A.M. P.11003. 1♂, Woody Head, Iluka, mouth of Clarence R., Sept. 1960, A. A. Cameron, A.M. P.13482. 3♂, 2♀, Long Reef, Collaroy, Apr. 1928, M. Ward, A.M. P.9073. 2♂, Cabbage Tree Bay (Shelly Beach) on coast at Manly, T. Whitelegge, A.M. P.14762. 1♀, Bottle and Glass Rocks, Port Jackson, Apr. 1933, G. P. Whitley, A.M. P.10295.

Remarks. Although many of the records do not so indicate, all the material listed above was presumably collected intertidally or in shallow water. In reference to the five specimens from Collaroy, McNeill and Ward (1930) state: "In canals of a tough encrusting sponge on the under surfaces of flat stones occurring in shallow water below low tide mark." Males to 6.8 by 7.1 mm; ovigerous females to 6.8 by 7.7 mm. Ovigerous females in April at Collaroy and Port Jackson; September, October, December, and January at Yamba.

Distribution. Known only from Queensland and New South Wales.

Pachycheles pisoides (Heller)

Porcellana pisoides Heller 1865, p. 73, pl. 6, fig. 3 (Nicobar Islands).

Pachycheles lijuensis Borradaile 1900, p. 424 (Loyalty Islands).

Pachycheles pisoides, Edmondson 1925, p. 19. Haig 1964, p. 371.

Pachycheles fronto Melin 1939, p. 114, text-figs. 69-71 (Bonin Islands).

Pisosoma fronto, Miyake 1943, p. 113, text-figs. 40-41.

Diagnosis. Front broad, sinuously triangular or faintly trilobate in dorsal view, trilobate in frontal view. Carapace with scattered, short, non-plumose hairs; chelipeds and walking legs covered with short and long non-plumose hairs. Inner margin of carpus of chelipeds with four strong, pointed teeth. Chela tuberculate near and on outer margin. Males with a pair of pleopods.

Material examined. 1♂, Port Gregory, under stones on reef flat at low tide, 26.xii.1962, B. R. Wilson, W.A.M. 4-63.

Remarks. The single specimen was pale orange, with a broad band of darker orange on the propodus of each walking leg. The carapace was 4.6 by 5.0 mm.

Distribution. Seychelles, Nicobar Is., Loyalty Is., Norfolk I., Kermadec Is., Ryukyu Is., Bonin (Ogasawara) Is., Hawaiian Is. Now recorded from Australia.

Genus PISIDIA Leach

Diagnosis. Basal antennal segment strongly produced forward and broadly in contact with anterior margin of carapace; movable segments far removed from orbit. Carapace usually rounded; armature various, but lateral carapace spines always present. Front prominent, strongly tridentate or trilobate. Chelipeds differing in size and form; fingers of one or both chelipeds twisted out of plane with manus, the distortion always most pronounced in the smaller cheliped. Sexually dimorphic: twisting of fingers more pronounced in adult males, less so in females and juveniles; spinulation of carapace and chelipeds frequently stronger in females and juveniles than in males. Dactyl of walking legs ending in a single terminal claw, lower margin with a row of movable accessory spinules, the most distal one often stout, enlarged. Telson of abdomen seven-plated.

Key to Western Australian species of Pisidia

1. Front strongly deflexed, median lobe much more strongly projecting than lateral lobes *dispar*
Front not deflexed, the three lobes about equally advanced 2
2. (1) Lateral frontal lobes bidentate and medium lobe quadridentate, front thus consisting of eight small, subequally projecting teeth *spinuligera*
Front consisting of three simple lobes, spinulate on their margins *cf. spinulifrons*

Pisidia spinuligera (Dana)

Porcellana armata Dana 1852, p. 426 (Mangsi Island N. of Borneo). Miyake 1942, p. 356, text-figs. 17-19.

Porcellana spinuligera Dana 1853, p. 1593 (new name for *P. armata*, preoccupied); 1855, pl. 26, fig. 14.

Porcellana latifrons Stimpson 1858, pp. 229, 243 (Hong Kong and Ousima Island); 1907, p. 190, pl. 23, fig. 4. Rathbun 1924, p. 31 (Cape Jaubert).

Porcellana danae Heller 1865, p. 74 (new name for *P. armata*).

Petrolisthes hellcri Kingsley 1880, p. 405, footnote (new name for *Porcellana danae*, preoccupied).

Pisidia spinuligera, Haig 1960, p. 208.

Diagnosis. Front very broad, not deflexed, somewhat produced beyond eyes; median lobe broad and quadridentate, narrow lateral lobes

bidentate, entire front thus consisting of eight small, subequally projecting, pointed teeth. A strong hepatic spine; one or two minute spinules at epibranchial angle; three strong spines on lateral margin posterior to cervical groove. Merus of chelipeds with strong inner lobe, toothed on its margin. Carpus with three or four shallow teeth on inner margin; outer margin with three strong spines including one at distal end. Chela with a row of spinules on proximal half, just to inside of outer margin. Merus of walking legs unarmed on anterior margin.

Material examined. 3♂, 6♀, Pender Bay, Mar. 1931, Mrs. B. Grey, B.M.N.H. 2♂, 1♀, Broome, June 1932, A.M. P.14448. 1♂, near entrance to Roebuck Bay, 5-9 fm, 26.ix.1929, A. A. Livingstone, A.M. P.14450. 1♂, 1♀, entrance to Roebuck Bay, 9 fm, 15.viii.1929, A. A. Livingstone, A.M. P.14451. 1♂, 1♀, between tides, June-Oct. 1929, A. A. Livingstone, A.M. P.14077. 1♂, 2♀, off Ninety Mile Beach between Cape Jaubert and Wallal, 5 fm, Sept. 1929, A. A. Livingstone, A.M. P.14093 & P.14449. 1♂, 45 miles W.S.W. of Cape Jaubert, 72-80 ft., 7.vii.1911, E. Mjöberg, U.S.N.M. 56434. 2♀, at and near Brown Station, Dirk Hartog I., Shark Bay, ½-3 m, 18.ix.1905, St. 30, Hamburg S.W. Australia Exped., Z.M.H. 11708. 1♂, 1♀, S.E. Dirk Hartog I., Shark Bay, among coral, Jan. 1957, B. R. Wilson, W.A.M. 206/7-57. 2♂, entrance to South Passage, Shark Bay, 9 m, 16.vi.1905, St. 23, Hamburg S.W. Australia Exped., Z.M.H. 11687. 1♀, N.W. of Heirisson Prong, Shark Bay, 11-12½m, 13.ix.1905, St. 16, Hamburg S.W. Australia Exped., Z.M.H. 11676. 12♂, 11♀, 3 juv., N.N.E. of Heirisson Prong, Shark Bay, 11-12½m, 18.vi.1905, St. 15, Hamburg S.W. Australia Exped., Z.M.H. 11666. 1♂, 2♀, Freycinet Reach, Shark Bay, 11-16 m, 12.ix.1905, St. 14, Hamburg S.W. Australia Exped., Z.M.H. 11664. 1♀, c. 2½ miles S.W. of Denham, Shark Bay, 3 m, 10.vi.1905, St. 7, Hamburg S.W. Australia Exped., Z.M.H. 11651. 1♂, c. 6 miles S. of Denham, Shark Bay, 4½-5 m, 18.vi.1905, St. 8, Hamburg S.W. Australia Exped., Z.M.H. 11654. 3♂, 1♀, Wreck Point, Abrolhos Is., southern group, 20.iv.1958, A. Robinson, W.A.M. 114-60. 2♂, 5♀, Abrolhos Is., southern group, Mar.-Aug. 1960, W.A.M. 173-60.

Remarks. The name originally given by Dana to this species, *Porcellana armata*, was preoccupied by *Porcellana armata* Gibbes 1850 (= *Petrolisthes armatus*). Dana himself introduced *Porcellana spinuligera* as a substitute, a fact which has been generally overlooked; Heller and Kingsley later introduced unnecessary substitute names into the synonymy. *Porcellana latifrons* Stimpson is a synonym of Dana's species.

Carapace, abdomen, and chelipeds orange, with irregularly shaped white spots. A red spot or streak about midway along upper margin of dactyl of cheliped; spines along lower margins of palm red. Merus and carpus of walking legs spotted; propodus white, with a thin, longitudinal orange stripe on upper margin and two each on inner and outer surfaces. Males to 7.1 mm; non-ovigerous females to 7.8 mm; ovigerous females to 4.9 mm. Ovigerous females

in March at Pender Bay; April at Abrolhos Islands; September between Cape Jaubert and Wallal.

Distribution. Ryukyu Is.; Palau Is.; Hong Kong; East Indian Archipelago. Reported once from Australia (off Cape Jaubert, Western Australia). Heller's (1865) Nicobar Islands record needs confirmation; to judge from his description he may have had a different species.

Pisidia cf. Spinulifrons (Miers)

Porcellana [allied to *serratifrons*], Miers 1884, p. 277 (Thursday Island).

?*Porcellana serratifrons*, Henderson 1888, p. 110 (part: Arafura Sea, not Hong Kong specimen nor pl. 11, figs. 5, 5a). Grant and McCulloch 1906, pp. 39, 40 (Mast Head Island; Port Denison).

Porcellana spinulifrons, Gordon 1931, p. 530, text-figs. 4c, 5.

Diagnosis. Front not deflexed; median lobe broad, spinulate on its distal margin, and slightly advanced beyond narrow lateral lobes which are spinulate on their inner margins. A strong hepatic spine; epibranchial margin with several fine spinules (very small in large specimens); three or four spines on lateral margin posterior to cervical groove. Merus of chelipeds with large inner lobe, its margin with a strong spine and several spinules. Carpus with two or three teeth on proximal portion of inner margin, and a few smaller spines on distal portion (in some large specimens, this armature reduced to very shallow lobes); outer margin sometimes with a row of spines, but these not always developed. Chela with a row of spines along outer margin (not always developed in large specimens). Merus of walking legs unarmed on anterior margin.

Material examined. 1♀, Broome, July 1905, Gale for Hamburg S.W. Australia Exped., Z.M.H. 11630. 19♂, 14♀, Broome, June 1932, A.M. P.10214. 1♀, Entrance Point, Broome, shore between tides on rocky reef, Aug. 1929, A. A. Livingstone, A.M. P.14769. 2♂, off Gantheaume Point, 4 fm, Aug. 1929, A. A. Livingstone, A.M. P.14079. 1♀, off Gantheaume Point, 4 fm, 30.viii.1929, A. A. Livingstone, A.M. P.14095. 2♀, off Roebuck Bay, 5-9 fm, June-Oct. 1929, A. A. Livingstone, A.M. P.14122. 13♂, 3♀, entrance to Roebuck Bay, 9 fm, diver, 15.viii.1929, A. A. Livingstone, A.M. P.14094 & P.14121. 2♂, near entrance to Roebuck Bay, 5-9 fm on Lithothamnion reef, 26.ix.1929, A. A. Livingstone, A.M. P.14114. 1♀, Roebuck Bay, 9 fm, Aug. 1929, A. A. Livingstone, A.M. P.14768. 4♂, 1♀, Roebuck Bay, between tides on sand flat, 8.viii.1929, A. A. Livingstone, A.M. P.14120. 1♂, Roebuck Bay, 5 fm, 15.viii.1929, A. A. Livingstone, A.M. P.14096. 1♂, off Cape Bossutt, 4 fm, 9.ix.1929, A. A. Livingstone, A. M. P.14104. 5♂, 2♀, off Ninety Mile Beach between Cape Jaubert and Wallal, 5 fm, Sept. 1929, A. A. Livingstone, A.M. P.14099. 2♂, 1♀, off Ninety Mile Beach near Wallal, 5 fm on gorgonids, Sept. 1929, A. A. Livingstone, A.M. P.14119. 3♂, 1♀, Port Hedland, Sept. 1961, Brown, W.A.M. 26-62. 11♂, 3♀, Onslow, July 1905, Gale for Hamburg S.W. Australia Exped., Z.M.H. 11624.

Remarks. This species is the one discussed and illustrated by Gordon (1931) under the name *Porcellana spinulifrons* Miers (Hong Kong specimens). D. S. Johnson, who examined the

types of *P. spinulifrons* Miers 1879 in the British Museum (Natural History), has informed me (personal communication) that the latter species is not identical with the one treated by Gordon. Dr. Johnson plans to name Gordon's species and to discuss it and several closely related forms in a forthcoming publication.

The Australian specimens referred to *Porcellana serratifrons* Stimpson 1858 by Henderson and by Grant and McCulloch should be re-examined; they very likely belong to the present species. In addition to the Thursday Island specimens collected by the "Alert" and mentioned by Miers, I have seen considerable material of this species from Northern Territory and Queensland. As for its extra-Australian distribution, there has been so much confusion with *serratifrons*, *spinulifrons*, and other forms that the range cannot be determined until several species are redefined and many specimens reexamined.

Males to 7.6 mm; non-ovigerous females to 5.2 mm; ovigerous females to 6.4 mm. Ovigerous females between June and October at Roebuck Bay; in July at Onslow; August at Gantheaume Point; September at Ninety Mile Beach and Port Hedland.

Distribution. Indian and western Pacific Oceans; more precision will have to await future studies, as noted above. Australia: Thursday Island and several other localities in Queensland and Northern Territory. Now recorded from Western Australia.

Pisidia dispar (Stimpson), n. comb.

Porcellana dispar Stimpson 1858, pp. 229, 242 (Port Jackson); 1907, p. 190, pl. 23, fig. 3. Haswell 1882b, p. 149 (Port Jackson; Port Stephens). Miers 1884, p. 275, pl. 30, fig. C (Port Jackson). Whitelegge 1889, p. 231 (Neutral Bay). Stead 1898, p. 208 (Port Jackson). Grant and McCulloch 1906, p. 40 (Port Curtis). Rathbun 1924, p. 31 (Cape Jaubert). Hale 1927a, p. 82, text-fig. 79 (South Australia); 1927b, p. 309 (Investigator Straits; Kangaroo Island).

Porcellana rostrata Baker 1905, p. 260, pl. 35, figs. 1, 1a-b (Investigator Straits).

Diagnosis. Frontal region depressed, its margin appearing transverse or convex in dorsal view; medium lobe sharply deflexed, visible only in frontal view, broad, forming an acute angle, and more projecting than lateral lobes. A strong hepatic spine; epibranchial margin unarmed; one or two small spines on lateral margin posterior to cervical groove. Merus of chelipeds with a strong, unarmed inner lobe. Carpus with three low, shallow teeth, directed distally, or three broad, shallow lobes on inner margin, the median tooth or lobe sometimes obsolete; outer margin with two or three small spines or teeth. Chela with a row of sharp granules or small spinules along outer margin. Merus of walking legs unarmed on anterior margin.

Material examined. 3♂, 1♀, Broome, June 1932, A.M. P.10209. 1♂, 2♀, Entrance Point, Broome, Aug. 1929, A. A. Livingstone, A.M. P.14102. 1♂, Gantheaume Point, 5.viii.1929, A. A. Livingstone, A.M. P.14118. 2♂, entrance to Roebuck Bay, 15.viii.1929, A. A. Livingstone, A.M. P.14076. 1♂, near entrance to Roebuck Bay, 26.ix.1929, A. A. Livingstone, A.M. P.14766.

1♂, off Cape Bossutt, 9.ix.1929, A. A. Livingstone, A.M. P.14767. 2♂, 2♀, Surf Point, entrance to South Passage, Shark Bay, 16.vi.1905, St. 23, Hamburg S.W. Australia Exped., Z.M.H. 11687. 1♂, 1♀, near bar of South Passage, Shark Bay, W.A.M. 339-62. 1♂, 1♀, Triggs I., W.A.M. 46-62. 1♀, 5 miles N. of E. end Rottneest I., W.A.M. 124-60. 1♂, 2 miles W.N.W. of Cottesloe, W.A.M. 350-62. 9♂, 3♀, Cottesloe, W.A.M. 10424/7, 10560/4, 11036, & 591-30. 2♀, Owen Anchorage off Sth. Fremantle Power House, W.A.M. 115-60. 1♂, N.E. of Garden I., W.A.M. 142-60. 1♂, 1♀, Careening Bay, Garden I., W.A.M. 138-60. 6♂, 3♀, Cockburn Sound, W.A.M. 133-60, 139-60, 141-60, 41-62, 42-62, 44-62, & 49-62. 1♂, Port Royal and N., Cockburn Sound, 30.ix.1905, St. 48, Hamburg S.W. Australia Exped., Z.M.H. 11723. 1♂, 1♀, Kwinana, 2-300 yards N.W. of no. 2 light buoy, W.A.M. 123-60. 6♂, 14♀, Palm Beach, W.A.M. 134-60. 3♂, 3♀, Warnbro Sound, 29.ix.1905, St. 53, Hamburg S.W. Australia Exped., Z.M.H. 11731.

Remarks. Males to 5.0 mm; non-ovigerous females to 3.2 mm; ovigerous females to 4.2 mm. Collected on reefs between tides, on boom piles, and in depths to 19½ fms. Ovigerous females in January and April at Cockburn Sound; March at Garden I. and Triggs I.; May at Rottneest I.; June at Broome and Shark Bay; August at Broome; December at Fremantle and Cockburn Sound.

Distribution. Reported only from Australia (Western Australia, South Australia, New South Wales, and Queensland).

Genus *PORCELLANA* Lamarck

Remarks. *Porcellana*, as it now stands, contains an assemblage of species which are not very closely related and should probably be assigned to several genera or at least subgenera. Such a revision must await a comparative study on a worldwide basis, for at present the relationships of the various species to each other and to those placed in certain other genera are unclear. In the meantime, I find it impossible to devise a satisfactory diagnosis for *Porcellana*.

Of the Western Australian species, *Porcellana habei* is the only one belonging to a group of forms allied to the type species, *P. platycheles* (Pennant). *P. gravelei*, with its tendency toward distortion of the dactyl of the minor chela, approaches *Pisidia*, but has a quite different general appearance from most members of that genus, particularly as regards the stoutness of the carpi of the chelipeds and the rather shallowly lobed front. Its closest affinities are perhaps with *P. foresti* Chace, a West African species. *P. ornata* bears a superficial resemblance to some members of genus *Petrolisthes*, particularly in the form of the chelipeds with their broad, flattened chelae; more than one author has assigned it to that genus. *P. nitida* and *P. furcillata* belong to a group of species which have two strong fixed claws on the dactyl of the walking legs, but which differ greatly from one another in several other characters.

Key to Western Australian species of Porcellana

1. Dactyl of walking legs with a single terminal claw and a row of accessory spinules 2
Dactyl with two strong, subequal fixed claws 4
2. (1) Front horizontal, strongly tridentate in dorsal view *habei*
Front strongly deflexed, appearing triangular in dorsal view 3
3. (2) Carapace nearly smooth; chelipeds obliquely rugose *gravelei*
Carapace strongly areolated and tuberculated; chelipeds tuberculate *ornata*
4. (1) Chelipeds and lateral margins of carapace unarmed; frontal teeth with entire margins *nitida*
Chelipeds and lateral margins of carapace armed with spines; frontal teeth spined *furcillata*

Porcellana habei Miyake

Porcellana habei Miyake 1961, p. 240, text-fig. 3 (Kyushu, Japan).

Diagnosis. Carapace smooth, strongly convex laterally. Front strongly tridentate, horizontal; median tooth with distinct longitudinal groove, more produced than lateral teeth and separated from them by a broad U-shaped notch; the three teeth subequal in breadth. Outer orbital angle produced into a large, acute tooth. Lateral margin of carapace with a distinct notch at cervical groove. Chelipeds subequal. Merus with a prominent, unarmed lobe on inner margin. Carpus with a low, broad lobe on inner margin and with a median longitudinal crest, this crest continued on chela which lies obliquely to plane of carapace and has a fringe of hair along outer margin. No armature on anterior margins of walking legs; propodus unarmed on posterior margin except for pair of spinules at distal end; dactyl with a single terminal claw and with three or four ventral spinules, the most distal one enlarged.

Material examined. 1 ♂, 40 miles W. of Cape Jaubert, 23 fm on sponge, 13.x.1962, R. W. George on "Dorothea", W.A.M. 327-62.

Remarks. Except in a few details, the Cape Jaubert specimen agrees very closely with Miyake's description and illustration. The frontal teeth are minutely crenulate along their margins and the median tooth notched just at the tip, characters not mentioned by Miyake. There is a small notch at the epibranchial angle, instead of the pronounced tooth shown in Miyake's illustration; and the merus of the third walking legs is much shorter and stouter than that of the other two pairs, whereas in Miyake's illustration it is about the same in all three pairs of walking legs. Since *Porcellana habei* was described from only two specimens, and the present example is the first to be reported since, no statement can be made as yet about the degree of normal variation; should the differences just mentioned prove to be constant, the Western Australian specimen will probably have to be assigned to a separate species. *Porcellana pulchra* Stimpson 1858, which has been recorded only from Japan and China, is a closely related form but differs markedly in the shape of the front, the median tooth being much broader than the lateral ones.

There are indistinct patches of pale orange on the anterior part of the carapace and on the chelae, especially at the base of the dactyl; according to Miyake, specimens preserved in alcohol were pale orange. The Cape Jaubert specimen measured 4.9 by 4.1 mm as compared with 5.8 by 5.3 mm and 5.3 by 4.5 mm for the two male types. Miyake's specimens were associated with a hermit crab.

Distribution. Previously known only from Kyushu, Japan. Now recorded from Australia.

Porcellana gravelei Sankolli

Pachycheles sp., Gravely 1927, p. 140, pl. 20, fig. 9.

Porcellana gravelei Sankolli 1963, p. 280, text-fig. 1 (Ratnagiri, India).

Diagnosis. Carapace strongly convex front to back; nearly smooth but with regions well marked. Front broad, well produced beyond eyes, and composed of three rather shallow lobes; frequently the entire frontal region rather strongly deflexed so that the front appears broadly triangular in dorsal view. Hepatic margin, and lateral margins of carapace posterior to cervical groove, minutely crenulate or with one to three minute spinules. Chelipeds subequal in form, but one may be distinctly larger than the other, particularly in large males; covered with close-set, flattened granules and obliquely rugose. Merus with a large, strongly projecting, triangular lobe on inner margin; carpus stout, inner margin with two broad, triangular teeth, frequently coalesced to form a strong lobe. Chela lies obliquely to plane of carapace. Dactyl of minor chela sometimes slightly to strongly twisted out of plane with hand. In males, a thick tuft of pubescence usually present in gape of fingers of minor chela; this never present in females. No armature on anterior margins of walking legs; dactyl with a single terminal claw and with about four movable spinules on lower margin.

Material examined. 1 ♂, Pender Bay, 1932, Mrs. B. Grey, B.M.N.H. 7 ♂, Broome, June 1932, A.M. P.10208. 1 ♀, off Roebuck Bay, 5-9 fm, June-October 1929, A. A. Livingstone, A.M. P.14108. 1 ♂, entrance to Roebuck Bay, 9 fm, 15.viii.1929, A. A. Livingstone, A.M. P.14763. 2 ♀, near entrance to Roebuck Bay, 5-8 fm, 26.ix.1929, A. A. Livingstone, A.M. P.14105. 1 ♂, between Cape Bossutt and Broome, 5 fm, June-October 1929, A. A. Livingstone, A.M. P.14083. 1 ♂, off Cape Bossutt, 4 fm, 9.ix.1929, A. A. Livingstone, A.M. P.14110. 1 ♂, Cape Bossutt, shore on reef and sand flat, 13.x.1962, R. W. George on "Dorothea", W.A.M. 320-62. - ♂, off Ninety Mile Beach between Cape Jaubert and Wallal, 5 fm, September 1929, A. A. Livingstone, A.M. P.14101. 1 ♀, off Ninety Mile Beach near Wallal, 5 fm on gorgonid, September 1929, A. A. Livingstone, A.M. P.14115. 2 ♂, 1 ♀, Point Gregory, N.W. side Peron Peninsula, Shark Bay, under stones on limestone reef flat at low tide, 1.i.1960, B. R. Wilson, W.A.M. 196-60. 2 ♂, 3 ♀, Port Gregory, under stones on reef flat at low tide, 26.xii.1962, B. R. Wilson, W.A.M. 1-63 and 2-63. 4 ♂, 3 ♀, Triggs I., 20.iii.1961, W. H. Butler, W.A.M. 39-62. 1 ♂, 2 ♀, Cottesloe, W.A.M. 10424/7 and 11036. 3 ♂, N.E. Garden I., 15 ft. on old

boom piles, 14.iii.1959, P. Barrett Lennard, W.A.M. 142-60. 1♂, Esperance, November 1960, W. H. Butler, W.A.M. 38-62.

Remarks. Sankolli did not mention the characteristic hair tuft, usually present in males but never in females, in the gape of the fingers of the minor cheliped. Neither did he mention the fact that in large males one chela is sometimes distinctly larger than the other, with the dactyl of the minor chela twisted and the fingers gaping instead of approximated along their inner edges. The latter character seems to be found only in the largest males; Sankolli's largest male specimens had a carapace length of no more than 2.5 mm, while some of the Australian examples were as large as 6.5 mm. Males to 6.5 mm; non-ovigerous females to 4.5 mm; ovigerous females to 6.0 mm. Ovigerous females in January at Shark Bay; March at Triggs I.; September at Roebuck Bay; December at Port Gregory.

Distribution. India at Ratnagiri (Sankolli) and at Krusadai Island, Gulf of Mannar (Gravely, as "*Pachycheles* sp."). Now recorded from Australia. In addition to the specimens from Western Australia, listed above, I have seen material from Northern Territory, Queensland, and New South Wales.

Porcellana ornata Stimpson

Porcellana ornata Stimpson 1858, pp. 299, 242 (Hong Kong); 1907, p. 188. Gordon 1931, p. 529, text-fig. 1. Miyake 1943, p. 118, text-figs. 42-43.

Porcellana corallicola Haswell 1882a, p. 759 (Port Molle); 1882b, p. 150.

Petrolisthes? corallicola?, Miers 1884, p. 271, pl. 29, fig. C (Port Molle).

Petrolisthes dorsalis Miers 1884, p. 271.

Porcellana (?*Petrolisthes*) *corallicola* var., Walker 1887, p. 113, pl. 8, fig. 5 (Queensland).

Petrolisthes corallicola, Rathbun 1924, p. 29 (Cape Jaubert).

Porcellana sp., Gravely 1927, p. 141, pl. 20, fig. 14.

Diagnosis. Carapace strongly areolated and tuberculated, and sometimes with a few spines developed on dorsal surface; a row of two to six well-developed spinules on lateral margins posterior to cervical groove. Front narrow, well produced beyond eyes, with a deep median groove, and spinulate along its anterior margin; in dorsal view triangular, but in frontal view trilobate with strong median lobe directed downward. A pronounced tooth at outer orbital angle. Chelipeds subequal, spiny-tuberculate; merus with a well-developed lobe on inner margin; carpus with margins subparallel and armed with spinules, dorsal surface with three longitudinal ridges defined by deep sulci. Chelae broad and flat, *Petrolisthes*-like, lying obliquely to plane of carapace; surface with a median longitudinal ridge, outer margins denticulate and fringed with hair. Merus of walking legs with a row of spines on anterior margin; dactyl with a single terminal claw and a row of small movable spinules on lower margin.

Material examined. 1♀, Broome, June 1932, A.M. P.10210. 1♂, Gantheaume Point, between tides, June-October 1929, A. A. Livingstone, A.M. P.14073. 1♀, entrance to Roebuck Bay, 9 fm, 15.viii.1929, A. A. Livingstone, A.M. P.14107. 1♂, off Roebuck Bay, 5-9 fm, June-October 1929,

A. A. Livingstone, A.M. P.14112. 1♂, 45 miles W.S.W. of Cape Jaubert, 72 ft, 7.vii.1911, E. Mjöberg, U.S.N.M. 56406. 1♂, 45 miles W.S.W. of Cape Jaubert, 72 or 80 ft, 7.vii.1911, E. Mjöberg, U.S.N.M. 56405.

Remarks. Examination of a series of specimens from several localities in the Pacific Ocean, in addition to the Australian material, shows that there is considerable intraspecific variation in the degree of areolation of the carapace, tuberculation of the chelipeds, and spinulation of frontal and cheliped margins. There seems to be little doubt that *Porcellana ornata* and *P. corallicola* are synonymous. Males to 5.3 mm; females to 6.0 mm.

Distribution. Southern India; Mergui Archipelago; Japan; Hong Kong; Singapore. Australia (Western Australia and Queensland).

Porcellana nitida Haswell

Porcellana nitida Haswell 1882a, p. 758 (Port Denison); 1882b, p. 148.

Porcellana nitida var. *rotundifrons* Miers 1884, p. 274, pl. 30, fig. B (Port Denison; Friday Island; Dundas Straits; Port Darwin; Arafura Sea).

Diagnosis. Carapace markedly convex both laterally and front to back, smooth, but completely and evenly covered with short, transverse lines. Front horizontal, not deflexed; projecting beyond eyes, trilobate with median lobe very broad, rounded-triangular, more produced than laterals which are very narrow and often not sharply defined; margins of frontal lobes entire. Outer orbital angle produced into a broad tooth, sometimes bifurcate-tipped; a sharp, strong tooth on hepatic margin; epibranchial angles with a marked lateral projection, unarmed; lateral margins of carapace unarmed posterior to epibranchial angles. Chelipeds subequal, smooth; carpus broadest distally, its margins unarmed; chelae elongate, lying nearly vertically to plane of carapace, smooth, unarmed; inner margin of fingers with a thick tuft of hair. Anterior margin of walking legs unarmed; dactyl with a deeply bifurcate tip, forming two sub-equal fixed claws, and with a single, small movable spinule on lower margin.

Material examined. 1♂, Broome, June 1932, A.M. P.10203. 1♂, between Broome and Wallal on Ninety Mile Beach, c. 8 fm, 1930, Capt. R. Bourne, A.M. P.9931. 1♂, 10-20 miles W. of Lagrange Bay, 12-25 fm, 13.x.1962, R. W. George on "Dorothea", W.A.M. 348-62. 2♀, 40 miles W. of Cape Jaubert, 23 fm, 13.x.1962, R. W. George on "Dorothea", W.A.M. 330-62. 1♂, off Ninety Mile Beach between Cape Jaubert and Wallal, 5 fm, Sept. 1929, A. A. Livingstone, A.M. P.14080. 1♂, Port Hedland, 1905, Gale for Hamburg S.W. Australia Exped., Z.M.H. 11512.

Remarks. The specimen from the Palau Islands referred to *Porcellana nitida* by Miyake (1942, p. 359, text-figs. 20-22; 1943, p. 129, text-fig. 50) cannot belong to this species because it has a strong tooth on the lateral margin of the carapace behind the epibranchial angle; in none of the specimens examined, nor in the types, is there an indication of even incipient spinulation or crenulation on the carapace margins. With Miyake's record removed from the synonymy the species becomes restricted to

Australia, where it is perhaps an endemic. Miers' variety *rotundifrons* is based on adults of *P. nitida*, which was described by Haswell from juvenile material. The differences in the form of the front mentioned by Miers can be attributed to growth. Males to 7.4 mm; ovigerous females 7.2 and 7.3 mm, off Cape Jaubert in October.

Distribution. Australia (Northern Territory and Queensland). Now recorded from Western Australia.

***Porcellana furcillata*, sp. nov.**

(Fig. 2)

Description. Carapace a little longer than broad; nearly smooth, with protogastric regions lightly indicated and other regions scarcely marked. Front broad, horizontal, not deflexed, produced beyond eyes; median lobe broad, its surface concave, apex tipped with two or three strong spinules, a larger spine on either side near tip; separated by broad, U-shaped notches from narrow lateral lobes which have their tips acute and curved inward, inner margins armed with several spinules. Outer orbital angle produced into a strong spine; a strong

spine or tooth on hepatic margin; a small but distinct epibranchial spinule. Lateral margins posterior to cervical groove with three or four spinules.

First movable antennal segment with a small anterodistal spinule; second and third unarmed; flagellum long, slender, without hairs.

Chelipeds smooth, devoid of hairs. Merus with a strong inner lobe, its margin crenulate and bearing two teeth; outer margin with two strong spines; lower surface with a strong spine at inner distal angle. Carpus with five to seven shallow, wide-set teeth on inner margin, these teeth varying in size and some of them occasionally much reduced or obsolescent; outer margin with three strong spines including the one at distal end. Chelae elongate, one somewhat larger than other, lying at a very oblique angle to plane of carapace; outer margin with a sharp crest bearing a row of minute granules, these becoming larger on distal portion of manus and on pollex; just to inside of this margin, proximal half of chela with a row of five to eight strong spines. Fingers crossed at tips, which are not notched; outer margin of dactyl smooth, or with a row of fine spinules similar

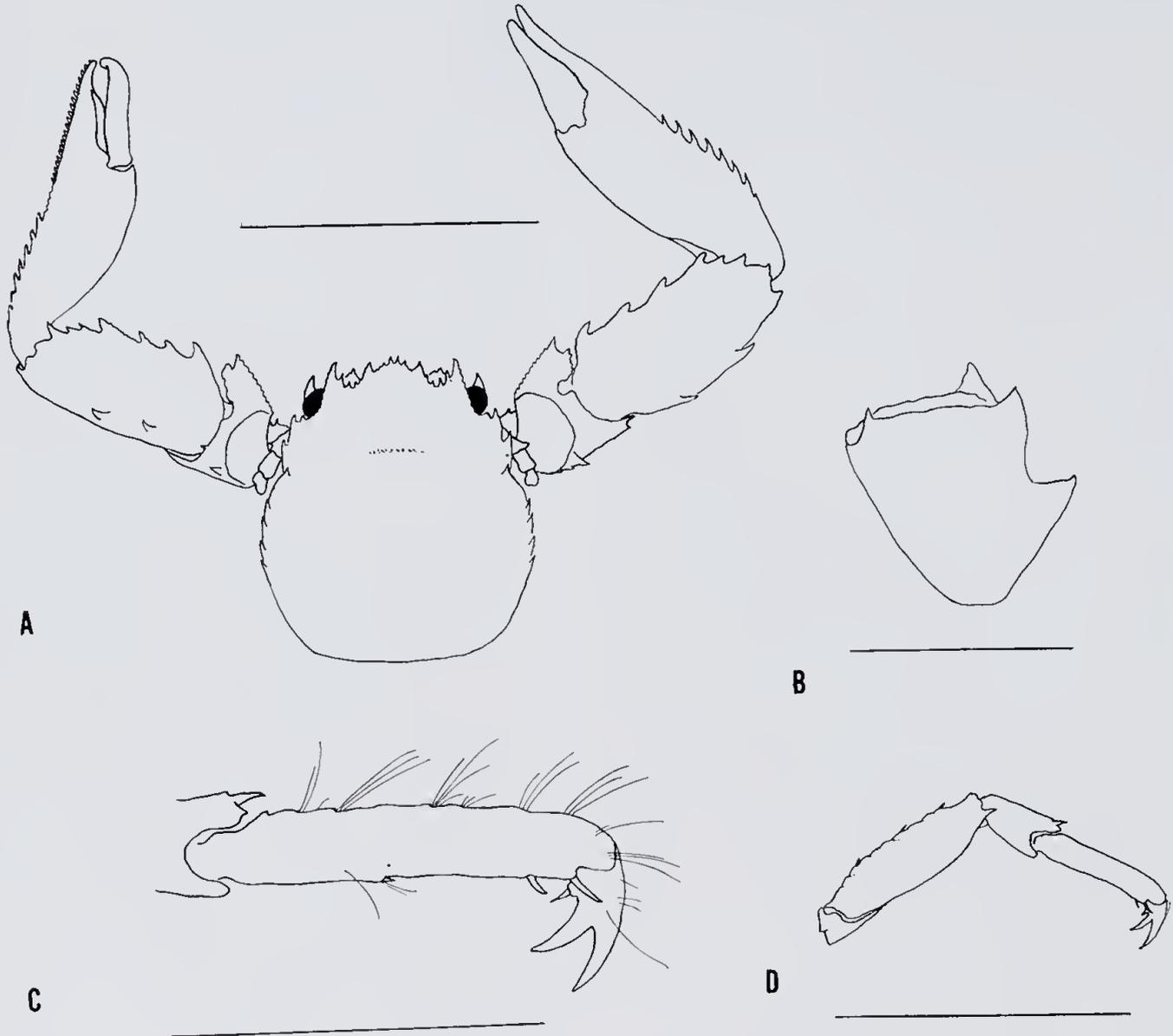


Figure 2.—*Porcellana furcillata*. A, dorsal view of holotype; B, basal segment of antennule; C, propodus and dactyl of right first walking leg; D, right first walking leg. Scales for A and D = 5 mm; for B, 0.5 mm; for C, 2 mm.

to those of outer margin of pollex; inner side of fingers at their bases with a short tuft of fine hair. In larger chela, fingers generally somewhat gaping, with a tooth on cutting edge of pollex, and shorter in comparison to length of manus than in smaller chela, which has fingers meeting along entire length of straight cutting edges.

Walking legs long and slender, with long, scattered setae. Anterior margin of merus armed with several spines. Carpus with an anterodistal spine, more strongly developed on first pair of legs. Propodus with a slender, movable spinule about midway along posterior margin and three similar spinules at posterodistal end. Dactyl deeply cleft into two strong, subequal fixed claws; lower margin with a single small, movable spinule.

Telson of abdomen seven-plated.

Holotype. Ovigerous female (5.1 by 4.6 mm), 60 miles W. x N. of Bedout Island, 25 fm, 12.x.1962, R. W. George on "Dorothea", W.A.M. 344-62.

Paratypes. QUEENSLAND: 1♂, 1♀, Albany Passage, Cape York, Aug.-Oct. 1907, C. Hedley and A. R. McCulloch, A.M. P.14764. WESTERN AUSTRALIA: 1♂, Roebuck Bay, 9 fm, Aug. 1929, A. A. Livingstone, A.M. P.14765. 1♀, off Roebuck Bay, 5-9 fm, June-Oct. 1929, A. A. Livingstone, A.M. P.14091. 1♂, 72 miles W. x N. of Bedout I., 25 fm, 12.x.1962, R. W. George on "Dorothea", W.A.M. 357-62. 1♂, 2 miles W. of Legendre I, Dampier Archipelago, 23 fm. 9.vi.1960, B. R. Wilson on "Davena", W.A.M. 128-60.

Remarks. *Porcellana furcillata* is perhaps allied to *P. quadrilobata* Miers 1884, a species which has been collected in Australian waters but is not yet recorded from Western Australia. In *P. quadrilobata* the median frontal lobe has a distinct notch, and the carpus of the chelipeds is unarmed along the outer margin. *P. furcillata* bears a superficial resemblance to *Pisidia spinuligera* (Dana), from which it is easily distinguished by the deeply bifurcate dactyl of the walking legs.

Males 3.5 by 3.0 mm to 4.0 by 3.6 mm; non-ovigerous female 3.6 by 3.2 mm; ovigerous females 4.9 by 4.5 mm and 5.1 by 4.6 mm. Ovigerous females between August and October at Cape York and in October off Bedout I.

Distribution. Known only from the localities listed above, in Western Australia and Queensland.

Genus PORCELLANELLA White

Diagnosis. Basal antennal segment strongly produced forward and broadly in contact with anterior margin of carapace; movable segments far removed from orbit. Carapace considerably longer than broad, smooth, sides subparallel; without spines except for projection of outer orbital angle. Front horizontal, not at all deflexed, produced well beyond eyes, strongly tridentate. Chelipeds subequal, smooth, unarmed. Chelae elongate, lying nearly vertical to plane of carapace, with a crest of hair on inner surface. Walking legs short, smooth, their anterior

margins unarmed. Dactyls very short; multi-unguiculate, with four strong, fixed spines. Telson of abdomen seven-plated.

Porcellanella triloba White

Porcellanella triloba White 1852, p. 394, pl. 5, figs. 2, 2a (off Cape Capricorn). Johnson 1964, p. 100 (Bowen).

Porcellana triloba, Haswell 1882b, p. 149.

Diagnosis. Lateral frontal lobes about three-fourths length of median lobe. Outer orbital angle acute or spiniform. Inner margin of merus of chelipeds with a strongly developed lobe. Most proximal spine of dactyl of walking legs much smaller than other three.

Material examined. 1♂, 1♀, 36 miles S.W. of Adele I., 40 fm, 17.x.1962, R. W. George on "Dorothea", W.A.M. 333-62. 1♂, between Broome and Wallal on Ninety Mile Beach, c. 7 fm, 1931, Capt. R. Bourne, A.M. P.10020. 1♂, Roebourne, 21.ix.1959, C. Lambert, W.A.M. 161-60. 2♂, 2♀, mainland at Antenni Mia, Point Samson, or Rosemary I., Dampier Archipel., on a pennatulid, 26-30.viii.1961, B. R. Wilson, W.A.M. 47-62. 1♂, 1♀, S.E. of Rosemary I., Dampier Archipel., 3-5 fm, 26.viii.1961, G. W. Kendrick and B. R. Wilson, W.A.M. 24-62. 1♂, N.W. of Heirisson Prong, Shark Bay, 11-12½ m, 13.ix.1905, St. 16, Hamburg S.W. Australia Exped., Z.M.H. 11676. 1♀, Freycinet Reach, W. of Middle Flat to N. point of Heirisson Prong, Shark Bay, 11-16 m, 12.ix.1905, St. 14, Hamburg S.W. Australia Exped., Z.M.H. 11665.

Remarks. Recently Johnson (1964) showed that *Porcellanella picta* Stimpson, which many authors have considered synonymous with *P. triloba*, may be separated on the basis of a number of constant characters. The material from Western Australia all agrees with *P. triloba* in Johnson's restricted sense. Johnson assigned earlier records to one or the other of the two species as far as was possible on the basis of reexamined material and published descriptions and illustrations, and concluded that the only certain localities for *P. triloba* are N.E. Australia and Palau Islands. The Palau Islands record, however, was based on a third species of *Porcellanella* recently described by Sankarankutty (1963, p. 273) as *p. haigae*. *P. triloba* should thus be considered a strictly Australian form, at least pending the re-examination of the specimens on which several published records were based.

Males to 9.5 by 6.8 mm; non-ovigerous females to 9.0 by 6.7 mm; ovigerous females to 8.4 by 6.3 mm. Ovigerous females in August at Dampier Archipelago or vicinity, and in October off Adele I.

Distribution. Definitely known only from Australia (Queensland, at Bowen and off Cape Capricorn). Now recorded from Western Australia.

Genus POLYONYX Stimpson

Diagnosis. Basal antennal segment strongly produced forward and broadly in contact with anterior margin of carapace; movable segments far removed from orbit. Carapace usually broader than long, particularly in females;

strongly convex front to back. Front deflexed, trilobate or transverse, usually appearing transverse in dorsal view. Chelipeds large, differing in size and form. Dactyl of walking legs with at least two well-developed fixed claws and often with spinules on lower margin. Telson of abdomen seven-plated. Pleopods present in males of all but a few species.

Key to Western Australian species of *Polyonyx*

- | | | | | | | |
|--------|---|------|------|------|------|------------------------|
| 1. | Lateral margin of carapace armed with spines | .... | .... | .... | .... | 2 |
| | Lateral margin of carapace unarmed | .... | .... | .... | .... | 3 |
| 2. (1) | Ventral claw of dactyl of walking legs not nearly at a right angle to axis of dactyl | .... | .... | .... | .... | <i>suluensis</i> |
| | Ventral claw of dactyl of walking legs nearly at a right angle to axis of dactyl | .... | .... | .... | .... | <i>telestophilus</i> |
| 3. (1) | Claws of dactyl of walking legs subequal or at least with dorsal claw well developed in comparison to ventral claw | .... | .... | .... | .... | 4 |
| | Ventral claw of dactyl of walking legs much larger than dorsal claw | .... | .... | .... | .... | 6 |
| 4. (3) | Ventral surface of chelae with a pronounced longitudinal crest in proximal half; a large lobe on inner margin of merus | .... | .... | .... | .... | <i>triunguiculatus</i> |
| | Ventral surface of chelae without such a crest; meral lobe vestigial or absent | .... | .... | .... | .... | 5 |
| 5. (4) | Dactyl of walking legs with a single rather large, stout spinule in addition to the two main claws; male with pleopods | .... | .... | .... | .... | <i>obesulus</i> |
| | Dactyl of walking legs with two small, slender spinules in addition to the two main claws; male pleopods lacking | .... | .... | .... | .... | <i>biunguiculatus</i> |
| 6. (3) | Front transverse; merus of chelipeds with a vestigial lobe; propodus of walking legs with 12 or more ventral spinules | .... | .... | .... | .... | <i>transversus</i> |
| | Front with median lobe produced; merus of chelipeds with a well-developed lobe; propodus of walking legs with four or five ventral spinules | .... | .... | .... | .... | <i>maccullochi</i> |

Polyonyx suluensis (Dana)

Porcellana suluensis Dana 1852, p. 414 (Sulu Sea); 1855, pl. 26, fig. 4. Rathbun 1924, p. 30, pl. 1, figs. 15-16 (Cape Jaubert).

Polyonyx denticulatus Paulson 1875a, p. 32, pl. 1, fig. 11 (*nomen nudum*); 1875b, p. 89, pl. 11, fig. 6 (Red Sea). Johnson 1958, pp. 98, 100, text-fig. 1.

Polyonyx hexagonalis Zehntner 1894, p. 187, pl. 8, figs. 18, 18a (Amboina).

Polyonyx suluensis, Haig 1964, p. 373, text-fig. 3.

Diagnosis. Carapace roughly hexagonal, as broad as, or slightly broader than, long; surface with scattered long hairs. Lateral margins armed with spines. Front very broad, trilobate, median lobe prominent, acute. Merus of chelipeds with a prominent lobe on inner margin, armed with several spines. Carpus with about four strong spines on inner margin. Major cheliped nude or hairy; minor chela densely covered with long hairs. Propodus of walking legs with one ventral spinule in addition to three at distal end. Dactyl with two large, subequal fixed claws; no accessory movable spinules on lower margin.

Material examined. 1 ♀, 45 miles W.S.W. of Cape Jaubert, 72-80 ft, May-July 1911, E. Mjöberg, U.S.N.M. 56435. 1 ♀, off Ninety Mile Beach between Cape Jaubert and Wallal, 5 fm, Sept. 1929, A. A. Livingstone, A.M. P.14089.

Remarks. Both specimens were ovigerous; the carapace length of one of them was 3.2 mm. In view of its abundance throughout most of its range, it is surprising that this species has been so seldom collected in Western Australia.

Distribution. Indian Ocean (Red Sea; Seychelles; Saya de Malha; Cargados Carajos); Japan southward to Philippine Islands and East Indian Archipelago. In Australia reported only from Western Australia.

Polyonyx telestophilus Johnson

Polyonyx telestophilus Johnson 1958, pp. 98, 103, text-fig. 2 (Singapore). Haig 1964, p. 376, text-fig. 4.

Diagnosis. Carapace roughly hexagonal, a little broader than long; nearly or completely devoid of hairs. Lateral margins armed with spines. Front very broad, trilobate, median lobe prominent, acute. Merus of chelipeds with a prominent inner lobe, minutely denticulate or crenulate and sometimes bearing a single, larger tooth. Carpus with distal portion of inner margin produced as a strongly convex lobe; less produced proximal portion crenulate or with one to three teeth. Chelipeds slightly hairy or devoid of hairs. Propodus of walking legs with one ventral spinule in addition to three at distal end. Dactyl with two large, fixed claws, the ventral one distinctly larger and longer than the dorsal and directed at almost a right angle to axis of dactyl; no accessory movable spinules on lower margin.

Material examined. 1 ♀, between Malus and Gidley Is., Dampier Archipelago, 10 fm, 1.vi.1960, Royce on "Davena", W.A.M. 137-60.

Remarks. The single Western Australian specimen, an ovigerous female, had a carapace length of 4.4 mm and breadth of 5.6 mm. Johnson (1958) found the species to be strictly commensal with alcyonarian corals of genus *Telesto* at Singapore.

Distribution. Gulf of Siam; Singapore; Amboina. Now recorded from Australia.

Polyonyx biunguiculatus (Dana)

Porcellana biunguiculata Dana 1852, p. 411 (type locality not stated); 1855, pl. 26, figs. 1a-d.

Polyonyx biunguiculatus, Stimpson 1858, p. 229. Johnson 1958, pp. 100, 105, text-fig. 3. Haig 1964, p. 377.

?*Porcellana biunguiculata*, Haswell 1882b, p. 147 (Holborn Island).

?*Polyonyx biunguiculatus*, Ortmann 1894, p. 30 (Thursday Island).

Polyonyx tuberculatus var., Rathbun 1924, p. 31, pl. 1, fig. 17 (Cape Jaubert).

Diagnosis. Carapace subrectangular, broader than long especially in females; surface devoid of hairs. Lateral margins unarmed. Front trilobate, median lobe subrectangular. Merus of chelipeds with a vestigial inner lobe. Inner margin of carpus straight, unarmed. No crest on proximal half of ventral surface of chela. Dorsal surface of chelipeds without hairs. Propodus of walking legs with one ventral spinule in addition to three at distal end. Dactyl with two large, subequal fixed claws; two small, movable spinules on lower margin. No pleopods in males.

Material examined. 1 ♀, King Sound, B.M.N.H. 1 ♀, 45 miles W.S.W. of Cape Jaubert, 72 ft, 7.vii.1911, E. Mjöberg, U.S.N.M. 56433.

1♂, 2 miles W. of Legendre I., Dampier Archipel., 23 fm, 9.vi.1960, B. R. Wilson on "Davena", W.A.M. 128-60. 1♂, Gidley I., Dampier Archipel., 10 fm, 1.vi.1960, R. D. Royce on "Davena", W.A.M. 129-60. 1♂, 3♀, W. approaches to Mermaid Strait, Dampier Archipel., 20 fm, 27.v.1960, R. D. Royce on "Davena", W.A.M. 117-60. 1♂, Malus I., Dampier Archipel., 10 fm, 31.v.1960, R. D. Royce on "Davena", W.A.M. 180-60. 2♂, Exmouth Gulf or Shark Bay, trawled, winter 1960, R. McKay on "Peron", W.A.M. 76-62.

Remarks. The U.S.N.M. specimen is part of the material reported by Rathbun (1924) as "*Polyonyx tuberculosus* de Man, var.". The Queensland records of Haswell and Ortmann need to be verified in the light of Johnson's (1958) revision of *Polyonyx*, in which he showed that *P. biunguiculatus* has frequently been confused with other species; but specimens I have examined from several Queensland localities are definitely referable to *P. biunguiculatus*.

Ground colour pale yellow, thickly speckled with orange-red; the colour especially concentrated on fingers of chelae. Broad bands on walking legs. Males to 6.9 by 8.4 mm; ovigerous females to 4.6 by 6.9 mm. Ovigerous females in May at Dampier Archipelago and in July at Cape Jaubert.

Distribution. Indian Ocean (Eritrea; Seychelles; ? Ceylon); western Pacific Ocean from Formosa Strait southward to East Indian Archipelago. Australia (Western Australia and Queensland).

Polyonyx obesulus Miers

Porcellana obesula White 1847, p. 130 (*nomen nudum*; ? Madgica-Sima Islands). Adams in Adams and White 1848, p. iii.

Polyonyx obesulus, Miers 1884, p. 272, pl. 29, fig. D (Port Darwin; Prince of Wales Channel; Port Denison; West Island). Henderson 1888, p. 115 (Flinders Passage). Johnson 1958, pp. 99, 108, text-fig. 4. Haig 1964, p. 378.

?*Porcellana (Polyonyx) tuberculosa* de Man 1888, p. 424, pl. 19, fig. 1 (Amboina).

Polyonyx parvidens Nobili 1905, p. 161 (Gulf of Iran).

Diagnosis. Carapace subovate, broader than long, particularly in females; surface devoid of hairs. Lateral margins unarmed. Front trilobate, median lobe rounded or subrectangular. Merus of chelipeds with a vestigial inner lobe. Inner margin of carpus straight, unarmed. No crest on proximal half of ventral surface of chela. Dorsal surface of chelipeds without hairs. Propodus of walking legs with one ventral spinule in addition to three at distal end. Dactyl with two large, subequal fixed claws; a single rather large, stout spinule on lower margin.

Material examined. 1♂, 23 miles S.W. of Troughton I., 25 fm, 22.x.1962, R. W. George on "Dorothea", W.A.M. 336-62. 1♂, Broome, W.A.M. 9457/8. 1♂, Broome, June 1932, A.M. P.10265. 1♀, near entrance to Roebuck Bay, 5-8 fm, 26.ix.1929, A. A. Livingstone, A.M. P.14453. 1♂, 2 miles S.W. of Peak I., 10 fm, 18.vi.1960, B. R. Wilson on "Davena", W.A.M. 136-60. 1♀, 9 miles S.W. of Geraldton, 20 fm in large sponge, 30.x.1956, R. W. George, W.A.M. 43-62.

Remarks. The type locality of *P. obesulus*, according to White (1847) and as indicated in records at the British Museum (Natural History), was the Madgica-Sima Group, which is in the

Ryukyu Archipelago (see Haig 1964, p. 380). But Adams in Adams and White (1848, p. iii) stated that what were evidently the type specimens were dredged in the Sulu Sea. The latter locality seems more likely in view of the fact that the species is not otherwise reported as far north as the Ryukyu Islands.

Males to 5.0 by 7.1 mm; ovigerous female 5.7 by 7.7 mm. Ovigerous female in October at Geraldton.

Distribution. Indian Ocean including Gulf of Iran; western Pacific Ocean, from Philippine Islands (perhaps from Ryukyu Islands?) southward to East Indian Archipelago. Australia (Northern Territory and Queensland). Now recorded from Western Australia.

Polyonyx triunguiculatus Zehntner

Polyonyx triunguiculatus Zehntner 1894, p. 185 (Amboina). Johnson 1958, pp. 99, 110.

Polyonyx acutifrons de Man 1896, p. 384 (Atjeh, Sumatra); 1898, pl. 32, figs. 49, 49a-d.

Diagnosis. Carapace subovate or subrectangular, broader than long, especially in females; surface devoid of hairs. Lateral margins unarmed. Front trilobate, median lobe prominent, narrow, acute. Merus of chelipeds with a well-developed lobe on inner margin. Inner margin of carpus straight, unarmed. Chela with a pronounced longitudinal crest on proximal half of ventral surface. Dorsal surface of chelipeds without hairs. Propodus of walking legs with one ventral spinule in addition to three at distal end. Dactyl with two large, subequal fixed claws; one or two small movable spinules on lower margin.

Material examined. 1 cheliped, Broome, June 1932, A.M. P.14454. 1♀, 40 miles W. of Cape Jaubert, 23 fm on sponge, 13.x.1962, R. W. George on "Dorothea", W.A.M. 328-62. 2♀, 3-4 miles off N.E. end Delambre I., Dampier Archipel., 10 fm, 5.vi.1960, B. R. Wilson on "Davena", W.A.M. 126-60. 1♂, 2 mi. S.W. of Peak I., 10 fm, 18.vi.1960, B. R. Wilson on "Davena", W.A.M. 136-60. 1♂, Exmouth Gulf or Shark Bay, trawled, winter 1960, R. McKay on "Peron", W.A.M. 76-62. 3♂, 1♀, Shark Bay, 8.vii.1962, "Peron", W.A.M. 334-62.

Remarks. Colour of preserved specimens pale orange, with darker orange areas on carapace and chelipeds. On the dorsal surface of the carapace there is a large patch of the darker shade on either side, leaving a pale median stripe with parallel sides which joins pale areas on frontal and posterior parts of the carapace. On the chelipeds there is irregularly-shaped light and dark mottling. Males to 7.0 by 8.9 mm; non-ovigerous female 3.7 by 4.7 mm; ovigerous females to 6.9 by 9.3 mm. Ovigerous females at Dampier Archipelago in June, Shark Bay in July, and Cape Jaubert in October.

Distribution. Throughout the Indian Ocean including the Red Sea; in the western Pacific reported only from Singapore, Amboina, and Sumatra. Now recorded from Australia.

Polyonyx transversus (Haswell)

Porcellana transversa Haswell 1882a, p. 759 (Bowen); 1882b, p. 150.

Polyonyx transversus, Baker 1905, p. 262, pl. 36, figs. 2, 2a (off Newland Head). Hale 1927a, p. 83, text-fig. 80. McNeill and Ward 1930, p. 363, pl. 59, fig. 3 (Botany Bay);

Port Curtis; Western Port). Pope 1946, p. 91, text-fig. (Pittwater). Dakin 1952, p. 352 (Gunnamatta Bay). Johnson 1958, pp. 99, 115.

Diagnosis. Carapace subovate or subrectangular, broader than long particularly in females; surface devoid of hairs except for fringe on frontal margin. Lateral margins unarmed. Front transverse, with median lobe very slightly developed. Merus of chelipeds with a vestigial lobe. Inner margin of carpus developed into a prominent, convex lobe, broadest distally and unarmed. Dorsal surface of chelae and inner margin of carpus thickly hairy. Propodus of walking legs with more than 12 spinules along lower margin. Dactyl with two fixed claws, ventral much larger than dorsal one; two stout spines on lower margin.

Material examined. 1♂, 1♀, Cockburn Sound, 5.iv.1959, Stn. 146, W.A.M. 113-60. 4♀, S. end Careening Bay, Garden I., Cockburn Sound, from *Chaetopterus* tubes, 1.iii.1959, Mar. Group Nat. Club, W.A.M. 119-60. 14♂, 11♀ Careening Bay, Garden I., from *Chaetopterus* tubes on intertidal flats, 26.xi.1961, B. R. Wilson and marine group, W.A.M. 37-62.

Remarks. The type specimens were taken from the siphons of a bivalve mollusc, *Aspergillum*. Johnson (1958) stated that there is no definite information as to the habitat of the species in the more southern records. However, McNeill and Ward (1930, pp. 363 and 364) gave rather detailed information about the habitat of specimens in the collections of the Australian Museum. Of specimens from Botany Bay they stated: "Both specimens were taken from "U"-shaped worm tubes, occupied by a species of the polychaet *Chaetopterus*, where they were found reclining in the inflated basal portion of their sanctuaries, at a depth of about fourteen inches from the surface of the tidal flats exposed at low tide." Of the Port Curtis specimens collected by M. Ward: "He remarked that they [worm tubes] were found in the soft mud at the extreme low tide line, or close thereto in shallow drains and pools. In each worm tube examined a male and female crab were present. The tubes were not more than one foot deep in the mud, and, owing to the fragile nature of their structure, great difficulty was experienced in digging them out." They concluded: "The fact that so very few specimens have been recorded. . . combined with the evidence already to hand, suggest that the creature. . . is invariably a commensal. This would account for its apparent rarity in collections." Further information on the *Polyonyx-Chaetopterus* association is provided by Pope (1946).

The ground colour of preserved specimens is pale orange, with mottlings of darker orange on the carapace and chelipeds. Males to 6.4 by 8.3 mm; non-ovigerous females to 7.6 by 10.5 mm; ovigerous females to 8.0 by 11.0 mm. All three lots of specimens examined included egg-bearing females.

Distribution. Apparently an Australian endemic; reported from Queensland, New South Wales, Victoria, and South Australia. Now recorded from Western Australia.

***Polyonyx maccullochi*, sp. nov.**

(Fig. 3)

Polyonyx obesulus (?), Grant and McCulloch 1906, p. 41 (Port Curtis).

Description. Carapace subovate, only slightly broader than long (c. 1.2 times in both males and females); surface smooth, hairless except for fringe on frontal margin; sides sparsely hairy. Front narrow, with a strong median lobe forming a slightly acute angle and extending well beyond the obtuse lateral lobes; in dorsal view appearing transverse or slightly convex.

All segments of antennal peduncle smooth; flagellum long, slender, with a few vestigial hairs. Ventral surface of outer maxillipeds not hairy.

Chelipeds rather sparsely hairy; no hairs on upper surface, some on lower surface of merus and chela and in gape of fingers, and a sparse fringe on outer margins of chelae. Upper surface of chelipeds smooth, sometimes lightly punctate but without rugosities or tubercles. Merus with a well-developed, convex lobe on inner margin. Carpus with inner margin produced into a prominent lobe, unarmed and evenly convex throughout its length. Males: Major chela swollen, without crest on surface; fingers strongly curved outward; fixed finger with a strong rounded tooth on cutting edge at base, movable finger with a tooth at base and another about midway along cutting edge; outer margins of fingers smooth. Minor chela rather slender, without crest, less swollen than major chela; fingers long and slender, not out-curved, their inner margins minutely crenulate; outer margin of fixed finger with a row of small, sharp tubercles, movable finger with a few similar tubercles on outer surface near tip. Females: Major chela with fingers longer and much less out-turned than in males, on the whole resembling minor chela; teeth on cutting edges of fingers not well developed. Minor chela as in males. Walking legs with a fringe of long, plumose hairs on margins. Merus unarmed on lower margin, that of third walking leg about twice as long as broad. Propodus armed on lower margin with four or five stout movable spinules including the pair at distal end, that of third walking leg about twice as long as broad. Dactyl very narrow in comparison to propodus; one or two minute spinules on its lower margin proximal to bifid tip. Male with a pair of pleopods.

Holotype male (4.2 by 5.1 mm). Entrance to Roebuck Bay, 9 fm, 15.viii.1929, A. A. Livingstone, A.M. P.14117.

Paratypes. QUEENSLAND: 1♀, Port Curtis, 7 fm, F. E. Grant, A.M. G.5754. WESTERN AUSTRALIA: 1♂, 1♀, Broome, June 1932, A.M. P.10268. 1♀, entrance to Roebuck Bay, 9 fm, 15.viii.1929, A. A. Livingstone, A.M. P.14123. 1♂, 1♀, Denham, Shark Bay, 4-22.ix.1905, St. 65, Hamburg S.W. Australia Exped., Z.M.H. 11733. 1♀ (juv.), c. 2½ miles S.W. of Denham, Shark Bay, 3 m, 10.vi.1905, St. 7, Hamburg S.W. Australia Exped., Z.M.H. 11651. 1♂ (juv.), Brown Station, Dirk Hartog I., Shark Bay, 2½-4½ m, 18.vi.1905, St. 28, Hamburg S.W. Australia Exped., Z.M.H. 11698. 1♂, 1♀, entrance to Useless Inlet, Shark Bay. ¾-2 m, 13.ix.1905, St. 18,

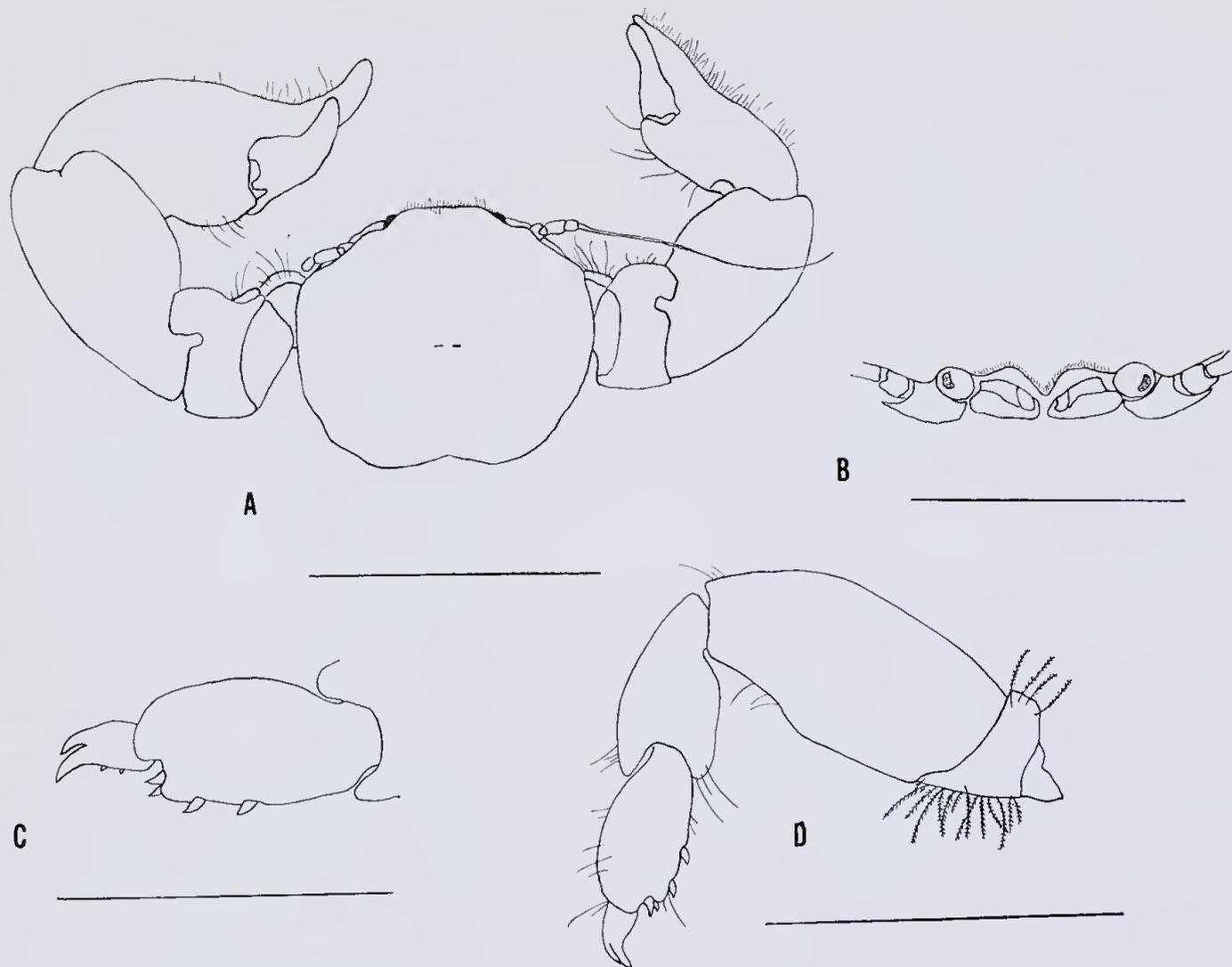


Figure 3.—*Polyonyx maccullochi*. A, dorsal view of holotype; B, anterior view of frontal region, paratype; C, propodus and dactyl of left third walking leg, paratype; D, left third walking leg, paratype. Scale for A = 5 mm; for B, 3 mm; for C, 1 mm; for D, 2 mm.

Hamburg S.W. Australia Exped., Z.M.H. 11679. 2♂, Shark Bay, 8.vii.1962, "Peron", W.A.M. 334-62.

Remarks. *Polyonyx maccullochi* belongs to a well-defined group of *Polyonyx* species (designated the "*P. sinensis* group" by Johnson 1958) in which the lateral margins of the carapace, and the inner margins of the merus and carpus of the chelipeds, are unarmed; the chelipeds are hairy; and the dorsal claw of the dactyl of the walking legs is much smaller than the ventral claw. The two species of this group now reported from Western Australia, *P. maccullochi* and *P. transversus*, can be readily distinguished from each other by the characters given in the key and diagnoses. Of the other Indo-West Pacific members of group *sinensis* treated by Johnson, only *P. cometes* Walker and *P. utinomii* Miyake agree with *P. maccullochi* in having a well-developed lobe on the inner margin of the merus of the chelipeds. In *P. cometes* the dorsal surface of the chelipeds is densely hairy, whereas in *P. maccullochi* this surface is devoid of hairs. In *P. utinomii* the median frontal lobe is weakly produced, and the propodus of the walking legs bears only three spinules on its lower margin.

The specimen from Queensland listed above is the one questionably referred by Grant and McCulloch (1906) to *Polyonyx obesulus*.

Substrates, where mentioned on the labels with the material examined, were sand or sand and mud. There was no indication of commensalism, but it is likely that members of this species occur at times in association with *Chaetopterus* or other organisms as do most species of group *sinensis*. Males to 5.1 by 6.2 mm; females to 5.1 by 6.4 mm.

Distribution. Known only from the localities listed above, in Western Australia and Queensland.

Genus **RAPHIDOPUS** Stimpson

Diagnosis. Basal antennal segment strongly produced forward and broadly in contact with anterior margin of carapace; movable segments far removed from orbit. Carapace subovate, broader than long. Front transverse and tridentate, not prominent nor greatly deflexed. Chelipeds subequal. Dactyl of walking legs a straight, slender spine, with an acute tip; no supplementary spinules. Telson of abdomen seven-plated.

Raphidopus ciliatus Stimpson

Raphidopus ciliatus Stimpson 1858, pp. 228, 241 (Hong Kong); 1907, p. 185, pl. 22, fig. 5.

Rhaphidopus ciliatus, Grant and McCulloch 1906, p. 42 (Port Curtis).

Diagnosis. Sides of carapace, inner and outer margins of chelipeds, upper and lower surface of chelae, and walking legs very heavily setose. Lateral margins of carapace and outer margin of carpus of chelipeds armed with spines. Upper surface of carpus with a median longitudinal row of tubercles or spinules.

Material examined. 1 ♀, Roebuck Bay, shore on sand flat between tides, 8.viii.1929, A. A. Livingston, A.M. P.13737.

Remarks. The single specimen had a carapace length of 6.0 mm and breadth of 7.7 mm.

Distribution. Japan; Hong Kong. Australia at Port Curtis, Queensland. Now recorded from Western Australia.

Acknowledgments

I am most grateful to Dr. R. W. George of the Western Australian Museum for placing his institution's collection of Porcellanidae at my disposal and for his patience in answering numerous questions concerning it. I am indebted to Mr. F. A. McNeill and Dr. J. C. Yaldwyn for the loan of specimens housed in the Australian Museum, and in particular to Mr. McNeill for providing information on and photographs of the types of several porcellanid species; and to Dr. A. Panning and Dr. F. A. Chace, Jr., who sent additional material from their respective institutions, the Zoologisches Museum, Hamburg, and the U.S. National Museum. I also wish to thank Dr. Isabella Gordon, through whose kindness I was able to examine type and other material during a visit to the British Museum (Natural History).

My sincere thanks go also to several persons who assisted this investigation in other ways. Dr. J. Forest of the Muséum d'Histoire Naturelle, Paris, answered questions concerning type specimens in his institution. Dr. L. B. Holthuis of the Rijksmuseum van Natuurlijke Historie, Leiden, provided valuable advice on certain problems of nomenclature. An exchange of opinions and information with Dr. D. S. Johnson of the University of Malaya, Singapore, helped to clarify several points.

I also wish to thank the administration of the Allan Hancock Foundation for providing the working space in which this investigation was carried out.

List of Genera and Species

Genus *Petrocheles* Miers
australicensis (Miers)

Genus *Petrolisthes* Stimpson
scabriculus (Dana)
militaris (Heller)
moluccensis (de Man)
boscii (Audouin)
haswelli Miers
teres Melin
ohshimai (Miyake)

Genus *Pachycheles* Stimpson
sculptus (H. Milne Edwards)
johnsoni sp. nov.
granti sp. nov.
pisoides (Heller)

Genus *Pisidia* Leach
spinuligera (Dana)
cf. *spinulifrons* (Miers)
dispar (Stimpson)

Genus *Porcellana* Lamarck
habei Miyake
gravelei Sankolli
ornata Stimpson
nitida Haswell
furcillata sp. nov.

Genus *Porcellanella* White
triloba White

Genus *Polyonyx* Stimpson
suluensis (Dana)
telestophilus Johnson
biunguiculatus (Dana)
obesulus Miers
triunguiculatus Zehntner
transversus (Haswell)
maccullochi sp. nov.

Genus *Raphidopus* Stimpson
ciliatus Stimpson

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11.—A new species of *Nectria* (Asteroidea, Goniasteridae) from Western Australia

By S. A. Sheperd* and E. P. Hodgkin**

Manuscript received 16th February, 1965; accepted 27th April, 1965.

Abstract

A new species of starfish belonging to the genus *Nectria* is described and figured. All specimens collected so far are from the lower west coast, between 29° and 34° South latitude in shallow water down to 55 feet.

Nectria wilsoni sp. nov.

(Fig. 1)

Diagnosis

Disk large, arms thick at base and slightly tapering. The plates on the aboral surface of the disk form elevated paxilliform tabulae, as is typical of the genus, and are covered with relatively large protuberant hemispherical granules. The peripheral granules form a radiating fringe. Distally the aboral tabulae are low and have a large central granule surrounded by a ring of small granules. Papulae are rare or absent from the distal part of each arm.

The species differs from other members of the genus in the size and appearance of the granules of the aboral tabulae, both on the arms distally and on the disk. The granules are coarser and larger and the tabulae somewhat more elevated and closer together than in *N. ocellata* (Perrier), to which it otherwise bears some resemblance.

Description of holotype

Rays 5. R/r is 77/26 mm R = 3r. Br is 30 mm at the base, 15 mm at the middle and 12 mm near the tip of the ray.

Aboral plates of disk and base of rays form large paxilliform tabulae, elevated about 3-4 mm and flat on top. The shaft of each tabula hourglass-shaped and about 2-3 mm across at narrowest point widening to 4-6 mm across on the crown. Crowns of tabulae subequal, more or less rounded in outline and crowded so that they frequently touch adjacent crowns. Tabulae covered with swollen hemispherical protuberant granules of from 0.4 to 1.0 mm across; the peripheral granules similar in shape and character, though sometimes longer. Each disk tabula has about 16 to 24 peripheral granules and 10 to 20 inner granules among which there may be considerable disparity in size. On the rays, the tabulae are smaller and lower and on the distal two thirds of ray are crowded,

low, and difficult to distinguish. These distal plates each have a large central granule, protuberant and hemispherical, about 1 mm across and surrounded by a ring of 8-12 small hemispherical granules.

Papulae on the disk in groups of 6-14 between the connecting ossicles of the aboral plates and in decreasing numbers to about half way along the ray, rare or wanting on the distal half, absent between the marginal plates.

Madreporite low, about 2.5 mm across and hidden under the tabulae midway between centrum and margin.

Marginal plates distinct, about 21-24 in each series on each side of ray; proximally higher than long and covered with a more or less uniform coat of granules, but on the distal half squarish and a central granule on each plate is enlarged and dominant (fig. 1, B).

Oral intermediate plates covered with coarse rounded granules close enough to obscure the outlines of the plates.

Ambulacral plates with 2 or 3 (sometimes 4 proximally) furrow spines about 2 mm long and more or less rounded and blunt. Subambulacral spines 2, similar to furrow spines but shorter and thicker, occasionally a second series of granuliform subambulacral spines.

Two pedicellariae were detected behind the furrow series each with 4 or 5 slender slightly curved spines bending inwards against one another (fig. 1, E). They were not seen elsewhere.

Oral plates with 6 or 7 stout prismatic or quadrate marginal spines, the innermost stoutest, flattened where they are contiguous. On the surface of each plate there are 3 or 4 stout prismatic spines with rounded edges and distally on each plate a group of 6 to 8 small granules.

Colour

All specimens have been a strong red when fresh, varying from deep orange to magenta on both surfaces. The skin of the papular areas and between the granules of the oral surface may be pale, almost white.

Material Examined

The Holotype (W.A.M. no. 3-65) is labelled "Sorrento Beach near Perth, 2 fath., 27/1/63" and was collected by B. R. Wilson. Nine other specimens have been examined and are designated paratypes, eight of these are lodged in the Western Australian Museum and the ninth in the South Australian Museum.

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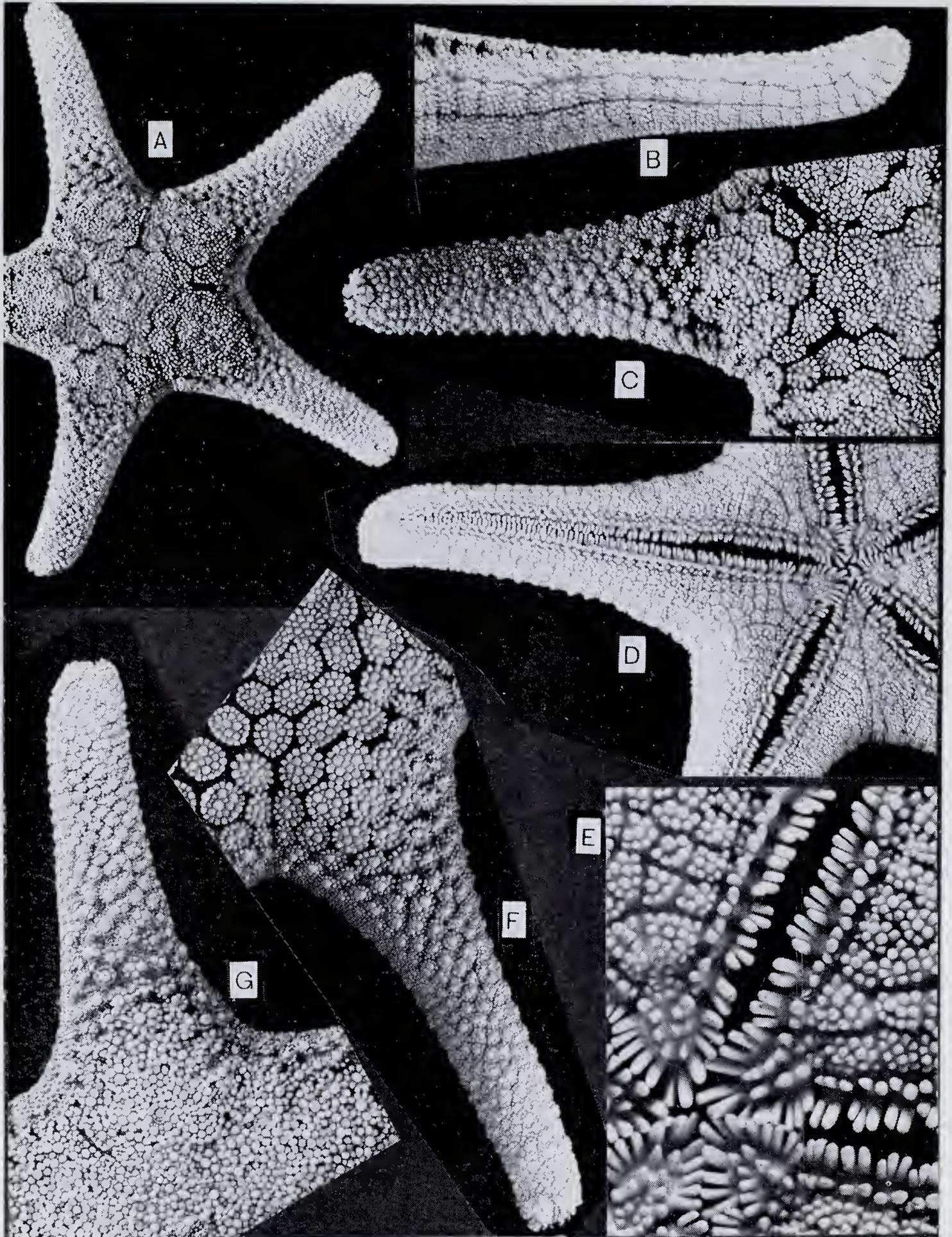


Figure 1.—*Necria wilsoni* sp. nov. A-E: Holotype, W.A.M. No. 3-65. F: Paratype, W.A.M. No. 1-65. G: Paratype, S.A.M. No. K 613.

- W.A.M. 18-59. R = 63 mm Eagle Bay,
Cape Naturaliste, 30 ft., rock.
- W.A.M. 19-59. R = 75 mm Dunsborough,
30 ft.
- W.A.M. 2-62. R = 85 mm Hamelin Bay
near Cape Leeuwin, on jetty piles.
- W.A.M. 3-62. R = 110 mm Off Beagle
Island (29° 50' S.), probably in a cray-
fish pot.
- W.A.M. 1-65. R = 54 mm Dunsborough,
at 55 ft. on rock.
- W.A.M. 2-65. R = 90 mm Sorrento reef,
near Fremantle, on sea grass.
- W.A.M. 4-65. R = 90 mm Sorrento reef.
- W.A.M. 5-65. R = 83 mm Sorrento beach,
18 ft., on sea grass, near limestone.
- S.A.M. K 613. R = 69 mm Hall Bank near
Fremantle.

With the exception of W.A.M. 3-62, all were collected by B. R. Wilson.

These specimens show some variability in the coarseness of the granulation, which is particularly noticeable on the aboral tabulae. Two of the smaller paratypes (W.A.M. 1-65 and

S.A.M. K613) have smaller and less protuberant granules (fig. 1, F) and in this respect approach the finer granulation of *N. ocellata*. They also have longer and more slender arms, but this may be attributable to their size. In others (W.A.M. 2-62, 2-65, 4-65, 5-65,) the granules of the aboral tabulae are larger and the peripheral granules more elongate (fig. 1, G). The type thus occupies an intermediate position between the extremes as they are now known. There is much variation in the separation of the tabulae in preserved specimens; in some they are well separated so that the peripheral granules are not in contact, but in others they are so tightly packed that the outlines of individual tabulae are obscured. The peripheral granules of the tabulae are mobile and may be preserved in any position from flat to almost vertical.

The presence or absence of pedicellariae has no significance. In four specimens they are absent, in one they are common both orally and on the shafts of the tabulae, and in the rest aborally only.

The ratio R/r ranges from 2.8 to 3.2, averaging 3.1.

12.—Further studies of the polymorphic species *Crinia insignifera* Moore (Anura, Leptodactylidae) on Rottnest Island

by A. R. Main*

Manuscript received 16th February, 1965; accepted 27th April, 1965

Abstract

Three populations of the polymorphic *Crinia insignifera* Moore on Rottnest Island have been studied from 1959 to 1964. Over the period of the observations the seasonal rainfall pattern has gone from dry to wet and during the same period the proportion of adults in the population has declined. Also during the warm dry 1959 and mild dry 1961 winters there was a poor survival of adults of the lyrate morph and a good survival of the ridged morph. However, during the years of observation, the morph frequency among recruits was constant from year to year.

Negri soak

Lake Negri is a small salt lake to the west of Bagdad from which it is separated by a low sandy area. The shore of the lake is vegetated by *Salicornia*, *Gahnia* and *Sporobolus*, *Scirpus nodosus* and then the *Stipa-Poa* steppe.

During 1960, while searching for road building material, the Rottnest Board of Control excavated a small depression in the *Gahnia* zone on the northern edge of Lake Negri. The depression is about 15 feet square and up to 12 inches deep, and surrounded by the *Gahnia* tussocks both standing and uprooted. In the winter of 1960 this depression filled with rainwater and in it a small breeding congress of frogs established itself. It is presumed that the stock of this colony was derived from the population of a small seep in the *Gahnia* on the north-west side of Negri. In seasons of high rainfall the pond floods the adjacent lake shore. In the very wet year of 1963 the lake level rose and the flooded depression and saline lake became confluent with the consequent death of all tadpoles and most adults.

Introduction

The present observations are a continuation of those reported earlier (Main, 1961) on the polymorphic frog, *Crinia insignifera* Moore. The earlier observations have been extended so that intra- and inter-locality comparisons of polymorph frequency and juvenile recruitment are possible. The observations presented cover the years from 1959 to 1964 inclusive which by good fortune encompass extremes of seasonal heat, cold, and drought. Localities mentioned in the text are shown on the map in Hodgkin and Sheard (1959).

Lighthouse swamp

This is an area of peaty soil in an interdune depression not associated with salt lakes. The area is vegetated by *Arthrocnemum* spp., *Salicornia australis*, *Gahnia trifida* and *Sporobolus virginicus*. During the winter the depression is covered with water of varying depth and *Crinia insignifera* breeds throughout the swamp wherever the water is shallow. In exceptionally wet years the water level rises and floods the lower parts of the surrounding *Stipa-Poa* grassland. During the dry season of the year frogs can only be obtained from beneath stones among a grazed area of *Sporobolus* on the northern part of the swamp which passes to the north into sand dunes and coastal limestone vegetated with *Stipa*, *Poa* and *Acanthocarpus*.

Description of swamps sampled

Bagdad soak

An extensive area of freshwater seepage occurs on the western end of Lake Bagdad where ground water derived from sand dunes to the west of Lake Bagdad seeps out above a fossil shell bed which in this area forms the beach and bed of the lake. Passing away from the lake are found zones of vegetation as follows; a close cropped mat of *Sporobolus virginicus* which is heavily grazed by the quokka (*Setonix brachyurus* Quoy and Gaimard) at all seasons; then an area dominated by closely grown tussocks of the sedge, *Gahnia trifida*, which merges to the landward into an arid steppe of *Stipa*, *Poa* and *Acanthocarpus preissii*. Within the *Gahnia* zone there is a small depression about 10 feet long by 7 feet wide which contains water only during the winter (May to August) and at other times is grown over with *Sporobolus virginicus*. No *Gahnia* occurs in this depression. During the summer frogs of the genus *Crinia* can be located beneath the *Gahnia* tussocks adjacent to this depression. In years of heavy rainfall the soak does not increase its area but overflows into the adjacent lake.

Sampling and measurement

As in the earlier study samples were taken twice yearly: at post-breeding in November and at pre-breeding in March. At Lighthouse swamp samples were obtained by turning all the stones on the northern part of the swamp. These stones were carefully replaced after sampling. At Bagdad soak the standing and dead *Gahnia* tussocks adjacent to the depression were searched and a similar method was adopted at Negri. One sample was taken in June 1960 from a breeding congress on Lighthouse swamp at night by using a head-torch. Snout to vent

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length measurements were made with vernier callipers while holding the frog on a flat surface. The phenotype of the frog was recorded at the time snout-vent measurement was made.

Results

Size distribution in samples

Breeding commences each winter in May or June and young frogs are metamorphosing by late August to mid-September as the ponds are drying. These young frogs feed and grow throughout the late spring and summer as rain showers permit them to forage from their hiding places.

Size distribution of breeding or sexually mature animals are shown in the upper histogram of Figure 1. This figure also shows the distribution by sex of animals caught in Lighthouse swamp in June 1960. In this situation males were calling, and females were either gravid with eggs, in oviduct, clasped and egg-laying, or spent. The size distribution can be taken as indicating sexual maturity at about 20 mm snout-vent length. The distribution also shows that females tend to be larger than males.

The size distribution of the post-breeding sample is shown in the lower histograms of Figure 1. This sample is clearly bi-modal. From the sample taken in June 1960 it is clear that the right hand group are sexually mature while the left hand group are immature and probably the progeny of the June breeding. This histogram also shows the size distribution of animals marked in November 1959 or March 1960 and recaptured in November 1960. It is noticeable that none of these recaptures are below the minimal length of sexual maturity established by the June 1960 sample. Collections made during the following years produced no case in which animals marked as juveniles in November or March were below 20 mm snout-vent length when recaptured the next November.

A number of egg masses were raised in artificial outdoor ponds within the Zoology department yards on the mainland. In these, development to metamorphosis was slower but subsequent growth and mortality appeared to be comparable to that in field situations. Progressive snout-vent length measurements of these animals are as follows: December 1, 1960—mean 9.3 mm, range 7.9 to 12.4 mm; January 31, 1961—mean 14.3 mm, range 10.9 to 16.4 mm; March 15, 1961—mean 17.9 mm, range 16.9 to 18.6 mm. This rearing trial suggests that sexually mature frogs could be obtained twelve months after egg laying.

Field recaptures of individually marked animals from all three localities supports the above interpretation. However, frogs over 21 mm snout-vent length show very irregular growth and it was concluded that once an animal attains maturity it cannot be aged on size alone. Consequently, age distribution of the post-breeding samples has been restricted to juveniles, that is offspring of most recent breeding (< 20 mm) and adults, that is more than one year old (> 20 mm). This recognition of recruits as distinct from adults does

offer increased opportunities in analysing genetic and age composition of population through a series of years.

Mortality and longevity

The heavy field mortality precluded establishment of detailed survivorship curves. For example in November 1961 on Lighthouse swamp 312 juveniles were individually marked. The following November a sample of 151 frogs yielded 22 adults of which only 4 were of the series of 312 juveniles marked the previous year. Recoveries were much higher in the early years. These have not been plotted because there is so much difference between the early and later years; a fact reflected in the change in numbers of adults and juveniles in the population (Tables 2, 3 and 4).

The longest recorded period for an individual survival at each locality was: Lighthouse swamp, 2 years, marked as adult November 1960 recaptured November 1962; Bagdad soak, 2½ years, marked as juvenile November 1961, recaptured March 1964; Negri soak, 2½ years, marked as juvenile November 1960, recaptured March 1963.

Population size

Population estimates. These have been made by the method in Main (1961), except in 1964 when simple recapture data were used to calculate population estimates by means of a Lincoln index. The results are shown in Table 1.

TABLE 1

Estimates of size of post-breeding populations of C. insignifera at three swamps on Rottneest Island.

Year	Lighthouse	Bagdad	Negri
1955	1,021	....	....
1959	261	....	....
1960	330	337	189
1961	580	....	165
1962	702	....	817
1963	....	....	....
1964	1,341	....	....

Errors in method of making estimates. In dry seasons disturbed frogs retreat to secure hiding places and so are not caught. Also, in dry seasons there is not a good admixture of marked and unmarked animals and therefore there is a tendency to get spurious population estimates. November 1962 was a dry period, while the November 1961 sampling period was overcast and with dew each night. During the November 1964 sampling period light rain showers were common. The census in 1955 (Main, 1961) followed an exceptionally wet season and somewhat similar wet conditions prevailed during 1964. There is every reason to believe that the high estimates of these years truly represent the population size.

Age structure

The specimens have been categorised into adult and juvenile using the snout-vent lengths determined in Figure 1. Data are presented in Tables 2, 3 and 4.

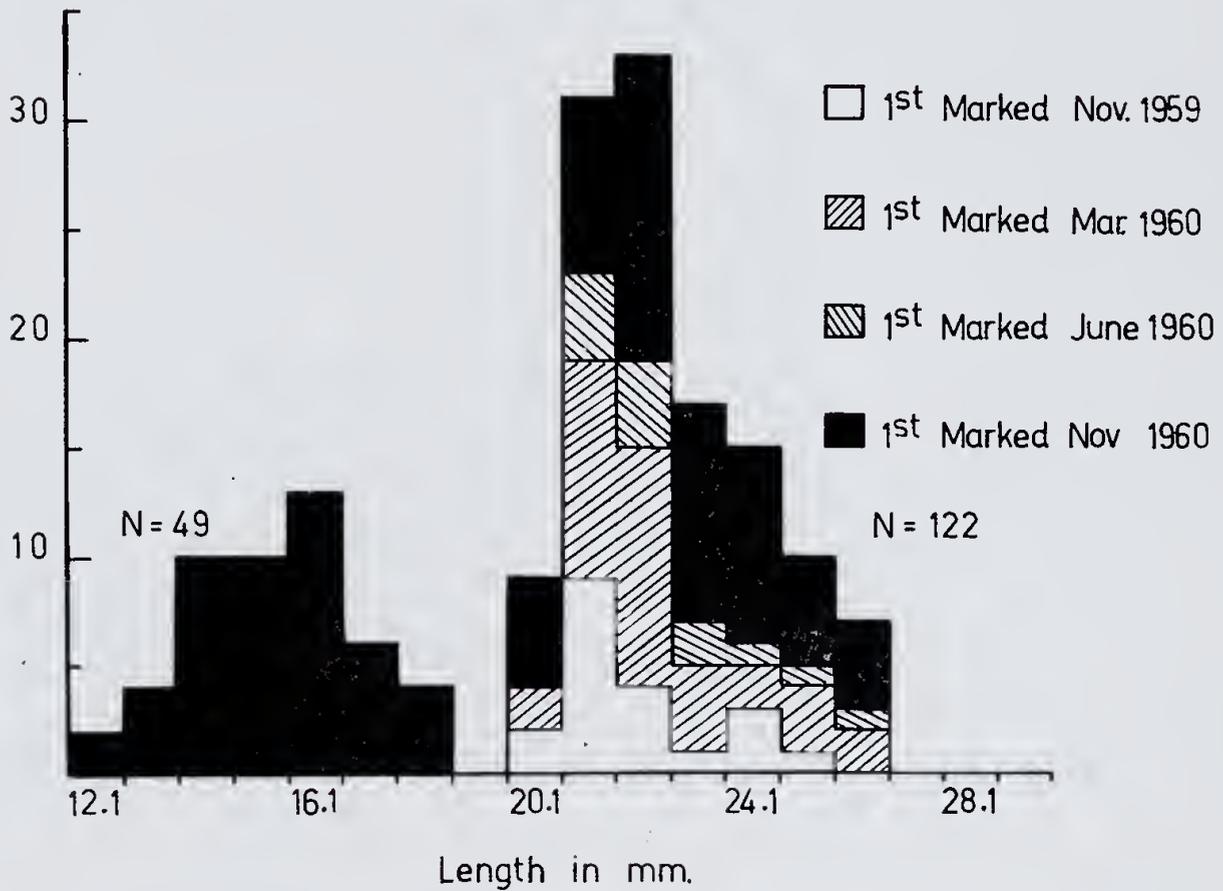
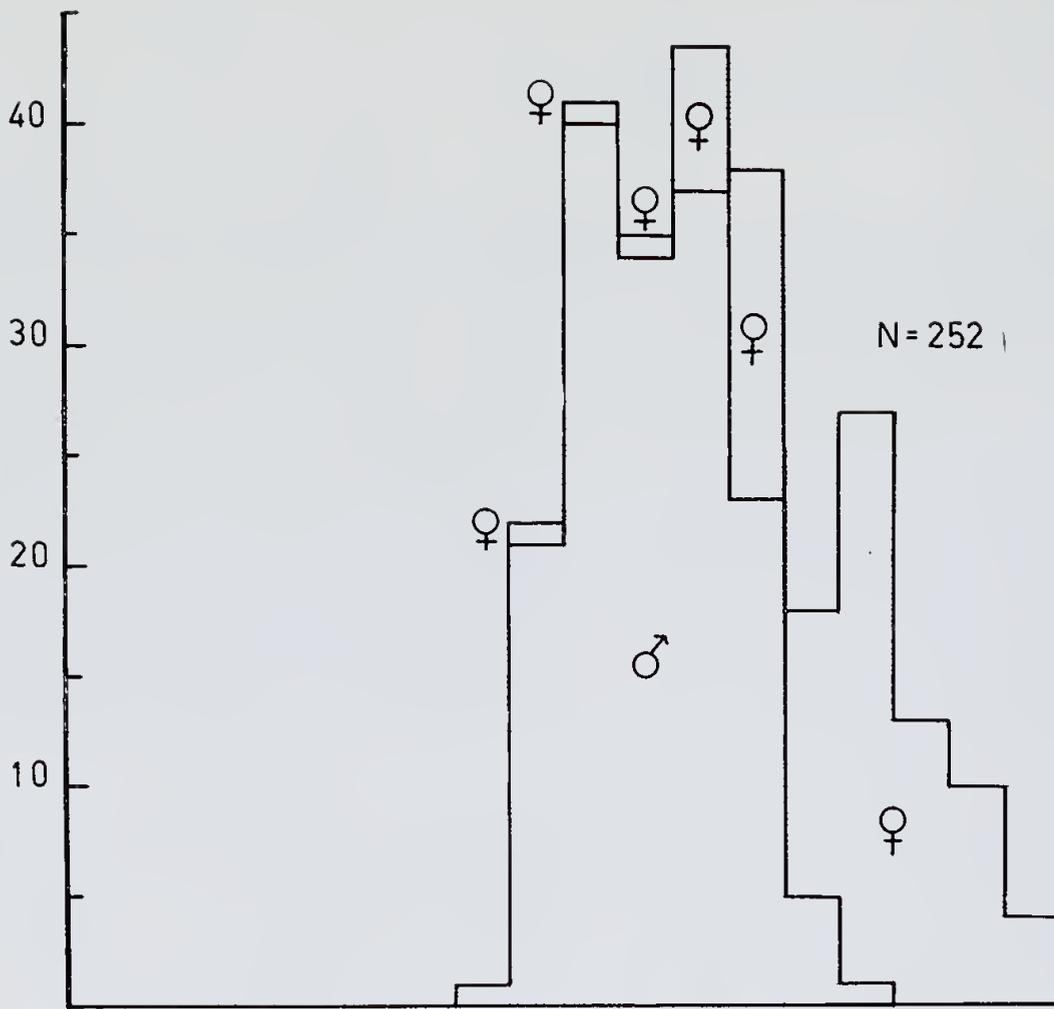


Figure 1.—Histograms of snout-vent measurements of two samples of *Crinia insignifera* collected from Lighthouse soak, Rottneest Island. Upper. Sample collected June, 1960. Lower. Sample collected November, 1960.

Annual changes within localities

All November samples from each locality show a pattern characterised by greater adult frequency in the earlier years and greater juvenile frequency in later years. These changes are most marked in the Lighthouse swamp and Negri soak populations in which the differences are statistically highly significant (Lighthouse swamp $p < 0.001$, Negri soak $p > 0.001$, < 0.01), at least pronounced at Bagdad soak. These differences reflect changes in adult survival and recruitment, particularly as each of these contributes to the population structure; survival was good in the early years and recruitment poor, later the adult survival was poor and recruitment relatively good. While the foregoing is true for the series of observations, comparison of each observation with the preceding one shows that at Lighthouse swamp statistical significance in the proportion of juveniles to adults is reached between November 1960 to November 1961, and again between November 1962 and 1963. At Negri soak statistical significance in the proportion of juveniles to adults is reached between November 1960 to November 1961, p almost 0.02 and November 1962 $p < 0.01$. Tests are not possible on the full Bagdad soak series.

Inter-population comparisons

Comparisons are only possible for the three years 1960 to 1962. The differences between November 1960 samples from Lighthouse and Negri are highly significant ($p < 0.001$). In 1961 the differences between Lighthouse swamp and Bagdad soak are highly significant ($p < 0.001$, but the differences between Lighthouse swamp and Negri soak are not significant. In 1962 Lighthouse swamp and Negri soak are not different but each is significantly different from Bagdad soak ($p < 0.001$).

In 1963 no sample was taken from Bagdad soak and the Negri soak population was catastrophically reduced by salt water flooding. In 1964 the Negri soak population was still very small. The Bagdad soak population was not

estimated, but juveniles were common, while the Lighthouse swamp population was very large and dominated by juveniles.

Genetic composition of populations

Lighthouse swamp. The data are presented in Table 2. A statistical analysis of these results shows:

Total population. A change in frequency of morphs between November 1959 and November 1960 ($p < 0.05 > 0.02$) with no statistically significant change subsequently.

Recruitment. There is no statistically significant difference between recruitment from year to year.

Differential survival of frogs. The age categories developed suggest that the March sample is comparable with the adults of the following November. Comparison shows November 1959 adults to differ significantly from the March 1959 sample (p almost 0.001, χ^2 10.22) but other samples are not significantly different.

Bagdad soak. The data are presented in Table 3. A statistical analysis of these results shows:

Total population. There is no statistically significant difference in morph frequencies in the samples over the years.

Recruitment. There is no difference in morph frequencies among recruits from year to year.

Differential survival of frogs. There is a significant difference in frequency of morphs present between March 1961 and adults November 1961 (chi square 4.268 $p < 0.05$, > 0.02).

Negri soak. The data are presented in Table 4. A statistical analysis of these results shows:

Total population. There is no significant difference in morph frequencies present from year to year.

TABLE 2

Lighthouse Soak; composition of population samples by phenotype and age.

Year and Month	Composition by Phenotype		Composition by Age and Phenotype				Composition by Age	
	Ridged	Lyrate	Adult		Juvenile		Adult	Juvenile
			Ridged	Lyrate	Ridged	Lyrate		
1959—								
March	49	50	....	....	....	....	....	....
November	54	25	38	11	16	14	49	30
1960—								
March	41	24	....	....	....	....	....	....
November	90	81	63	59	27	22	122	49
1961—								
March	22	24	....	....	....	....	....	....
November	206	178	45	27	161	151	72	312
1962—								
March	34	30	....	....	....	....	....	....
November	85	66	12	10	73	56	22	129
1963—								
March	36	36	....	....	....	....	....	....
November	127	98	3	3	124	95	6	219
1964—								
March	13	7	....	....	....	....	....	....
November	375	270	11	9	364	261	20	625

TABLE 3

Bagdad Soak; composition of population samples by phenotype and age.

Year and Month	Composition by Phenotype		Composition by Age and Phenotype				Composition by Age	
	Ridged	Lyrate	Adult		Juvenile		Adult	Juvenile
			Ridged	Lyrate	Ridged	Lyrate		
1960—								
March	44	48	...	...	...	...	...	...
November ...	33	32	33	30	...	2	63	2
1961—								
March	61	61	...	...	...	...	...	...
November ...	51	32	34	16	17	16	50	33
1962—								
March	45	38	...	...	...	...	...	...
November ...	12	5	7	3	5	2	10	7
1963—								
March ....	...	...	...	...	...	...	...	...
November ...	2	1	...	...	...	...	...	...
1964—								
March	22	12	...	...	...	...	...	...
November ...	16	9	2	1	14	8	3	22

TABLE 4

Negri Soak; composition of population samples by phenotype and age.

Year and Month	Composition by Phenotype		Composition by Age and Phenotype				Composition by Age	
	Ridged	Lyrate	Adult		Juvenile		Adult	Juvenile
			Ridged	Lyrate	Ridged	Lyrate		
1960—								
March ....	...	...	...	...	...	...	...	...
November ...	24	21	11	7	13	14	18	27
1961—								
March	35	16	...	...	...	...	...	...
November ...	54	34	14	5	40	30	19	70
1962—								
March	13	5	...	...	...	...	...	...
November ...	48	31	3	3	45	28	6	73
1963—								
March	17	3	...	...	...	...	...	...
November ...	...	2	...	...	...	...	2	...
1964—								
March ....	...	...	...	...	...	...	...	...
November ...	2	...	1	1	1	1	2	2

Recruitment. There is no difference in morph frequencies among the recruits in the years 1960 to 1962.

Differential survival of frogs. There is no statistical difference in morphs present between March 1961 and November 1961 adults.

Intra-population comparisons

Total populations. All populations are statistically similar from year to year with respect to frequency of morphs present.

Recruitment. All populations are similar with respect to frequency of morphs present among recruits.

Differential survival of frogs. The November 1961 samples from all populations show a decline in the lyrate morph compared with the previous March. Only in the case of Bagdad soak does this reach statistical significance. However, when the March and November samples from the three localities are pooled, the large sample does show the change to be significant almost at the $p = .02$ level (chi square 4.80). This suggests that the decline in frequency of lyrate animals is real and not an artefact of sampling.

Discussion

Earlier (Main, 1961) I attempted to explain the differences in morph frequency between the pre- and post-breeding samples in 1959 as follows;

"The advantage enjoyed by the ridged morph may be due to:

- (a) More rapid development so that, as larvae, ridged animals may take advantage of more ephemeral waters in dry years.
- (b) The larvae of the morph may be able to tolerate the warmer temperatures which are found in warm dry seasons."

The earlier information was interpreted in the absence of a distinction between the contributions of recruitment and adult survival to the total morph frequency. Ability to distinguish juveniles of the recent breeding from older animals in a post-breeding sample now allows another interpretation which can be considered after reviewing the results presented above.

Classification of the November samples into recruits and adults has exposed the threefold nature of the problem viz.:-

Constancy of phenotypes in recruitment; changes in survival among frogs of one phenotype in two seasons (1959; 1961); domination

of total population by juveniles towards the end of the study period. It is of interest to see whether any of the observed changes in the populations can be related in any way to the different seral stages present at each locality and/or the different seasonal weather pattern over the years of the study.

Ecological succession

Of the three localities described earlier Negri soak is clearly earliest in the succession, no rotting litter has accumulated and the water is still alkaline. On the other hand Bagdad soak is nearest the climax, especially with respect to surrounding sedges. The data suggest that seral stage only has an effect on population structure insofar as at Bagdad soak the decline in adult frequency is delayed compared with the other two sites.

Seasonal weather pattern

The seasonal weather for the years 1959 to 1964 has been summarised in Table 5. The seasons have varied from warm dry (1959) to cold dry (1960) mild dry (1961) to mild wet (1963). Over this range of environmental conditions there has been no statistically significant change in the proportion of phenotypes present among the recruits.

TABLE 5

Perth weather, May to September, years 1959 to 1964 inclusive.

Year	Temperature Average Deviation from Mean (°F.)	Rain-days Deviation from Mean (days)	Sunshine Deviation from Mean (hours)	Rainfall Deviation from Mean (inches)
1959	+ 2.2	— 9	+ 66	— 10
1960	— 1.9	— 4	+ 81	— 6
1961	+ 1.1	— 12	+ 80	— 4
1962	+ 1.4	+ 3	....	— 4
1963	+ 1.1	+ 25	— 155	+ 4.5
1964	+ 0.24	+ 9	+ 3.0	+ 3.28

In the warm dry 1959 season there was a significantly poorer survival of the lyrate animals at Lighthouse (the only place then under

observation). Again in the mild dry 1961 season the data are suggestive that lyrate survival is poorer in all localities. When data of all localities are pooled the decline is significant almost at the $p = .02$ level. It thus appears that lyrate adults are less able to stand warm winter conditions than ridged animals.

Conclusions

Over the period of the observations the seasonal rainfall pattern has gone from dry to wet and during the same period the proportion of adults in the populations has also declined. These changes are statistically most marked at Negri soak and Lighthouse swamp. The explanations of these observations appear to lie in a combination of, habitat preferences of adult frog, seral stage and minor local topographic conditions. *Crinia insignifera* is a frog which can only persist in swamps or marshes that are dry during the summer. During winter time they enter water to breed, but at other times leave the water and occupy adjacent marshy, but not flooded parts such as the *Gahnia* zone surrounding Bagdad soak. It so happens that the Bagdad soak is the only one in which flooding of the adjacent sedges does not take place in wet years. Here, so to speak, the adults are never flooded out into the inhospitable and unsuitable grassland and it is here that the survival of adults appears best. In the other localities adults are driven into unsuitable habitats by flooding in wet years and this is reflected in the declining proportion of adults in population samples as the years become wetter.

Acknowledgments

The work was done with the facilities offered by the Rottnest Biological Research Station while the author was in receipt of a Research Grant from the University of Western Australia.

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13.—Notes on the composition and structure of the Duketon Meteorite

by M. J. Frost*

Manuscript received and accepted 16th March, 1965

Abstract

The Duketon Meteorite, whose discovery in 1948 was previously reported by the author, is a medium octahedrite in the sense of Lovering and others (1957). Schreibersite, and possibly cohenite, are present, but neither troilite nor lawrencite was observed. Analyses of two samples gave:—Fe (by difference) 91.9, 92.1; Ni 7.36, 7.14; Co 0.51, 0.48; P 0.244, 0.239; S 0.031, 0.029.

A preliminary note on the Duketon Meteorite with a history of the find, a description of the meteorite and photographs has already been published (Frost, 1958).

The Duketon Meteorite was found in 1948 resting on the surface about 10 miles north of Duketon, Western Australia. This is approximately long. 122° 22'E, lat. 27° 30'S giving the seven figure coordinate number (CN) — 1224, — 275. Its original weight was probably about 119 kg. (263 lb.). The surface, contrary to previous opinion, is not weathered and the very dark brown (Munsell 10YR2/2) striated crust is perfectly preserved.

Grinding and etching of a section indicates that the structure is, using the definition of Lovering and others (1957), that of a medium octahedrite. The average width of the kamacite plates, calculated from measurements after determining the orientation of the etched surface with the aid of table I of Belaiew (1923), is 1.0 mm. On the surface studied no troilite was observed but schreibersite, and possibly

cohenite, occur as grains and plates up to 0.02 x 0.3 mm. in cross-section, mainly within the plessite. The plessite is mostly of the fine-grained perthitic variety. There is no evidence of the presence of lawrencite.

TABLE I

Analyses (columns a and b) of two samples of Duketon Meteorite

		a	b	c
Fe	....	91.9	92.1	0.1
Ni	....	7.36	7.14	0.04
Co	....	0.51	0.48	0.01
P	....	0.244	0.239	0.005
S	....	0.031	0.029	0.005

Notes: Analytical results in weight per cent. Iron by difference. Column c: estimated standard error of results for a and b. Analyst: P. R. Hentschel.

Analyses of two fragments from the interior of the meteorite (Table I) indicate no unusual features. These analyses were made possible by a Research Grant from the University of Canterbury.

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of the
Royal Society of Western Australia

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1965

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