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BY G. M. CHIPPENDALE

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A varietal combination is made for *Lysiana exocarpi* var. *spathulata.* New records are given for nine species, with notes on six species, while two species are deleted from the Check List of Central Australian Plants.

CONTRIBUTIONS TO THE FLORA OF CENTRAL AUSTRALIA

No. 3

by G. M. CHIPPENDALE*

[Read 12 October 1961]

SUMMARY

A varietal combination is made for *Lysiana exocarpi* var. *spathulata*.

New records are given for nine species, with notes on six species, while two species are deleted from the Check List of Central Australian Plants.

GRAMINEAE

Stipa scabra Lindl., 8 m. west-north-west of Ayers Rock, M. Lazarides, 7/9/1956 (Herb. Aust. ML6152).

A new record for Central Australia.

Triodia clelandii N. T. Burbidge. This species replaces *Triodia* sp. nov. aff. *brizoides* mentioned by Chippendale (1959).

Triodia hubbardii N. T. Burbidge. This species replaces *Triodia* sp. nov. aff. *pungens* mentioned by Chippendale (1959).

PROTEACEAE

Hakea purpurea Hook. This was originally included in the Check List on the basis of a specimen collected by Tietkens in 1889 between Lakes Amadeus and MacDonald. However, this specimen is not of *H. purpurea*, but has affinities with that species, and will need further collecting to clarify its position.

LORANTHACEAE

Lysiana exocarpi (Behr. ex Schlecht.) Tiegh. var. *spathulata* comb. nov.

Syn. Loranthus exocarpi Behr. ex Schlecht. var. *spathulata* Blakely in Proc. Linn. Soc. N.S.W. 50 (1925) 10. Recent records of this variety include: 7 m. north of Aileron, on *Acacia coriacea* DC., R. E. Winkworth, 20/3/1955 (Herb. Aust. REW930). Ormiston Gorge, on *Callitris hugelii* (Carr.) Franco, G. Chippendale, 25/5/1956 (NT2095). Palm Valley, on *Ficus platypoda* A. Cunn., D. J. Nelson, 15/8/1961 (NT8355). Palm Valley, on *Callitris hugelii* (Carr.) Franco, D. J. Nelson, 15/8/1961 (NT8356). Palm Valley, on *Melaleuca glomerata* F. Muell., D. J. Nelson, 15/8/1961 (NT8359). Palm Valley, on *Melaleuca linariifolia* Sm., D. J. Nelson, 15/8/1961 (NT8362).

CHENOPODIACEAE

Bassia biflora (R.Br.) F. Muell. Previously recorded at Crown Point, Finke River, in 1913, by S. A. White, this species has again been recorded, but

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is apparently a rare species in Central Australia. Burt Plain, 36 m. north of Alice Springs, G. Chippendale, 22/6/1961 (NT8053).

Bassia glabra F. Muell. Tanami, G. Chippendale, 10/4/1959 (NT5594).

A new record for Central Australia.

PORTULACACEAE

Portulaca bicolor F. Muell. var. *rosea* Maiden et Betche. Paddy's Rockhole, ½ m. south-west of Arltunga, G. Chippendale, 25/3/1958 (NT4087). Ooraminna Pass, G. Chippendale, 29/7/1956 (NT2376).

A new record for Central Australia.

MIMOSACEAE

Acacia oswaldii F. Muell. 37 m. north-east of Lake Mackay, G. Chippendale, 16/6/1957 (NT3378). 40-50 m. west of Haast Bluff Settlement, A. J. Mahood, 12/8/1961 (NT8378).

A new record for Central Australia.

EUPHORBIACEAE

Euphorbia petala Ewart et L. R. Kerr. Wycliffe Well, A. J. Ewart, June, 1924. A specimen noted in the Melbourne Herbarium.

A new record for Central Australia.

ASCLEPIADACEAE

Pentatropis linearis Decne. in DC. Prod. viii (1844) 536. Syn. *P. kempeana* F. Muell. in Wings Southern Science Record II (1882) 172. Examination of types of these species at Melbourne Herbarium showed them to be of the same species, with the type of *P. kempeana* being depauperate. A further record of this species is 70 m. west-north-west of Mt. Singleton, G. Chippendale, 13/6/1957 (NT3348). Therefore, *P. kempeana* is deleted from the Check List.

CONVOLVULACEAE

Ipomoea polymorpha R. et Sch. James Range, H. Kempe, March 1885. A specimen noted while at interstate herbaria.

A new record for Central Australia.

VERBENACEAE

Dicrastylis doranii F. Muell. var. *doranii*. 70 m. west-north-west of Mt. Singleton, G. Chippendale, 13/6/1957 (NT3350).

A new record for Central Australia.

SOLANACEAE

Nicotiana megalosiphon Heurck et Muell. Arg. Recorded by Burbidge (1960) as extending to Central Australia, and a further record is Long Hole, 30 m. north-west of Willowra H.S., G. Chippendale, 30/7/1958 (NT4754).

Solanum lasiophyllum Dun. Lassetter's Cave, Hull River, G. Chippendale, 24/6/1958 (NT4619).

A new record for Central Australia.

COMPOSITAE

Wedelia spilanthoides F. Muell. This is deleted from the list of Central Australian plants, as the only specimen on which the record was based (Herb. Aust. RAP3298) has now been determined as *W. stirlingii* Tate.

Wedelia stirlingii Tate. Previously synonymised under *W. verbesinoides* F. Muell. ex Benth. by J. M. Black (1934), but now considered to be worthy of distinction. The long peduncles and linear lanceolate leaves are consistent in this species in Central Australia. 25 m. north-east of Undoolya Station, R. A. Perry, 6/3/1953 (Herb. Aust. RAP3298). 3 m. south of Glen Helen, G. Chippendale, 4/2/1955 (NT779). Palm Valley, G. Chippendale, 15/4/1956 (NT2031). Standley Chasm, G. Chippendale, 17/11/1954 (NT523). Standley Chasm, R. A. Perry, 4/9/1955 (Herb. Aust. RAP5384).

Wedelia verbesinoides F. Muell. ex Benth. Records of this species in Central Australia are of *W. stirlingii* Tate, as mentioned before.

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CONTRIBUTIONS TO THE FLORA OF CENTRAL AUSTRALIA

BY MICHAEL J. TYLER

Summary

The present paper is based on the writer's observations on eight species of Microhylid frogs collected in the Central Highlands of New Guinea, of which *Xenobatrachus rostratus* and *Metopostira ocellata* are new records for the region. The eggs of *Sphenophryne brevicrus, Asterophrys wilhelmana, Cophixalus darlingtoni* and C. *parkeri* are described, and the method of hatching employed by *Cuphixalus* sop. is reported. Available data on all known eggs of the New Guinea subfamilies *Asterophryinae* and *Sphenophryninae* are tabulated revealing, contrary to previous opinion, that a mucilaginous cord does not connect the eggs of all species. From a consideration O F the diversity of the forms of development employed by congeners, it is suggested that biological data are unlikely to prove of much value in the determination of phylogenetic affinities.

A TAXONOMIC STUDY OF AMPHIBIANS AND REPTILES OF THE CENTRAL HIGHLANDS OF NEW GUINEA, WITH NOTES ON THEIR ECOLOGY AND BIOLOGY

1. ANURA : Microhylidae

by MICHAEL J. TYLER[*]

[Read 12 October 1961]

SUMMARY

The present paper is based on the writer's observations on eight species of Microhylid frogs collected in the Central Highlands of New Guinea, of which *Xenobatrachus rostratus* and *Metopostira ocellata* are new records for the region. The eggs of *Sphenophryne brevicrus*, *Asterophrys wilhelmana*, *Cophixalus darlingtoni* and *C. parkeri* are described, and the method of hatching employed by *Cophixalus* spp. is reported. Available data on all known eggs of the New Guinea subfamilies *Asterophryinae* and *Sphenophryninae* are tabulated revealing, contrary to previous opinion, that a mucilaginous cord does not connect the eggs of all species.

From a consideration of the diversity of the forms of development employed by congeners, it is suggested that biological data are unlikely to prove of much value in the determination of phylogenetic affinities.

INTRODUCTION

In a discussion of the various modes of development of the Microhylidae, Parker (1934) refers to the habit of metamorphosis within the egg, common to genera whose centre of origin and distribution appears to be the Papuan region, and comments upon similarities between the development of New Guinea Microhylids, and the Neotropical Leptodactylid genus *Eleutherodactylus*. Although the ecology of many *Eleutherodactylus* species has been established (Noble, 1926; Lutz, 1944, 1946; Adamson *et al.*, 1960; Vallet and Jameson, 1961), very little attention has been paid to the ecology of New Guinea Microhylids.

Zweifel (1956a) emphasised the need for ecological information on New Guinea Microhylids, to facilitate the determination of phylogenetic affinities, at present established solely by the comparison of morphological characteristics. The desirability of this combination of criteria for the amphibia had previously been recommended by Noble (1927).

Since the publication of his 1956a paper, Zweifel has described *Cophixalus shellyi* (1956b), *Xenobatrachus obesus* (1960), *C. riparius* and *C. nubicola* (1962), bringing the number of New Guinea Microhylids which he recognises to a total of sixty-three. The appearance in life and habits of a dozen species are known from collectors' notes, but a field survey on them has not previously been undertaken.

The present paper records the writer's observations on the ecology and biology of eight species occurring in the Central Highlands of New Guinea. It is based on the results of a survey conducted in the vicinity of Nondugl (lat.

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5°49'S, long. 144°44'E.) in the Wahgi Valley, during the period January to July, 1960, and taxonomic studies at the British Museum (Natural History) from January to August, 1961, and is the first of a series of papers on the herpetofauna of that region.

GEOGRAPHICAL AND ECOLOGICAL NOTES

Future references to New Guinea will refer to the Australian Trusteeship Territory of New Guinea, previously known as "German New Guinea", or the "Australian Mandated Territory", unless otherwise stated. The term, "Central Highlands", refers here to that sector of the Western Highlands between Mount Wilhelm and Mount Hagen. The expression is not used by all the inhabitants, but it is employed here to prevent further confusion in the literature.

The Wahgi Valley is situated at an overall altitude of approximately five thousand feet above sea-level and the climate is sub-tropical. Grass-covered plains bordering the river terminate abruptly at the foot of the densely forested Wahgi-Sepik Mountain Divide to the north and the Kubor Range to the south. It is the former range which connects Mount Hagen to Mount Wilhelm and the highest peak in the vicinity of Nondugl is Mount Odan, estimated to exceed 12,300 feet. A sketch map of the area is depicted in Fig. 1.

The herpetofauna of the area includes several species believed to be endemic to the Central Highlands (Zweifel, 1956a, 1956b, 1958). Only two species of frogs have been reliably recorded on the Wahgi Plains (*Hyla darlingtoni* Loveridge and *Rana grisea* van Kampen), but at least sixteen Microhylids and Hylids are known to occur at higher altitudes.

MATERIALS AND METHODS

Field notes were compiled on details of habitat, colour in life, call, eggs and development. Adult and juvenile specimens were killed by the injection of a 2·5 p.c. formalin solution into the abdominal cavity, and were preserved for nine months in a similar solution before being transferred into 40 p.c. alcohol. Eggs were fixed in a 4 p.c. formalin solution to which cobalt nitrate and calcium chloride had been added. (For details see Tyler, in press).

Measurements quoted refer to those of preserved material unless otherwise stated. They were estimated to the nearest tenth of a millimetre with a Negretti and Zambra dial calliper. Body length : distance between tip of snout and anus. Ratio of the length of the tibia (measured from the convex surface of the knee to the tibio-tarsal joint, with the leg in the flexed position), to the snout-vent length (TL/S-V) is the reciprocal of that recently proposed and employed by Moore (1961), but follows the method of Zweifel, whose papers are extensively referred to. Inter-orbital space : breadth of parietals at superior, medial borders of orbits. Unless otherwise stated, the shape of the canthus rostralis and snout is that seen when viewed from above. The ratio of the distance between eye and naris to internarial distance is abbreviated as E-N/IN.

In the original descriptions of several species the appearance of the tympanum has been used as a characteristic, and is described as either "distinct" or "indistinct". Use of the term "distinct" implies that the annulus surrounding the tympanum is prominent, so that the tympanal region is raised. As the tympanum of specimens fixed in strong solutions of alcohol is often far more distinct than in a series of the same species fixed in weak formalin, the descriptions of this area in the present paper are based on specimens fixed in both preservatives wherever this has been possible.

Although the collection was taken at the height of the breeding season, sex determination of specimens lacking distinct secondary sexual characters proved difficult. Sex ratios have therefore been omitted and the term "adult" is used to describe individuals regarded to be within the size range at which breeding occurs.

The existence of native names for amphibians and reptiles occurring in the Wahgi Valley has been reported previously (Tyler, 1961a). The names used in the vicinity of Nondugl are of the Middle Wahgi Dialect and are quoted when they appear to be generally accepted. The spelling of these names is purely phonetical and they are recorded here for the benefit of future field workers.

The abbreviations of the names of institutions where the collection has been lodged are as follows:

B.M. = British Museum (Natural History)
A.M.N.H. = American Museum of Natural History
Austral. Mus. = Australian Museum.

SPECIES REPRESENTED

Subfamily Asterophryinae

Xenobatrachus rostratus (Méhely)

Choanacantha rostrata Méhely, 1898, Termés. Füzetek, 21, p. 175.

Material: Four specimens—Austral. Mus. R.16854; A.M.N.H. 67609; B.M. 1961.877-878.

Description: Single vomerine odontoid beneath posterior medial margin of each choana; snout obtusely pointed, distinctly prominent, twice as long as diameter of eye, smooth on all surfaces; canthus rostralis slightly rounded; loreal region oblique and concave; inter-orbital space less than three times as wide as an upper eyelid. Tympanum distinct, larger than diameter of eye; weak supra-tympanic fold present. Fingers short, not dilated, second slightly shorter than the fourth. Toes with very slightly dilated discs, third much longer than fifth; inner metatarsal tubercle indistinct. Tibiotarsal articulation reaching the shoulder when adpressed. Anterior to the clavicles and parallel with them, are two pairs of thin dermal depressions. Skin of dorsal surface slightly tuberculose.

Body length = 25·2-30·5 mm. (mean = 28·1 mm.).

Colour in life of dorsal and lateral surfaces of three specimens uniform slate, the fourth a dull orange. Tubercles black with light centres, forming distinct longitudinal rows upon dorso-lateral surfaces. Extremely faint mid-dorsal stripe extends from the external nares to the anus, where it divides and continues along the upper surfaces of the thighs and posterior surfaces of the tibiae to the plantar surfaces which are grey in three specimens and black in B.M. 1961.877. Side of head slate; supra-tympanic folds black, tympanal area dull orange.

Ventral surface pale creamy-yellow marbled with slate, densely so upon the throat. Thin mid-ventral line extends from mandibular symphysis to omosternum and there divides, crosses approximately over region of clavicles, and continues along posterior surface of arms to palms. This line is paler than ground colour in B.M. 1961.877, but in others it is a narrow area upon whose borders the slate pigments terminate abruptly. Palmar surfaces orange with grey patches, triangular in one specimen, but of no definite shape in others. Back of thighs and anal region black.

No appreciable change in colouration has occurred in alcohol.

Locality: All specimens were found beneath moss on 20.5.60 at the summit of a pass north of Banz (16 road-miles west of Nondugl), at an altitude of 9,000-9,500 feet upon the Wahgi-Sepik Divide. The pass was covered by low cloud, and the ground saturated with water.

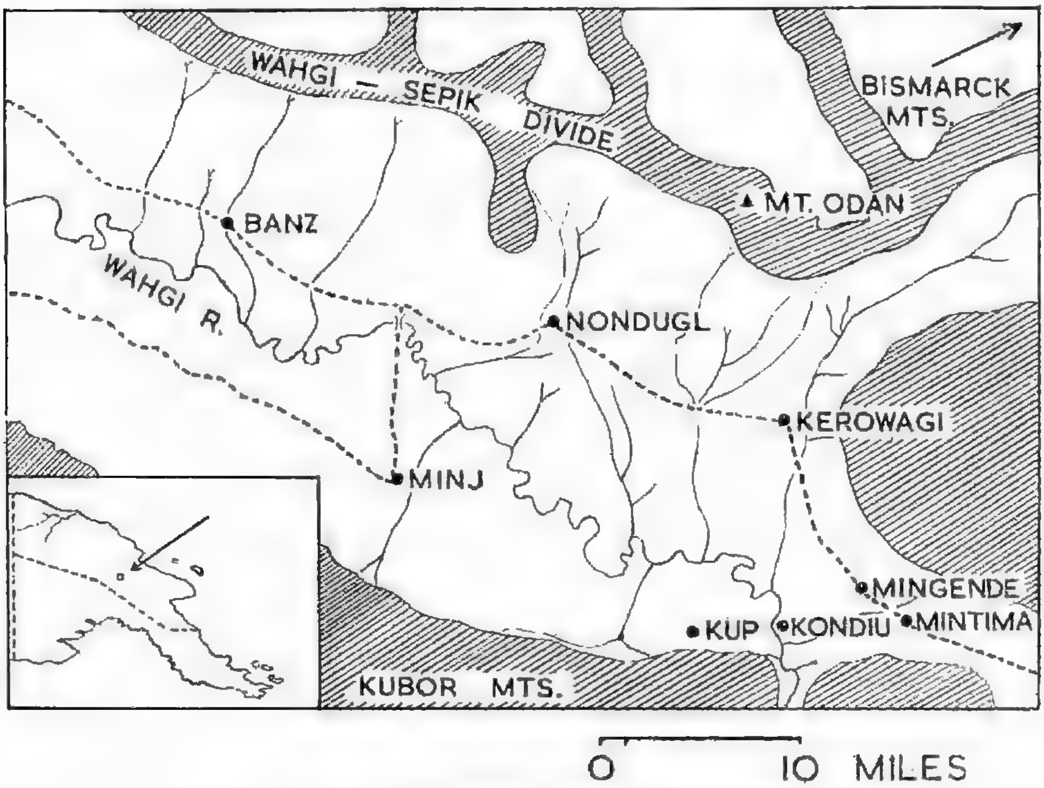

Fig. 1. Wahgi Valley in Vicinity of Nondugl.

Remarks: In the original description by Méhely (1898) and the redescription by Parker (1934) the lightly pustulose nature of the skin was not mentioned, but the state of preservation of their specimens could have diminished the apparence of this feature. The vomerine odontoids are similar to their illustrations but the toes, although described by Méhely as "feebly dilated" are not as dilated as in his plate. Parker mentions that the ventral surface of the snout is pustulose, and Boulenger's (1898) illustration of the type of *Chounacantha mehelyi* (regarded to be conspecific with *X. rostratus* by van Kampen (1923), and Parker (*loc. cit.*)) depicts prominent pustules upon the anterior surface of the snout. In the present series it is quite smooth on all surfaces.

The mid-dorsal stripe has been recorded by Burt and Burt (1932), van Kampen (*loc. cit.*) and Zweifel (1956a), to mention but a few authors and, where illustrated, is shown to be distinctive feature. Such a line is present in the series under discussion, but so faint that it is hardly visible macroscopically.

No mention has been made by any of the above authors of a mid-ventral line, and Dr. Zweifel, who kindly compared B.M. 1961.877 with the only other specimen of *X. rostratus* then in the collection of the American Museum of Natural History (No. 23584), informs me that it differs conspicuously in the ventral pattern. I have examined the two specimens in the British Museum (B.M. 1921.11.11.5 = 1938.6.5.80), and find that the ventral surfaces of both are white, densely marbled with pale brown—a difference that cannot be solely attributed to the length of time they have remained in preservative. Neither of the specimens possesses a dark throat or a mid-ventral line. They would appear to be similar in this respect to the ventral pattern of specimens examined by Vogt (1911), but Méhely mentions that there are more spots on the throat of the type than on the remainder of its ventral surface.

Van Kampen states that the ventral surface is "fiery red", in life, and Parker also states, "red in life". The present series is markedly different in this respect, and there is no appreciable change between colour in life and in preservative.

Development: The eggs of *X rostratus* have not been found in their natural state, but both Parker and Méhely have reported that those within gravid females they examined were macrolecithal. The ovarian size of eggs from a 47 mm. specimen were found by the former author to have a diameter of 3·5 mm. Other members of the *Asterophryinae* lay eggs of large yolk size away from water and there is no free-swimming tadpole stage. It may be safely assumed that *X. rostratus* undergoes a similar form of development.

Distribution: It would appear from the literature that, although recorded from many localities upon the mainland of New Guinea this species is relatively rare, for it has inevitably been recorded from single specimens. With the possible exception of *X. macrops* (van Kampen), this applies to other members of the genus, but the statement by Zweifel (1956a) that *X. bidens* (van Kampen) and *X. ophiodon* Peters and Doria are only known from single type specimens is at variance with Parker (1934). The latter author examined two specimens of *X. bidens* and a specimen of *X. ophiodon* described as a cotype.

This is the first time that *X. rostratus* has been found in the Central Highlands and probably the highest altitude at which it has yet been recorded.

Asterophrys wilhelmana Loveridge

Asterophrys pansa wilhelmana Loveridge, 1948, Bull. Mus. comp. Zool. Harv., 101 (2), p. 410.

Material: Forty-nine specimens—Austral. Mus. R.16822-16829; B.M. 1961.838-875. Twenty-six eggs – Austral. Mus. R.17605; A.M.N.H. 67614; B.M. 1961.881.

Description: This series agrees in all respects with the description of the type series and, being symphygnathine, with the qualification of Zweifel (1956a).

Body length = 17·1-58·5 mm.

The only description of the colour in life of this species is Loveridge's note of "dark slate", so the colour in life of the present series is recorded below.

Dorsally dark slate with a tint of violet (32 specimens), slate with brown patches (10), or dark brown upon pale yellow (7). (The last mentioned form was predominant at altitudes above 9,000 feet.) Side of head darker than dorsal colour; behind the eye and travelling obliquely from the angle of the jaws to the forearm is a streak, yellow in the smaller specimens and slowly deepening to a dull orange in those having a body length exceeding 45 mm. This marking is common to all but eight specimens, and in four of these it has been replaced by small, spherical, white dots, most densely aggregated upon the tympanum.

Ventral surface of body and limbs pale violet suffused with grey; palmar and plantar surfaces pale yellow; digits barred with brown. In one specimen the digits are completely black.

In alcohol the only change is that the yellow or orange streaks have faded.

Locality: The series was taken beneath rotting wood and in other damp situations in moss-forest on the Wahgi-Sepik Divide near Nondugl between 6,300 ft. and 10,500 ft. during the period 1.4.60 to 9.6.60.

Remarks: Fry (1916) erected the genus *Aphantophryne* for a series of six frogs collected by Mr. A. Guilianetti at 12,200 ft. on Mt. Scratchley, Papua, in 1896, and named the genotype *pansa*. The name of this monotypic genus was suppressed by Loveridge (1948) who demonstrated that, as the shape of the palatal ridges and terminal phalanges had been incorrectly depicted, the generic characteristics were so slight that there were no longer grounds for maintaining *Aphantophryne* as distinct from *Asterophrys*, to which he allocated *pansa*.

Asterophrys wilhelmana was described as a sub-species of *A. pansa* by Loveridge (*loc. cit.*), but was elevated to specific status when Zweifel (1956a) referred *pansa* to *Cophixalus*. Zweifel pointed out that as *pansa* is eleutherognathine, it could not be retained in a genus which is essentially symphygnathine.

The situation has therefore been reached where two representatives of different genera closely resemble each other in their superficial appearance. The present series compare favourably with a paratype of *wilhelmana* in the Australian Museum (M.C.Z. 25919) and two further paratypes in the British Museum (B.M. 1947.1.3.90-91).

Development: One 57 mm. female (Austral. Mus. R.16823) collected from beneath rotting vegetation on the Wahgi-Sepik Divide on 6.4.60, laid 55 eggs in captivity on the same day, of which 26 were preserved.

The eggs are of an extremely large size, the ova measuring 5·8-6·3 mm. in diameter and the albumen accounting for no more than 0·2 mm. of these figures. In life and in preservative the colour of the ova is white, but not densely so—the appearance being like that of an opaque glass.

There is no mucilaginous connection between the eggs, each being laid separately. When freshly laid, the surface of the albuminous capsule is firm to the touch and the eggs do not adhere to one another. Additional eggs believed to be of the same species were found on several occasions, but rarely in aggregations of more than six.

The smallest specimen known (M.C.Z. Paratype 25912 of 11 mm.) was collected by Capt. P. J. Darlington in the month of October, 1944. Freshly laid eggs were observed by the writer in April, so this species is probably similar to other closely allied species in having a developmental period estimated to range from eight to ten weeks.

Although the habitats in which eggs were found were always saturated with water, it was discovered that total immersion of an encapsulated embryo inevitably caused death within a few hours.

Eggs of *Cophixalus pansus* found by A. L. Rand in 1952, reported by Zweifel (1956a), were connected together in a bead-like string.

Call: The call is very much like the grunt of a pig or, more accurately, the inhalation of a human trying to imitate this sound. The duration of the call is no more than two seconds and it is repeated after long intervals.

Distribution: *Asterophrys wilhelmana* is apparently endemic to the Western Highlands, having only been reported from the type locality and Mount Hagen. The present material was therefore taken from an intermediate locality. Additional specimens were recorded, but not retained, on mountains within a thirty-mile radius of Nondugl.

Notes: The natives refer to the slate form as "*Dort*", and the extreme brown form as "*Korga*". Specimens that are intermediate between these colour patterns may be known by either name.

Metopostira ocellata Méhely

Metopostira ocellata Méhely, 1901, *Termés. Füzetek*, 24, p. 190.

Material: Ten specimens—*Austral. Mus.* R.16852, 17602, 17604; B.M. 1961, 831-837.

Description: The morphological characteristics of this series agree with Parker's (1934) redescription of the species.

Body length: 21·5-26·7 mm.; mean: 24·3 mm.

The colour in life of dorsal and dorso-lateral surfaces pale brown. Side of head from external nares, below canthus rostralis and eye, dark brown to black. Similarly coloured spot behind forelimb and above groin, connected by dorso-lateral streak which is continuous in four specimens and interrupted in remainder.

Throat grey, ventro-lateral body surfaces, thorax and upper abdomen pale red, profusely spotted with minute white spots. Lower abdomen and thighs a pale olive green; back of thighs variegated with very dark brown in five specimens.

Locality: All specimens were taken on the Wahgi-Sepik Divide at an altitude of 6,300 ft. near the native village of Bilikep, three miles north of Nondugl. One specimen was found beneath a flat stone near a stream on 4.4.60; six more were taken at the same locality on the following day, and a further three beneath rocks one hundred yards distant on 15.4.60.

Remarks: A coloured plate included with the type description (Méhely, 1901), depicts a distinctly greenish-brown dorsal surface, and a red and black ocellus above the groin. Van Kampen (1923) reports a red ocellus above the axilla of a specimen he examined and a yellow ocellus in the lumbar region. Parker (1934) also refers to a red ocellus, and this feature is still visible in a series of specimens in the British Museum collection (B.M. 1938.6.5.51-71), after over 20 years' preservation. It was at first considered that this feature might be restricted to adult specimens, for those described by the former authors are all in excess of 40 mm. body length. The present series are considered sexually mature, and alteration of the colour pattern of frogs after sexual maturity is unusual. Brongersma (1953) reports an ocellus on a 24 mm. female he examined, but the presence or absence of colour is not stated (Leiden Mus. 9836).

It was noticed that the shape of the snout appeared either rounded or blunt unless particular care was taken to ensure that the head of the specimen was on a completely horizontal plane when viewed. When correctly positioned, the snout tallied with Parker's description in being obtusely pointed.

Development: Van Kampen (1923) states, "the eggs in the ovary are few and large". In the present series, a gravid female (B.M. 1961.836) was found to contain eggs measuring approximately 4 mm. in diameter. The form of laid eggs and details of development are unknown.

Distribution: Zweifel (1956a) refers to locality records scattered throughout the island of New Guinea. The present locality is at a slightly higher altitude than those at which this species has been previously recorded and is the first record in the Central Highlands.

Notes: The stomach of one specimen (B.M. 1961.834) with a body length of 26·7 mm. was found to contain two earthworms measuring 55 mm. and 35 mm. in length.

Subfamily Sphenophryninae

Sphenophryne brevicrus (van Kampen)

Oxydactyla brevicrus van Kampen, 1913, Nova Guinea, 9, p. 465.

Material: Nine adult specimens, two juveniles and one egg. Austral. Mus. R.16855, 17601, 17603; A.M.N.H. 67615 (egg); B.M. 1961.1031-1039.

Description: Agree well with the diagnosis of Parker (1934). Tympanum length/eye length = 0·601; TL/S-V = 0·293.

Body length: Adults, 21·0-25·0 mm.; mean 22·7 mm. Juveniles, 6·9 mm. and 7·0 mm. respectively.

Colour in life of dorsal surface of head, body and limbs brown, with indistinct darker or lighter spots. Side of head very dark brown, continuing as a broad stripe along the lateral surfaces to the sacral region where it descends and becomes much fainter. In three specimens the stripes are accompanied superiorly by a series of faint spots, and inferiorly by a greyish-brown line.

Ventral surfaces generally grey, spotted with pale green on abdomen and orange on throat. Thin, pale mid-ventral line visible in one specimen.

In alcohol the pattern is similar, but the colour of ventral surface much paler than in life.

Locality: Collected at three localities on the Wahgi-Sepik Divide within 15 miles of Nondugl at altitudes of 6,000-9,000 ft. during the period 4.4.60-20.5.60. All taken on saturated ground beneath moss.

Remarks: The considerable differences in the relative tympanic size in three small groups of *S. brevicrus* examined by Zweifel (1956a) resulted in that author's tentative suggestion that there might be a geographic trend. The ratio of 0·601 for the present series conforms to this suggestion. A similar trend was suggested for the TL/S-V ratio with figures for Mt. Hagen and Mt. Wilhelm specimens being 0·295 and 0·267 respectively. The ratio of 0·293 for the present Wahgi-Sepik series is further evidence to support the theory of a trend and indicates a greater affinity to the Mount Hagen group.

The variation in colour has been discussed by Zweifel (*loc. cit.*) and Loveridge (1948). The pattern of markings exhibited by the present series follows the illustration of van Kampen (1923).

Development: Two specimens (B.M. 1961.1031-1032) found in small hollows beneath moss on the Wahgi-Sepik Divide at 9,500 ft. on 21.5.60 were each sheltering six yellow eggs. The adults were squatting at the ends of their burrows covering the eggs with their bodies. The diameter of each of the eggs was approximately 5 mm., and the albumen 0·2 mm. thick. They had been laid in the form of chains, each egg being connected to its immediate neighbours by single cords of colourless mucilage. The cords were approximately one millimetre in diameter and five millimetres long.

The eggs were at different stages of development. Those of B.M. 1961.1031 had not yet formed limbs or a tail, whilst the latter chain contained distinct juveniles possessing fully-developed and functional limbs and thin colourless tails.

The adults were placed with the eggs in tins lined with moss until 27.5.60 when it was discovered that B.M. 1961.1032 had eaten four eggs. The remainder of the eggs of this specimen completed metamorphosis. The froglets emerged on 10.6.60 and, after preservation, were found to measure 6·9 mm. and 7·0 mm. respectively. At the time of emergence they were a pale cream in colour except for slight pigmentation on the head and anterior portion of the dorsal surface and the upper surface of the limbs.

By 11.6.60 only one egg was found to be still alive and this was preserved as A.M.N.H. 67615.

Fourteen eggs of this species were found on Mt. Wilhelm by Capt. P. J. Darlington, and these were also accompanied by an adult specimen.

Call: Loveridge (*loc. cit.*) records that a call heard by Darlington at altitudes of up to 13,000 ft. on Mt. Wilhelm and described as "a woodeny croaking call" was presumed to have been made by this species. The identity of *S. brevicrus* as the species making this call must be regarded as tentative.

Distribution: This species has been recorded from many of the New Guinea mountain ranges and previous records include Mt. Wilhelm and Mt. Hagen.

Notes: A specimen with a body length of 25 mm. was in the process of ingesting an earthworm when captured. Although in a contracted state, the earthworm was found to have a body length of 78 mm. when preserved.

Cophixalus ateles (Boulenger)

Sphenophryne ateles Boulenger, 1898, Ann. Mus. Stor. nat. Genova, 38, p. 708.

Material: Twelve specimens — Austral. Mus. R.16837, 16856; B.M. 1961. 882-885, 945-946, 948; A.M.N.H. 67610-67612.

Description: Agree well with Boulenger's (1898) description of morphology, but first finger less than one-half of the length of the second and finger discs twice instead of three times the breadth of the penultimate phalanx. Skin smooth but longitudinal dermal ridges extend along dorsal surface of all specimens. TL/S-V = 0·422 mean.

Body length = 14·4-21·5 mm.; mean = 18·5 mm.

Colour in life of dorsal surface of body grey, head darker. Interocular bar clearly present (two specimens), faint (9), or absent (1); a narrow, cream mid-vertebral stripe present (3) or absent (9). Side of head as dark as dorsal surface of head (3), or distinctly darker (9); tympanum masked by this dark patch (11), or clearly visible and grey (1). Ventral surface pale grey. Throat darker than thorax and abdomen (5), darkening limited to lower jaws (6), or entire ventral surface the same colour (1). Groin and lower surface of thighs faint red in all specimens.

Thorax stippled with white. Digits barred with grey. Dark patch around anus. No appreciable change in colouration in preserved specimens.

Locality: Taken beneath moss on ground in moss-forest between 1.4.60 and 20.5.60 at various localities on the Wahgi-Sepik Divide within 15 miles of Nondugl. Altitudinal range 6,300-9,500 ft.

Remarks: Although Boulenger (1898) stated that his description of *Cophixalus* (*Sphenophryne*) *ateles* was based on "several specimens" taken at

Moroka in Papua by Dr. L. Loria in 1893, it is only the two paratypes (originally cotypes) in the British Museum (B.M. 97.12.10.146-147 = 1947.2.12.6-7) which have been the subject of any discussion in subsequent papers (Parker, 1934; Zweifel, 1956a, 1956b). The latter author was in error when he stated (1956a) that the species is known from only two specimens, for there are five additional specimens in the Museo Civico di Storia Naturale at Genoa, which have been designated a lectotype (M.C.S.N. 29116 A) and four lectoparatypes (29116 B) by Capocaccia (1957).

Boulenger's illustration of the hand of one of the cotypes does not agree favourably with the type specimens in the British Museum. As Parker (*loc. cit.*) pointed out, the first finger is shorter in the B.M. types than is depicted, whilst the writer has found that the ratio of the width of the finger discs to the width of the penultimate phalanx is exaggerated and that the finger discs are not as abruptly truncate.

Van Kampen (1923) suggested that the specimens of *ateles* might in fact prove to be juveniles of *C. verrucosus*, for he did not attach any particular importance to the relative size of the first finger. There is, however, no evidence to suggest that the type specimens were immature, or that growth of the digits is disproportionate if they had been.

Zweifel (1956a) assigned a specimen of *Cophixalus* from Mt. Hagen (A.M.N.H. 58170) to *ateles*, but commented that the tympanum was rather indistinct, whilst it was said to be distinct in *ateles* and that the finger discs were not large and truncate as Parker (1934) had described them to be. Differences between two additional specimens collected by the Rev. S. Shelly in the Wahgi Valley and Parker's description were such that Zweifel (1956b) described the two specimens as *shellyi* and designated A.M.N.H. 58170 a paratype. Dr. Zweifel kindly examined three of the present series and reported (*in litt.*) that they agree well with the types of *shellyi*.

In his description of *shellyi*, Zweifel states that it differs from the description of *ateles* in the following characteristics: "tympanum very indistinct; finger discs relatively smaller; side of head black, sharply contrasting with dorsal and lateral body surfaces". The distinctness of the tympanum of the paratypes of *ateles* is mainly due to the fact that all pigments have now disappeared and the original pattern cannot be distinguished. A dark mask said to be characteristic of *shellyi* is absent in the ateles paratypes, but drawings of three of the lectoparatypes supplied by Prof. E. Tortonese reveal a dark streak running from the posterior corner of the eye, anterior to the tympanum, to the axilla in two specimens, and scattered dots on the side of the head of the third. The British Museum paratypes have body lengths of 12·5 mm. and 12.8 mm. respectively, and the TL/S-V mean is 0·415. The body lengths of the Genoa specimens are 13-14 mm. (mean = 13·7 mm.), but their state of preservation is such that it is not possible to obtain accurate measurements of the limbs.

It does appear that *shellyi* is even closer to *ateles* than originally suspected, but until additional topotypic material of the latter is obtained, the specific status of *shellyi* must remain suspect, and it seems prudent to assign the present material to *ateles*.

Distribution: *Cophixalus ateles* is only known from the type locality of Moroka and *shellyi* from the Wahgi Valley.

Notes: Food items recovered from the present series include beetles, ants, spiders and mites of the family Parasitidae (Acari : Mesostigmata), which are predatory upon small Arthropods and were presumably ingested with their hosts.

Cophixalus darlingtoni Loveridge

Cophixalus biroi darlingtoni Loveridge, 1948, Bull. Mus. comp. Zool. Harv., 101 (2), p. 423.

Material: Eight adults and three juveniles—Austral. Mus. R.17593-17595; B.M. 1961.886-892.

Description: Morphological characteristics agree completely with the description of Loveridge and, as a comprehensive description has also been given by Zweifel (1956b), a further account here is unnecessary. The opportunity to record colour in life has been denied the above authors, so descriptions of two individuals is given below to illustrate variation.

B.M. 1961.889 – Dorsal and dorso-lateral surfaces black, with a thin white interocular bar and a faint triangular patch on the back of the head. Single white ocellus on either side of the sacrum. Ventral surface of body and limbs immaculate cream, ventro-laterals with small faint red spots. Limbs black above, red at sides. Cream patch on heel; plantar and palmar surfaces white.

Austral. Mus. R.17593 – Dorsal surface black with dark grey patches and a faint interocular bar. Bright green stripes on lateral body surfaces, at side of head (behind and below eye), and on back of forearm. Ventral surface pale grey mottled with dark brown, most noticeable on the lower jaw. Limbs black above spotted with grey, uniform grey below; a brilliant green stripe on the posterior surface of the thighs.

Other specimens varied in colour from a dull green ground colour to pale brown with darker markings.

Body length: Adults – 14·4-25·6 mm. (mean: 20·8 mm.); juveniles – 4·4-5·1 mm.

Remarks: *Cophixalus darlingtoni* was described by Loveridge (1948) as a sub-species of *C. biroi* (Mehely) from a series of fifty specimens collected by Capt. Darlington at Toromanbanau in the Bismarck Mountains, and was elevated to specific status by Zweifel (1956a). Zweifel considered that as the third toe was shorter than the fifth and therefore the converse of the condition in *biroi* and as the two forms were apparently allopatric, specific status was warranted.

The only other species of *Cophixalus* found in the same area as *darlingtoni* with which it could possibly be confused is *C. parkeri* Loveridge, but they can be readily distinguished when the TL/S-V ratios are compared, for that of *darlingtoni* is considerably higher than *parkeri*.

The present series compare favourably with the British Museum paratypes (B.M. 1947.1.3.92-93).

Locality: Taken beneath moss in dense moss-forest at several localities on the Wahgi-Sepik Divide, between 1.4.60 and 28.5.60. Altitude range: 6,500-9,500 ft.

Development: On 13.4.60 eighteen eggs were found in a hollow beneath a rotting log at Bamna in dense moss-forest at an altitude of 6,500 ft. Each of the eggs had a diameter of approximately five millimetres and they were connected together in the form of a chain by single cords of colourless mucilage, approximately three millimetres long. The embryos possessed functional, pigmented limbs and long colourless tails, but their bodies were still spherical and unpigmented. The chain was placed between layers of saturated moss and daily observations made upon it.

It was noticed that the developing froglets lay passively upon their backs, occasionally making spasmodic movements of their limbs, and frequently waving their tails, which were entirely free and not adposed to the inner surface of the egg capsule.

On 19.4.60 one of the eggs was opened and the motile juvenile removed and preserved. Three days later the method of emergence from the eggs was observed. As this is the first record of the procedure employed by a New Guinea Microhylid, the following extract from field notes is quoted:

"22.4.60—Whilst examining the eggs of *C. darlingtoni* this morning, I noticed that two of the froglets were very active. At short intervals both of them extended their limbs, distending the capsules in which they were enclosed. The movements were extremely violent and, within a few minutes, one of the froglets penetrated the capsule with both arms. Gaining a purchase against the inner surface of the capsule with both feet, it forced its body through the split, and emerged within ten minutes.

"The second froglet split the capsule with its hind-limbs. The process of emergence in this case occupied more than an hour, for it appeared to find it difficult to force its body backwards through the split."

The specimens described above were preserved as B.M. 1961.891-892. The former died immediately it was exposed to bright sunlight. No further froglets emerged and, on 30.4.60, eighteen days from the date of collection, the remainder of the chain died when the albumen became covered with a growth of mould.

Distribution: This species is known from the type locality of Toromanbanau, where fifty specimens were taken at 7,500 ft., and Kondiu in the Wahgi Valley where fifty-six specimens were collected by Rev. Shelly (Zweifel, 1956b), approximately twenty-five miles west of the type locality. Kondiu is at an altitude of 5,000 ft., but it is probable that the Rev. Shelly's specimens were taken at an higher altitude in the nearby moss-forest.

The locality at which the present series was taken is slightly further from the type locality than Kondiu. The fact that so few specimens were taken over a long period of extensive collecting would suggest that this species is distributed further to the east or normally exists in dense but localised communities.

Notes: The native name for this species is "*Kiris*".

Cophixalus parkeri Loveridge

Cophixalus variegatus parkeri Loveridge, 1948, Bull. Mus. comp. Zool. Harv., 101 (2), p. 425.

Material: Sixty-five adult and juvenile specimens. Austral. Mus. R.16841-16851, 17596-17600; B.M. 1961.893, 899-944 and fourteen eggs; Austral. Mus. R.17606; A.M.N.H. 67613; B.M. 1961.944.

Description: Canthus rostralis uniformly rounded (12 specimens), or angular (24) but extremely obtuse; inter-orbital space as broad as (53) or broader than (13) the breadth of an upper eyelid; diameter of tympanum between one-half and two-thirds of eye diameter; third toe as long as (50) or slightly longer than (16) the fifth. Sub-articular discs are present and the tibio-tarsal articulation of the hind limb reaches the eye (44) or nearer to the eye than the tympanum (22).

Body length: 10·0-36·2 mm.

The colour in life as seen in the present series reveals a considerable amount of variation between the ground colouration of the dorsal surface and the markings upon it. Dorsal surface of body and limbs either a pale murky brown or green, of head paler, bounded by a transocular or interocular bar. Behind this bar, on the scapular region, is a W-shaped marking, quite frequently raised into a dermal fold. Other folds often project from the posterior termination of the head above the distal termination of the transverse processes of the thoracic vertebrae to the lumbar region where they terminate abruptly. Remainder of the dorsal surface of body and limbs pale lime green, pale yellow or grey, either so densely covered with intense brown spots that the ground colour is almost entirely obscured or with a few areas lightly stippled with brown. Gular region usually darker than thorax and abdomen.

Remarks: At the time of writing, the only published records of *C. parkeri* are reports of three specimens taken singly (Loveridge, 1948; Zweifel, 1956a, 1956b), but Zweifel states (*in litt.*) that large numbers have since been taken by the Sixth Archbold Expedition.

Cophixalus variegatus parkeri was elevated to specific rank by Zweifel (1956a). Loveridge's material upon which the description of the new subspecies was based consisted of a single gravid female of 28 mm. and his comparison with *variegatus* was based on a specimen of that species in the collection of the Museum of Comparative Zoology (M.C.Z. 9385) which had been received from the Berlin Museum as *Hylophorbus boettgeri* (Méhely). Parker, who had redescribed *variegatus* (1934), examined the proposed new form, but offered no opinion on the value of the characters which Loveridge selected to distinguish it from *variegatus*.

Zweifel (1956a) found relative leg-length to snout-vent length a useful character for distinguishing the species of *Cophixalus*. Although consideration must be paid to the fact that he had, at that time, only a single specimen of *parkeri* and two of *variegatus* at his disposal, the differences in relative leg length between these forms was found to be less than that between any pair of eight species he examined with the exception of *ateles* and *cheesmanae* which are readily distinguished by other characters.

Development: Three chains of eggs were collected from beneath rotting wood at Bamna. The first, on 6.4.60, consisted of eighteen eggs measuring 5·0 mm. in diameter, connected by mucilaginous cords in the same manner as *C. darlingtoni*. The second and third chains, consisting of thirteen and twenty-three eggs respectively, were taken at the same locality on the following day. The appearance of the eggs of *parkeri* and *darlingtoni* was found to be very similar, but juveniles could be distinguished quite readily by the difference in the relative leg-lengths.

The number of mature ova dissected from seven gravid adults ranged from twenty-one to twenty-seven, suggesting that more than one chain may be laid by each individual.

From the three chains collected only one specimen emerged. The remainder died in captivity as a result of mould forming upon the outer egg membrane. Emergence was effected in a manner similar to that of the previous species.

Call: A short, low, monotonal whistle.

Distribution: *Cophixalus parkeri* is only known from the Wahgi Valley and the mountains at its eastern and western entrances.

Notes: Although normally terrestrial in habits, *parkeri* is occasionally scansorial. Three specimens were found on a narrow, moss-covered ledge, thirty feet up the face of a vertical cliff.

The natives refer to specimens of *parkeri* as either "*Dem-boor-boor*" or "*Pippy-a*". *Dem* means "wood", and "*boor*" rotten. Repetition of *boor* emphasises the condition of the wood and the name is therefore descriptive of the habitat where this species is frequently found.

Pippy-a probably means "quick-one", but its derivation is rather obscure for the title is not descriptive of the creature's habits.

A migrant kingfisher (*Halcyon sancta* Vigors and Horsfield) was observed to accept a specimen of this species of frog. Full details of this observation have been published elsewhere (Tyler, 1961b).

Cophixalus riparius Zweifel

A large gravid female included in the present collection (B.M. 1961.947) was submitted to Dr. Zweifel for his opinion. He reported (*in litt.*) that he considered it to be a representative of an undescribed species of *Cophixalus*, and stated that similar material had been collected by the Sixth Archbold Expendition to New Guinea. Dr. Zweifel subsequently named the new species *C. riparius*, and permitted the writer to examine the manuscript of the paper in which the description appeared.

Description: *Cophixalus riparius* is described to attain a maximum size of approximately 50 mm. snout-vent length and frequently reaches 45 mm., which is greater than in any other known species in this genus. TL/S-V = 0·383 (0·35-0·43); E-N/IN = 0·877 (0·79-0·97).

The present specimen, measuring 44·3 mm., agrees in most respects with Zweifel's description but, whereas *riparius* is said to lack teeth, B.M. 1961.947 possesses vomerine teeth. They are situated in narrow, diagonal rows considerably beneath and between the small, oblique, oval choanae. Also, the tympanum is quite distinct as opposed to the type description of: "Only the lower edge of the tympanum can be distinguished and that but faintly".

The TL/S-V and E-N/IN ratios of 0·433 and 0·946 respectively are well above the means of the type series, but within the defined ranges.

Locality: Taken beneath debris on bank of River Gar at Bamna (6,300 ft.), near Nondugl, on 24.4.60.

DISCUSSION

Metamorphosis

The available information on the development of the *Asterophryinae* and *Sphenophryninae* is so limited that generalised statements about the entire subfamilies must be regarded as tentative.

Ovarian eggs of thirty-six species have been examined by various authors and many are described by Parker (1934). All are unpigmented and the majority macrolecithal, the range of diameters being from 1·5 mm. (*Oreophryne annulata* (Stejneger)) to 6·5 mm. (*Asterophrys doriae* (Boulenger)).

The majority of the members of the Microhylidae are small creatures, so the increase in the size of ova has naturally been accompanied by a reduction in the numbers formed. The total of fifty-five for *Asterophrys wilhelmana* reported in the present paper is the highest number recorded to date.

The sites selected for deposition by the ten species whose eggs have been found in the field are moist, unexposed situations which, with the exception of *Cophixalus biroi*, are away from water. Chains of eggs of *Oreophryne anthonyi* (Boulenger) were found by Mr. A. L. Rand (Zweifel, 1956a) attached to the roof of cavities in the epiphyte *Hydnophytum*. All other known eggs are quite free and unattached to either animate or inanimate objects. The manner of fertilisation and oviposition is unknown, but both presumably take place at the site of deposition.

The eggs are laid separately; connected directly together in a chain by the walls of the egg capsules; in a chain with each individual separated from its immediate neighbours by a mucilaginous cord, or in a chain with some members connected by their capsule walls and others by cords.

The eggs of *O. anthonyi* mentioned above were described as being in the form of a "clump". Dr. Zweifel has re-examined the eggs for the writer and describes them (*in litt.*) as follows: "One group of five has cords separating some eggs, and others joined envelope to envelope. Another clutch has ten still joined in a string, again both with cords and direct contact. With the eggs rather squashed together, they could be described as being in a clump, but can be separated into a continuous string."

The presence of a mucilaginous cord between eggs of species known at the time of Parker's (1934) monograph, led that author to state that this feature is a characteristic of the New Guinea Microhylidae. Although a similar cord has not yet been recorded in other families, it is now apparent that it is not common to all New Guinea genera. Data upon laid ova is summarised in Table 1.

Parker drew attention to similarities between the development of New Guinea Microhylids and the neotropical genus *Eleutherodactylus* of the family Leptodactylidae (Ceratophryidae). The eggs of *Eleutherodactylus* are macrolecithal, joined in the form of a chain by the walls of the egg capsules and laid away from water.

In the absence of information on the embryology of the *Asterophryinae* and *Sphenophryninae*, comparisons between these subfamilies and *Eleutherodactylus* must be largely based on superficial appearances.

Eleutherodactylus spp. (e.g. *E. nasutus* Lutz (Lutz, 1946)) and *C. birot* (Méhely, 1898) possess non-muscular, highly vascular tails which are membranaceous and, being apposed to the inner surface of the egg capsule, serve as respiratory organs. In *C. darlingtoni*, *C. parkeri*, *Sphenophryne brevicrus* and *Oreophryne anthonyi* the tail is cylindrical, muscular and free, and does not appear equipped to serve a specialised respiratory function.

The mature embryos of *Eleutherodactylus* possess an ectodermal egg-tooth, consisting of a cornified caruncle situated upon the tip of the snout, above the symphysis of the premaxillae (Noble, 1926). This structure, which aids the liberation of the juvenile from the capsule, has not been recorded in the Microhylidae. The extent to which the egg-tooth is utilised during liberation varies between individuals and the description of the emergence of one of a series of *E. parvus* Girard observed by Lutz (1944) is very similar to that of *C. darlingtoni* recorded in the present paper.

The duration of metamorphosis of *E. nasutus* is approximately four weeks and *E. guentheri* slightly longer (Lutz, 1946). Although the complete period of development of any New Guinea Microhylid has yet to be established, the opinion drawn by the writer from the present investigation is that metamorphosis extends over a period exceeding eight weeks. The increase could be associated with the colder climate experienced in the Central Highlands.

The environmental conditions necessary for the survival of eggs are critical. It would appear that the medium upon which the eggs are laid must be saturated with water, and the development of mould upon some of the eggs may have resulted from a reduction in the moisture content of their media.

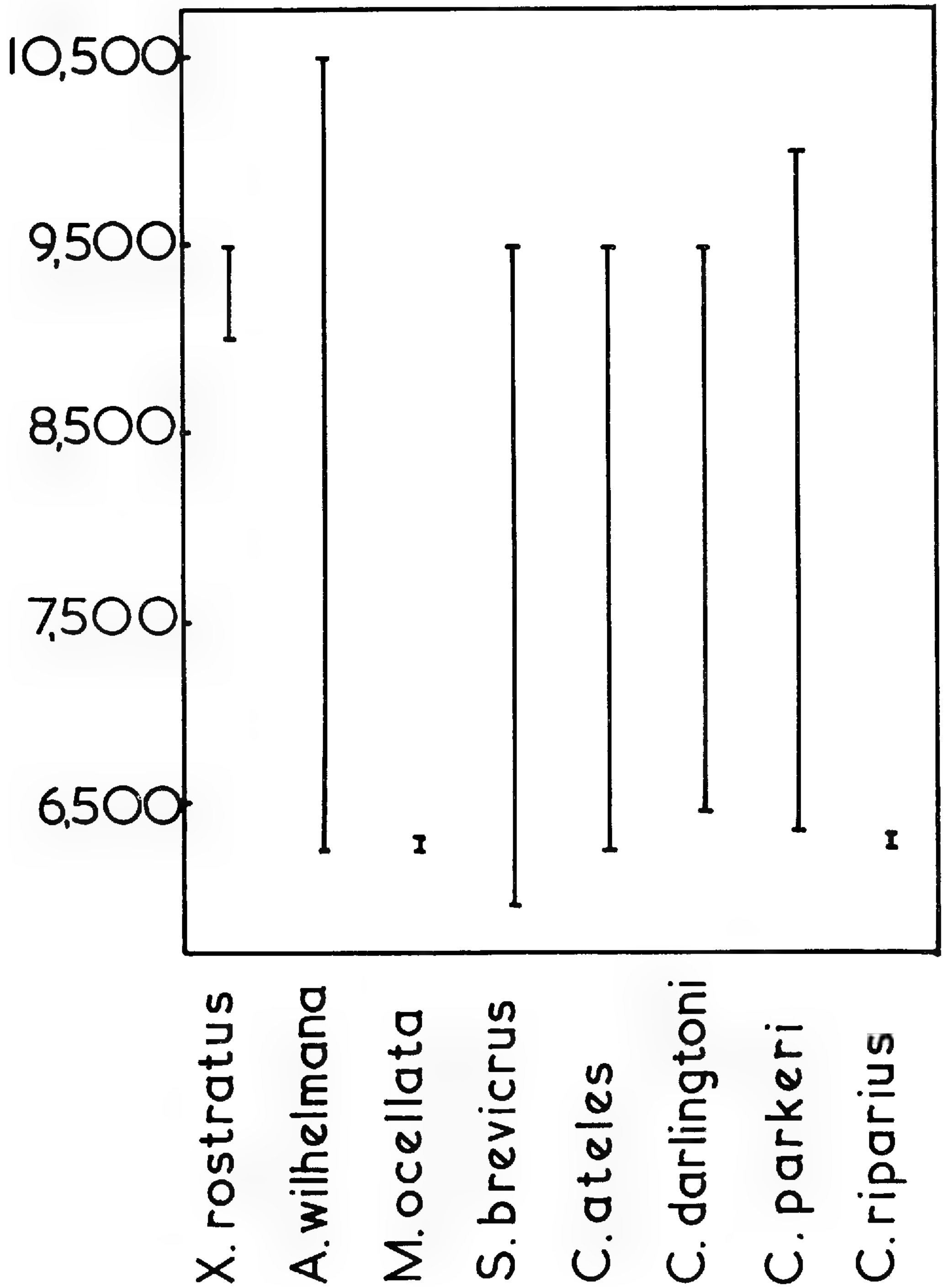

Fig. 2. Comparison of the distribution of Central Highlands Microhylidae at various altitudes.

Adamson *et al.* (1960) injected chorionic gonadotrophin into the dorsal lymph sac of captive specimens of *E. martinicensis* (Duméril and Bibron), but were unable to induce ovulation. If the Microhylids respond similarly, it is likely that details of their development will remain unknown until eggs collected in the field can be reared under laboratory conditions.

The presence of an adult male or female frog at the site of a group of developing eggs has been recorded in *Sphenophryne brevicrus*, *Oreophryne anthonyi*, *O. flava* Parker, *Cophixalus pansus*, *C. darlingtoni* and *C. parkeri*. It is not inconceivable that the adults guard the developing eggs from predators to compensate for the reduction in the number laid, and the recorded observation of an adult *S. brevicrus* devouring four eggs may have been induced by the deprivation of alternative food. Parental care is not a common phenomenon amongst frogs, and the majority of cases involve the transportation of developing spawn by an adult. Protection of deposited spawn is of far rarer occurrence, but Fernandez and Fernandez (1921) record the female *Leptodactylus ocellatus* of Argentine guarding immature tadpoles.

TABLE 1

Description of the eggs of New Guinea Microhylids.

	Max. egg No.	Egg diam. in mm.	Form
Asterophryinae			
Asterophrys robusta	?	"large"	cord
A. wilhelmana	55	5.5-6.3	independent
Sphenophryninae			
Sphenophryne brevicrus	6	5	cord
Oreophryne flava	10-20	5	cord
O. biroi	?	4	?
O. anthonyi	31	4.5-5.5	direct or cord
Cophixalus biroi	?	?	cord
C. pansus	20	3.1-3.6	direct or cord
C. darlingtoni	18	5	cord
C. parkeri	23	5	direct or cord

It was observed that the tremendous force of the torrential rains which fell on the lower mountain slopes pulped any exposed clumps of spawn of the Hylid genera *Hyla* and *Nyctimystes*. At altitudes above 9,000 ft., where the moss-forests are replaced by montane grassland, there is no canopy to protect the frogs or their spawn from the rains, and the selection of an almost subterranean habitat by the Microhylids is their only means of survival.

Feeding Habits

The cryptozoic Microhylids have been regarded as myrmecophagus feeders, but it is becoming apparent that their diet consists of a variety of food items, of which some are of substantial size. Zweifel (1960) recorded the recovery of large earthworms from the stomachs of *Asterophrys oxycephala* (Schlegel) and *Xenobatrachus obesus* Zweifel. In the present paper similar prey were found to have been ingested by *Metopostira ocellata* and *Sphenophryne brevicrus*.

Developmental Data as a Guide to Phylogenetic Affinities

The diversity of the form of deposited ova within the genera *Asterophrys* and *Cophixalus* suggests that phylogeny supplemented by developmental data could result in a complete systematic reorganisation. Information is so limited, however, that the extent of specific variation has yet to be established. If specific variation proves to be as diverse as that found on the generic level, it is unlikely that this form of data will prove of much value in determining phylogenetic affinities.

Distribution

The distribution of most of the species described in this paper is restricted, at least in the Wahgi Valley region, to the saturated moss-forests whose lower limits are slowly being raised as a result of deforestation by natives. At several situations secondary grasslands now reach altitudes exceeding eight thousand feet, and it may be safely assumed that at least a few of the Microhylids were once distributed at lower altitudes than those at which they are found today. Associated with the changing environment, a reduction in the variety and density of the populations of other vertebrates has been reported by Mayr and Gilliard (1954), but it is unlikely that the nature of the terrain will permit much further deforestation, and an additional modification of altitudinal distribution as far as the amphibia are concerned, is unlikely to occur.

The present range of distribution upon the Wahgi-Sepik Divide (Fig. 2) reveals an almost constant pattern for the *Sphenophryninae*, but considerable variation within the *Asterophryinae*.

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THE RELIC NATURE OF SOME CENTRAL AUSTRALIAN PLANTS

BY G. M. CHIPPENDALE

Summary

THE RELIC NATURE OF SOME CENTRAL AUSTRALIAN PLANTS

by G. M. Chippendale[*]

[Read 9 November 1961]

When planning his trip into Central Australia with the Horn Expedition, R. Tate had visions of finding a mountain chain with "remnants of that pristine flora which existed on this continent in Paleocene times — probably a beech, possibly an oak, elm, or sycamore" (Tate, 1896). However, Tate found the MacDonnells to be comparatively barren, with some "novelties" in the ravines.

Crocker and Wood (1947) listed the MacDonnell-James Range system as one of the principal refuges of the arid period which might be placed as about 4,000-6,000 years ago. It is agreed that this arid period largely destroyed the flora which had existed in a wetter Pleistocene period, and that survival foci such as the MacDonnell Ranges have preserved some remnants of the Pleistocene flora. Yet, Burbidge (1960) considers that the Pleistocene flora was not decimated to the extent postulated by Crocker and Wood. The suggestion of recolonising elements persisting "even during the most arid stages by occupying suitable habitats in the vicinity of scattered and temporary waters" does seem to be more realistic. So, here a relic area can be regarded as a place where plants of a former higher rainfall period have survived. The ranges of Central Australia which are concerned would include the MacDonnell, James, Krichauff, George Gill, and possibly the Stuart Bluff range systems. Plants which fall truly into the relic category are very few, but discussion can be made on the status of a number of species.

In considering the Central Australian range system as a reclusium, a most important point must be that the topography has been virtually unchanged for a very great period. Therefore, the plants to be considered as true relics of a past flora must only represent the flora which *existed in the ranges in the past.* This, perhaps, is a specific application of the Crocker and Wood suggestions. Whether these species have, in fact, been able to expand their area and for possible speciation to take place is highly problematical.

Considering the unreliable, and often extremely low rainfall in most of the Australian arid zones, it seems clear that the genus *Triodia* which inhabits much of this area was able to resist the ages of aridity which are postulated by most authors. Burbidge (1953) postulated that *Triodia* must have existed during the Pleistocene pluvial cycle, probably in a restricted arid zone, assuming some zonation in rainfall as at present. The genus has since expanded its area, and now shows a peripheral grouping of species with *T. pungens* as a focus. *T. hubbardii* Burbidge (1960) is a recently described species with a distribution in stony or rocky slopes in the central range system, extending to Vaughan Springs. *T. clelandii* Burbidge (1960) has a similar distribution. Could these two species be remnants of the nucleus of the genus which is presumed to have existed in a dry central area during the pluvial cycle?

It can be agreed, however, that a species such as *Macrozamia macdonnellii* which is now found in comparatively few localities was probably more widespread in the ranges of the past. This species, together with some other true relic species, has little, if any, variation, and appears unable to expand its area. This may indicate that it is really in the process of becoming extinct, and present-

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day activities are not aiding its preservation. It mainly occupies tourist areas where the large, egg-sized seed is somewhat of a curiosity, and is collected by many tourists. Also, nurserymen and others are constantly enquiring to official, commercial and private sources for supplies of this seed.

In the case of *Livistona mariae*, another true relic, there is some evidence that it has very slightly expanded its area, as some young individuals are now found at Running Waters, which is about twenty-five miles from Palm Valley. This occurrence was not mentioned by Giles, Kempe, or Tate and this must be significant at least in the case of Tate who recorded several other species, viz., *Naias major* and a species of *Potamogeton* at Palm Creek and Running Waters. Both of these are aquatic and are consequently restricted in area in the arid Central Australia, but it is problematical whether this occurrence, which is so discontinuous with other occurrences of the species, is biological or historical.

The ferns of Central Australia contain only two endemic species, *Gymnogramme reynoldsii* and *Cheilanthes vellea* and these are restricted to ranges such as the MacDonnells, and also occur in the Flinders, Everard, Birksgate and Musgrave Ranges of South Australia. These are very hairy species and are rare in occurrence, and have resisted desiccation by this adaption and by their habitat such as in gorges or on sheltered hillsides. Certain other ferns, i.e. *Cyclosorus gongylodes, Histiopteris incisa, Lindsaea ensifolia, Nephrolepis cordifolia, Adiantum hispidulum*, and *Pteris tremula*, are confined, in Central Australia, to extremely small points of the central range system, and these habitats are widely separated from other occurrences of these species. With the exception of *Pteris tremula*, which occurs in southern and eastern Australia and New Zealand, these species are pantropic in distribution. In Malesia they are found in open places but under a comparatively high rainfall. Existence in the arid Centre has been reliant on their protection from the sun and by being in a small microclimate around more or less permanent rockpools or springs. For instance, at Tallaputta Gorge, several of these ferns are common in a grotto which is overshadowed by high rock walls on three sides and overhung by rocks. A spring feeds down the walls to a pool in the grotto which only covers about 150 square feet. The sun may only shine directly into this grotto for an hour or so daily. Other occurrences of some of these ferns are on the southern side of the George Gill Range. At several of the rock holes in these ranges, in the drought since 1956, during several visits two years apart, an impression was gained of marked diminution of the amount of *Adiantum hispidulum* at Reedy Creek, and likewise of *Cyclosorus gongylodes* at Kathleen Creek rockhole. However, are these ferns relic in Central Australia? It would seem impossible for them to expand their area in the arid centre under present day conditions, and it is perhaps a matter of comparatively short time during a continuation of the present drought, or in a future one, that these occurrences may be completely desiccated.

Psilotum nudum was recorded at Reedy Creek by Tate in "rocky clefts overhanging rock pool". *Typha angustifolia* is common in pools at Palm Valley and in gorges of the George Gill Ranges. *Diplachne fusca*, a grass, is only found near water in Palm Valley, and *Ottelia ovalifolia*, an aquatic of reedbeds on the Australian mainland, is recorded from the Reedy Creek rockpool. *Lomandra patens* A. Lee is found only in several narrow, rocky ravines in the Krichauff Range area.

Trema aspera could be regarded as the "elm" sought by Tate. This species has a diffuse disjunct distribution and in the separate areas where it is found the forms are identical. Also the plants are very few in number, mainly at Standley Chasm, Emily Gap and Simpsons Gap. This would indicate that the species has not yet had time to change its form and therefore its discontinuity is not of extreme antiquity.

Hakea multilineata var. *grammatophylla* is found only at high altitudes at Standley Chasm, Mt. Sonder, Central Mt. Stuart, and perhaps other like habitats. Burbidge (1960) suggests that this is the possible result of northward migration during an earlier pluvial period.

Certain plants, viz., *Polygonum attenuatum*, *Polygonum lapathifolium*, *Polygonum minus*, *Drosera burmannii*, *Drosera indica*, and *Myriophyllum verrucosum*, are found only near or in water such as seasonal river pools or rockpools, and all but the latter species have a wide distribution in and out of Australia, always in similar habitats. So, although these species are rare, with apparent discontinuous distribution, this seems to be of biological causes.

Burtonia polyzyga has been found at only two localities, so far, both in the Haast Bluff area and is quite likely a true relic species. *Daviesia arthropoda* has been recorded only from Wild Eagle Plain and Mt. Olga and it seems clearly a relic; both of these are of endemic genera.

Several *Acacia* spp., viz., *A. strongylophylla* and *A. validinervia*, occur in the MacDonnells, and also in similar areas in northern South Australia. Then, *Acacia basedowii* var. *viridis* is only found at Standley Chasm. Another undescribed *Acacia* sp. which has been related to *A. doratoxylon* is fairly widespread in the central range system. Considering the wide distribution of *Acacia*, however, it seems probable that these species are adapted to the conditions due to biological reasons, such as edaphic factors. True facts about such cases can only be revealed from a general study of the genus *Acacia*.

Eriostemon argyreus has been found only at Mt. Sonder, and is related to Western Australian species. No other species of the family *Rutaceae* is found in Central Australia, so that this *Eriostemon* is quite isolated; it must be a relic species.

Comesperma sylvestre and *C. viscidulum* are of rare occurrence in the MacDonnells but the former species is also found in Queensland and the latter at Victoria Springs.

Diplopeltis stuartii is found in the ranges and also as far north as Wauchope (Northern Territory) and north-west to Tanami and east to near Ooratippra. It is a rare species, with no wide collections to link up its distribution. Other species of the genus are in Western Australia so that this species is at the edge of the genus distribution. Has the stress of the arid period prevented this genus from expanding? Was this species more common and is it now being gradually eliminated by droughts?

Dodonaea viscosa var. *spathulatum* is confined to gorges in the MacDonnells. *Spyridium spathulatum* occurs in the Krichauff Ranges and at Mt. Lofty and Kangaroo Island. *Sida cryphiopetala* was described from a specimen from Brinkley's Bluff, and its distribution is only in gorges of the MacDonnells, at Mt. Olga and in the Flinders and Everard Ranges. *Rulingia magniflora* was described from Mt. Olga, but has a similar distribution to the previous species. *Hibbertia glaberrima*, also, has a similar distribution. *Baeckea polystemona* was described from Brinkley's Bluff and has only been found in the central range system.

Eucalyptus sessilis is only found on slopes in the ranges, but yet is very closely related to *E. pachyphylla* which grows on sandplains and extends to the southern part of the Barkly Tableland. Is the restricted species more primitive than its relation? Was it a form which separated from *E. pachyphylla* and has become a relic?

Actinotus schwarzii is restricted to a few protected localities in the Mac-

Donnells, and its nearest relative is *A. helianthi* which grows mainly on the Central Coast of New South Wales. *Trachymene gilleniae* occurs only in the MacDonnells.

A few isolated plants of *Plumbago zeylanica* are found in the MacDonnells with the nearest occurrence of this pantropical species being near Wave Hill, about five hundred miles north-west. Likewise, *Jasminum calcarium* is rare in the Ranges, and is found at Limbunya, a similar distance north-west.

Plectranthus sp. aff. *parviflorus* appears to be a restricted endemic species with a near relative extending to some Pacific Islands. *Prostanthera schultzii* is found, so far, only on Mt. Sonder. *Ruellia corynotheca* and *R. primulacea* occur in the MacDonnells and at Burdekin in Queensland. Related species, *Goodenia grandiflora* and *G. horniana*, are found in similar localities in gorges of the central range system.

Bidens bipinnatus, which is common in both hemispheres and occurs commonly on the eastern coast of Australia, is also found in protected areas of the MacDonnells. *Brachycome blackii* from the MacDonnells is of obscure origin according to Davis (1948) who discussed the relationship within the genus. *Helichrysum kempei* is isolated from closely related species, and Burbidge (1958) states that this "emphasises the refugial nature of some of the flora of the MacDonnell Ranges". *Olearia ferresii* is in the central ranges and in the Everards and Musgraves. *Senecio laceratus* and *Wedelia stirlingii* are limited to the central ranges.

While there are, then, some true relic species in the Central Australian flora, there are other possibly confusing elements such as those with a distribution which is entirely connected with the occurrence of natural waters. These cannot be relics, and there is no suggestion that they have ever occurred in any but their present type of habitat. This limited range of habitat does not necessarily make the occurrences discontinuous, but certainly leaves the species in a precarious position.

There is a group of species which are confined to the presumed refuge mountains in South and Central Australia; these include *Callitris hugelii*, *Sida cryphiopetala*, *Hibbertia glaberrima*, *Rulingia magniflora*, *Jasminum lineare*, *Heliotropium asperrimum*, *Pandorea doratoxylon*, *Olearia ferresii* and some others. However, there is no evidence to suggest that these are relic species. They are endemic species, undoubtedly representative of a flora which is adapted to the mountain environment of the arid zone.

Monographic studies of a number of genera such as *Ptilotus*, *Bassia*, *Kochia*, *Indigofera*, *Cassia*, *Acacia*, *Eremophila* and *Goodenia* are necessary to throw more light on discussions of the development of the Central Australian flora. The future of much of this flora is in doubt because of the present continued drought, even though this is of small time sequence historically. Stocking of new areas is proceeding and the forces of wind-drift are most marked in some areas.

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GEOLOGY AND PETROLEUM PROSPECTS OF THE SIMPSON DESERT

BY R. C. SPRIGG

Summary

The Simpson Desert of Central Australia until recently has been considered as one of the more formidable deserts in the world. With the advent of aircraft, soft-tyred and multi-wheeled vehicles and air-driven drilling equipment this attitude is changing. Because of their general lack of physical impediments other than problems of sand and spinifex mounds, alluvial deserts are not unattractive places to search for oil. They are by nature frequently the geomorphically "negative" parts of the earth's crust, and, in that the seas readily invade such low-lying areas, they are consequently also preferred habitats of petroleum. Until recently little was known geologically of the Simpson Desert area proper, except that it obscured part of the Great Artesian Basin, and that a complex of Palaeozoic basins projected into and beneath it from the west, north and south. The drilling of water wells on cattle stations in marginal portions of the desert has provided some new leads to geological understanding of the desert areas, but it is the geological and geophysical operations of Geosurveys of Australia Ltd., Delhi Australian Petroleum Ltd. and Santos Ltd. that have provided much of the new basic understanding. Flamingo Petroleum N.L. and the South Australian Mines Department have also entered the desert area in basic geophysical exploration. The Bureau of Mineral Resources are systematically attacking the geology from the north.

GEOLOGY AND PETROLEUM PROSPECTS OF THE SIMPSON DESERT

By R. C. Sprigg, M.Sc.

[Read 9 November 1961]

INTRODUCTION

The Simpson Desert of Central Australia until recently has been considered as one of the more formidable deserts in the world. With the advent of aircraft, soft-tyred and multi-wheeled vehicles and air-driven drilling equipment this attitude is changing.

Because of their general lack of physical impediments other than problems of sand and spinifex mounds, alluvial deserts are not unattractive places to search for oil. They are by nature frequently the geomorphically "negative" parts of the earth's crust, and, in that the seas readily invade such low-lying areas, they are consequently also preferred habitats of petroleum.

Until recently little was known geologically of the Simpson Desert area proper, except that it obscured part of the Great Artesian Basin, and that a complex of Palaeozoic basins projected into and beneath it from the west, north and south.

The drilling of water wells on cattle stations in marginal portions of the desert has provided some new leads to geological understanding of the desert areas, but it is the geological and geophysical operations of Geosurveys of Australia Ltd., Delhi Australian Petroleum Ltd. and Santos Ltd. that have provided much of the new basic understanding. Flamingo Petroleum N.L. and the South Australian Mines Department have also entered the desert area in basic geophysical exploration. The Bureau of Mineral Resources are systematically attacking the geology from the north.

PREVIOUS INVESTIGATIONS

Few investigations other than of geographical nature and which principally considered the mechanics of desert formation, had been carried out in the main Simpson Desert area prior to about 1958.

C. T. Madigan, D. Mawson and A. Voisey had carried out the principal earlier geological investigations about the northern perimeter and these were of a broad reconnaissance nature. R. L. Jack of the South Australian Mines Department had earlier attempted correlation of Artesian Basin Mesozoic stratigraphy across the desert in its southern extensions, and T. W. E. David and W. Howchin had earlier visited and described presumed Permian glacigene deposits near Finke, N.T.

The first serious effort to map the desert geologically was made by Geosurveys of Australia Limited in 1959 under the supervision of the writer. In this work, principal field mapping was carried out by J. Johnson and M. Audley-Charles. Previously R. Brunnschweiler and H. Wopfner of Geosurveys on behalf of Santos Ltd. had geologically mapped considerable areas about Oodnadatta on the western margin of the desert.

In 1958-1959 the writer carried out aerial geological mapping and air photo interpretation of about a third of one million square miles of the Great Artesian

Basin, and this included the whole of the Simpson Desert environment of approximately 80,000 square miles. This project, along with very extensive low-level aerial reconnaissance carried out collectively by R. C. Sprigg, R. Brunnschweiler and H. Wopfner, on behalf of Santos Limited, greatly expanded the structural understanding of the Simpson Desert, and its immediate environments.

In 1958 the writer published in the American Association of Petroleum Geologists a summary report of the petroleum prospects of the Great Artesian Basin. This was the first publication to hint at oil prospects in and about the Simpson Desert area itself. During and since that time, company explorations have been expanded into the area principally by: Santos Limited; Delhi Australian Petroleum Co. Ltd.; Frome Broken Hill Co. Pty. Ltd.; Phillips-Sunray Petroleum Companies; Three States Petroleum Ltd.; Associated Freney Oilfields N.L.; Flamingo Petroleum Co. N.L.; and Magellan Petroleum Corporation.

In the late 1950's the Northern Territory Mines Department's geological section extended hydrological investigations into the northern and western desert margins to assist local pastoralists in the search for stock water. By this time the Bureau of Mineral Resources had become interested in the area, and commenced detailed geological mapping of 4-mile map sheet areas in about 1959. Their explorations have since been extended across the northern margins of the desert. Preliminary results (unpublished) of these surveys have been made available. The geologists in charge of these field operations were K. G. Smith, J. W. Smith, D. R. G. Woolley, R. R. Vine and E. N. Milligan, under the supervision of N. Fisher and A. Condon.

The desert is practically completely lacking in outcrops older than Recent alluvials over most of its area. Consequently, geophysics must continue to provide most of the advance information relating to the probable depth, nature and structure of deep sedimentation prior to deep stratigraphic drilling. A summary of geophysical activities is given later in this report.

ACCESSIBILITY

Andado cattle station, the outermost desert outpost, occupies a series of low rises (Cretaceous shales) that form a "bridge" into the Simpson Desert from the north-west. Tracks have been extended from the homestead to the east, south and north, and it is possible to loop north-east to the eastern MacDonnell Ranges via Camel Flat, or the Hale River via Madigan's Lookout.

The advent of multi-wheeled vehicles and of bag-type and other low pressure tyres, is making it possible to traverse desert areas more readily. Deserts are no longer serious obstacles, but in fact have much to commend them in exploration. Reconnaissance aircraft, including helicopters, greatly facilitate operations.

Andado has its own airstrip and there are numerous available sites where airstrips could be readily constructed. Gravity surveys in progress by Geosurveys of Australia Ltd. on behalf of Beach Petroleum N.L. are currently establishing tracks completely across the desert from Finke to Birdsville.

The Adelaide-Alice Springs railway traverses the desert margin on the west and provides a number of passenger and goods trains services per week.

The nearest regular airline service on the west operates through Oodnadatta en route between Adelaide, Alice Springs and Darwin. A weekly service operates through Birdsville on the east. The region is served by the Flying Doctor network, and by regular wireless telegraph services at intervals throughout the day.

PHYSIOGRAPHY

The Simpson Desert is one of Australia's largest desert areas (c. 80,000 square miles). It occupies a general topographically depressed belt descending below sea-level in the south where playa lakes attain quite large dimensions (Lake Eyre about 10,000 square miles). Madigan (1936, 1937a, 1937b, 1939, 1945, 1946), Crocker (1946), and Bonython (1956) and King (1956, 1960) have been foremost investigators of these phenomena.

The desert is characterised by remarkably parallel longitudinal or "seif" sand dunes for which the desert is famous. The trend of the main body of the dunes is N.N.W. in the direction of the existing and "sub-fossil" prevailing wind directions. These correspond with the dominating winter anticyclonic wind pattern, which brings the most persistent high-impact winds (20 m.p.h. or greater) from the south-south-east. The dunes are consequently the eastern arc of a sub-circular pattern of atmospheric circulation centred a considerable distance west of Lake Eyre. The dominating regional traction of sand in Central Australia is thus anticlockwise.

Not much translation of sand is occurring at present except in the environs of Lake Eyre, or where aborigines have burned extensively for game, or where the white man has overgrazed with stock. Mostly the dunes are "fixed" by bushy vegetation, and sand movement is restricted to the unstable dune crests. The Simpson Desert consequently is largely "fossil" and its climatic development is now considered to relate to the glacial phases of the Pleistocene (Sprigg, 1961b). The source of the sediment is practically entirely alluvial, the desert floor consisting of the relatively fine outwash products from surrounding ranges and plateaus. The dried-out interdune floors are deflated by high velocity winds, and also in more recent geological times under increasing arid conditions. The finer material winnows out as dust which may be transported enormous distances (Australian dust has been recorded causing haze in New Zealand during the more violent duststorms in the 1930s). The concentrated residual sand (with sub-rounded grains averaging about 0·60 mm.) is swept into dunes. In this manner the interdune corridors are zones of shallow aeolian erosion (wind-rifts) with the result that there is a tendency in some areas for the more stable dunes in slower alluviated areas to become isolated on "pedestals" one to several feet in height, as interdune top soils continue to be deflated. Crocker (1946) has shown that the sands of the interdune corridor floors are relatively immobile. Two sizes of sand grains dominate that bear an approximate 10 : 1 diameter ratio, and this brings stability by the resultant more efficient packing and sand grain interlocking.

Clay-pans are a prominent feature of the desert in that they are "scalds" representing the exposed surface of the soil "B", or clay, horizon. This gives a measure of the normal depth of erosion (6 to 12 inches) from which the material to build the dunes to 30 to 150 feet high has been derived and concentrated. No *deep* erosion by wind is required to account for the dune accumulations, for the dunes are mostly only several hundred feet across at the base but are usually separated by intervals of one-eighth to a quarter of a mile or more. Where alluvial deposition is in progress near debouchments of large "rivers", far more massive sand accumulations develop but these lack the characteristically open "sand-free" corridors of the desert proper. A suggestion of barchan development may also be observed in these zones.

Clay-pans occur more frequently to the south, culminating in the Lake Eyre salina (saliferous deposits of salt and gypsum) occupying the lowest portion of the depression.

GEOLOGY

The Simpson Desert is a topographically depressed alluvial area that obscures the junction of several intra-cratonic Palaeozoic basins emerging from the West Australian Pre-Cambrian shield. It also envelopes the most north-westerly developments of the Mesozoic Great Artesian Basin (Fig. 1).

Basement rocks are Archaean metasediments and acid to basic igneous intrusives. They are overlain, and/or separated, by thick sedimentary developments of Cambrian, Ordovician, (?)Devonian, (?)Carboniferous, Permian and Cretaceous ages. Trias-Jura may be present beneath the more central desert areas. (?)Triassic sediments have recently been recognised near Tarlton Downs immediately north of the desert. These are overlain by Quaternary alluvial deposits, including the extensive dune systems.

Proterozoic, Cambrian, Ordovician and Cretaceous sediments were extensively marine. Upper Palaeozoic sediments as they appear in outcrop marginal to the desert were dominantly continental. There is, however, reason to anticipate more marine-ness in the structurally "negative" areas now beneath the Simpson Desert. Permian sediments intersected in bores put down in marginal provinces to the desert to the south-west, for example, have recently (Ludbrook, 1961) been recognised to have penetrated such marine intercalations.

The basement complexes are intensively folded, faulted and igneous-intruded. These were deeply peneplaned and isolated by an enormous time break from later preserved sediments (the "ep-Archaean" interval and peneplane). Several distinct cycles of post-Archaean sedimentation can be recognised, accompanied or separated by orogenic and epeirogenic episodes of movement. A number of interconnected and semi-permanent sedimentary basins have evolved. Structural deformation within the Upper Proterozoic to Cambrian and Ordovician has accompanied gliding and dècollement formation. Jura-type anticlines, with near vertical limbs and separated by flat-lying strata, developed.

A feature of the tectonics of the northern Simpson Desert area was the development of Palaeozoic folding across dominantly east-west axes, over which have been superimposed gentle cross-warps of Mesozoic-Tertiary age with more nearly north-south trending axes. These latter probably developed in relation to NNW-SSE or NNE-SSW trending fault lineaments and/or lineamental fault blocks.

A. STRATIGRAPHY

Marginal to the Simpson Desert, sedimentary successions have preserved much of the geological record since Middle Proterozoic times. Evidence of vulcanism is almost entirely absent, and with few exceptions conglomerates are poorly developed. Tillites feature in the Upper Proterozoic; Permian glacio-fluvial boulder beds have been "interpreted" in several widespread localities around the northern and western perimeters of the desert. Some of these are possibly outwash remanié eroded from the Proterozoic glaciofluvials.

1. *Archaean*

Three provinces of Archaean igneous and metamorphic rocks converge on the desert from the north and west. The northernmost form a low barrier in this direction cutting off the desert from the Georgina Basin.

a. *The Arunta Complex* which shelves beneath the desert in the north is composed of gneisses, schists and intrusive rocks. Metasedimentary fold axes are confused in direction in this zone, but become more latitudinal in the west.

b. *The Musgrave Mountain Belt* trends eastwards into the Simpson Desert at about its centre, and represents the deeply exposed easterly extension of the Westralian Pre-Cambrian shield. In this area it is composed principally of deeply granitised metasediments, intrusive granites, charnockites, and ultrabasic complexes. Major east-west, crustal shear faults traverse the ranges, and in the extreme west have facilitated voluminous basic and ultra-basic intrusive and extrusive activity.

This metamorphic complex has provided a major source of sediment supply to the extensive basin areas about Central Australia since Proterozoic times. It is a geanticlinal area of great antiquity. (c.f. the Arunta block which is considerably younger, and is of the nature of an uplifted and sediment-stripped platform.)

Metasedimentary fold structure is generally remarkably subdued, and an east-west grain dominates most of the ranges. In the more easterly extensions, however, isoclinal folds with pronounced north-south axes (near Ernabella and Mt. Tieyon) are developed; they incline to NE-SW about Umbearra, near the north-western edge of the desert.

c. *The Peake and Denison Ranges* are inliers of gneisses and igneous rocks that protrude through Proterozoic, (?)Permian, and Mesozoic cover formations on the south-western margins of the Desert. A depressed and primarily subsurface platform of these rocks extends towards the south-west coast of Lake Eyre.

The foregoing basement exposures margin the desert as low ranges and inselbergs descending eventually beneath plains level. Doubtlessly the Musgrave Mountain Belt has been the most persistent "positive" geomorphic feature in Central Australia since Pre-Cambrian times. The presence of *major* crustal shear lineaments extending east-west in this zone (through Mt. Davies and south of the Musgrave Ranges) may have had much to do with this transcending uplift factor. In Australia these and other major crustal zones of shearing have exerted a major influence and control on sedimentation since Middle Proterozoic times and earlier.

All Archaean rocks are metamorphosed to a degree that is in strong contrast to the practically unaltered Upper Proterozoic and later sediments which cover them. The Upper Proterozoic and Archaean are separated from each other by the near perfect ep-Archaean buried "peneplane".

2. *Proterozoic*

As with the Archaean complexes, three principal outcrop areas of Proterozoic rocks are recognised which impinge on the Simpson Desert. These are the MacDonnell Ranges-Ferguson Ranges and their extensively pedimented extensions continuing eastward into Queensland, north of the desert; the piedmont and pedimented areas which skirt the Musgrave Ranges in N.T.; and the Peake and Denison Ranges in S.A. There is practically no evidence of igneous activity or metamorphism. An interbedded basalt flow occurs west of Granite Downs near Indulkina.

a. *The Ferguson Ranges and Eastward.* This is a belt of thick Upper Proterozoic deposition extending up into the Cambrian, and which laps onto Archaean core rocks to the north. The basal Heavitree Quartzite is overlain by a succession of shales, sandstones, limestones and dolomites passing above into tillitic developments, then into reddish shales and sandstones with included dolomites, to the base of the Cambrian. The Upper Proterozoic-Cambrian succession approximates 11,000 feet in thickness. Of this the basal Heavitree Quartzite and the Bitter Springs Limestones attain about 2,000 feet opposite the north end of the desert. The latter limestones are frequently highly organic. The overlying Pertatataka Group, approximately 3,000 feet thick, consists of interbedded sandstones, limestones and shale, with a disconformity and some evidence of glacial detritus low in the succession.

b. *Musgrave Range "Foothills"*. Upper Proterozoic sediments (principally sandstones, glaciofluvials, grey and red shales and inter-bedded limestones) nose around the plunging Musgrave Range promontory at the desert edge. Although the basal equivalent of the Heavitree Quartzite figures prominently along the northern course of this 400-mile long mountain belt in the west, there is evidence of its erosion from the eastern piedmont areas, and its replacement by the later "basal" (Sturtian) tillites.

The most easterly outcrop of Proterozoic sediments form the Mt. Kingston Ranges, about 25 miles north of Kulgara. These sediments strike E.N.E. to Horseshoe Bend, where they plunge beneath the desert in a flat-pitching anticline. The formations dip steeply northward (50-70 degrees), but folding finally drags them into a low anticlinal structure pitching eastward. Principally these are sandstones, flaggy and ripple-marked in part, also glauconitic and micaceous, and purplish to whitish in colour. Tillitic beds are present. They are shallow-water products, and presumably correlate with the Grants Bluff Formation across the desert to the north-east (Smith *et al.*, 1960, 1961).

Near Granite Downs, a thick succession of purple shales with yellow dolomites overlie well-developed basal tillites.

c. *The Peake and Denison Ranges*. A typical cross-section of Adelaide System sediments of great thickness occurs in these ranges which margin cores of basement rocks. They include a thick shale and dolomite sequence, overlain by tillites and glaciofluvials, and finally by shales and dolomites. The Cambrian, however, does not outcrop in the area (Reyner, 1955).

3. *Palaeozoic*

A very extensive succession of Palaeozoic sediments outcrop in the marginal areas of the Simpson Desert. Gaps in the sedimentary record relate to the Silurian, and possibly the Carboniferous. There is no known igneous activity or evidence of regional metamorphism in the area. Areas of practically continuous Palaeozoic sedimentation may well be preserved beneath the more (tectonically) negative zones of the Simpson Desert.

Lower Palaeozoic sedimentation, principally marine, dominates the known sedimentary record. Considerable thicknesses of Cambrian and Ordovician sediments exposed at the surface occupy elongate east-west basins or "troughs" bordering the Musgrave Mountain belt on its north and south sides, and which trend into the province of the Desert. (?) Devonian and Permian, continental and lacustrine sections, preserved in outcrop in the broader synclines, thicken towards the desert area, and are indicated to be more extensively preserved in this direction. There is ample scope for marine facies to develop into this downwarped zone.

a. *Lower Palaeozoic*

Several Lower Palaeozoic troughs converge on the Simpson Desert. These are the Amadeus and Officer Basins from the north-west and central-west respectively, and the Adelaide Geosyncline from the south. The Amadeus and Georgina Basins provide the most complete Cambro-Ordovician successions, whereas the Cambrian is completely missing in outcrop in the poorly outcropping Officer Basin. An enormously thick Cambrian succession is present in the Adelaide Geosyncline (16,500 feet thick) but Ordovician is absent in its northern areas, although it is developed in the Mootwingee area across the N.S.W. border.

(i) *Cambrian*: Cambrian sediments in outcrop about the Simpson Desert are restricted to the Amadeus and Georgina zones, respectively to the north-west and north. They also appear in the extreme south at the northern extremity of Lake Torrens. There is ample scope for their development below the desert itself.

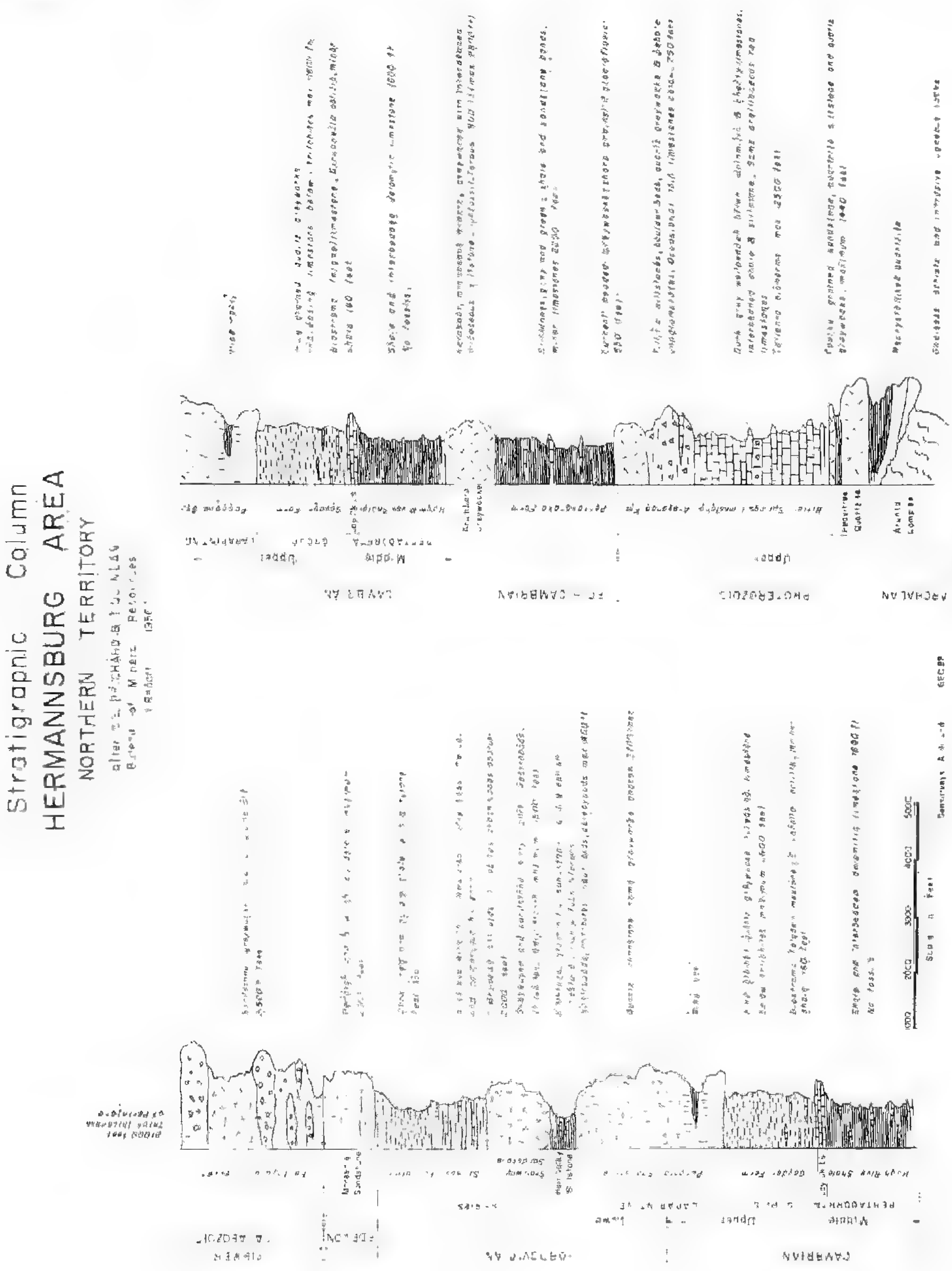


Fig. 2

Cambrian successions everywhere appear to overlie the Upper Proterozoic conformably, or very nearly so. There is little indication of any sedimentational break, and it is more a matter of definition or convenience as to where the boundary is drawn.

North of the Simpson Desert the Cambrian succession attains about 6,000 feet in thickness, consisting in ascending order of the Arumbera Greywacke, the Hugh River Shales, the Santa Teresa Limestone and the Pulya Pulya Sandstone (Smith *et al.*, 1960, 1961).

The Arumbera Greywacke is believed to attain about 2,000 feet thick, and is predominantly a whitish or reddish brown felspathic sandstone. The Hugh River shales together with the Santa Teresa Limestones also attain almost 2,000 feet in thickness. They are essentially part of a single shale-limestone association The brachiopods *Kutorgina* and *Nisusia* in the lower Hugh River shales indicate a lower Cambrian age for the unit (Bureau of Mineral Resources, general information).

The uppermost Pulya Pulya sandstone is generally a dense white clayey sandstone of uniform lithology. Fragmentary brachiopods and trilobites indicate an Upper Cambrian or Lower Ordovician Age.

Higher members of Ordovician age may be obscured beneath the desert levels to the south in which direction the general succession plunges.

In the Amadeus zone, Cambrian successions may attain several thousand feet in maximum thickness (Fig. 2) *Archaeocyatha* bioherms are developed in the lower limestones, principally east of the N.-S. railway.

Trilobitic limestones (*Redlichia*) are conspicuous in the Middle Cambrian. These latter are mostly darker-coloured and may be bituminous, they are set in thicknesses of shales. Sandstones are also present in the section, and one that is more conspicuous marks the base. Red beds are also well-developed at some levels.

The Georgina Basin Cambrian may attain 5,000 feet or more in thickness, and is made up extensively of limestones (Fig. 3), the middle and upper sections of which may be prolifically fossiliferous. Sandstone developments increase in the upper section and there are some shales.

In the approaches to the Musgrave mountain belt (southern Amadeus and northern Officer Basins) the Cambrian may be thin or entirely missing. These levels are occupied by an internal unconformity that reveals extensive contemporary erosion prior to deposition of the Ordovician. Late, or epi-Cambrian, diastrophism is indicated by stronger folding in the earlier beds. At Deep Well (on the railway south of Alice Springs), for example, Lower and Middle Cambrian beds were extensively and contemporily eroded and further to the south they were entirely removed. This situation intensifies also along the northern margin of the Officer Trough, where the broadly folded (?) Ordovician sandstones overlie relatively tightly folded uppermost Proterozoic in the immediate Musgrave piedmont zone.

Cambrian formations almost certainly occur widely beneath the Simpson Desert, for they form the cores of spectacular Jura-type folds which crop up at the desert's immediate northern margin. Seismic surveys indicate deep sedimentary sections in the coextensive desert areas.

(ii) *Ordovician*: Sedimentation during this interval in the Amadeus was dominantly arenaceous, but thin, highly fossiliferous shaley limestones are interbedded. Three to four thousand feet or more of cross-bedded and reddish sands dominate the section. Across in the Georgina Basin, limey sediments assume greater prominence, and the section appears to be best developed against (on the north side of) the MacDonnell-Winnecke basement "ridge" (Fig. 3).

Fossil assemblages of the Amadeus basin appear to be dominated by the ubiquitous (?)*Scolithes* "worm burrow" or "pipe-rock" (Upper Cambrian to Ordovician) in the great sandstone formations, and by the Horn Valley fauna in the narrow shaley limestone interbeds. This latter fauna includes *Orthoceros*, *Raphistoma*, *Orthis* and *Dalmanites* in super abundance.

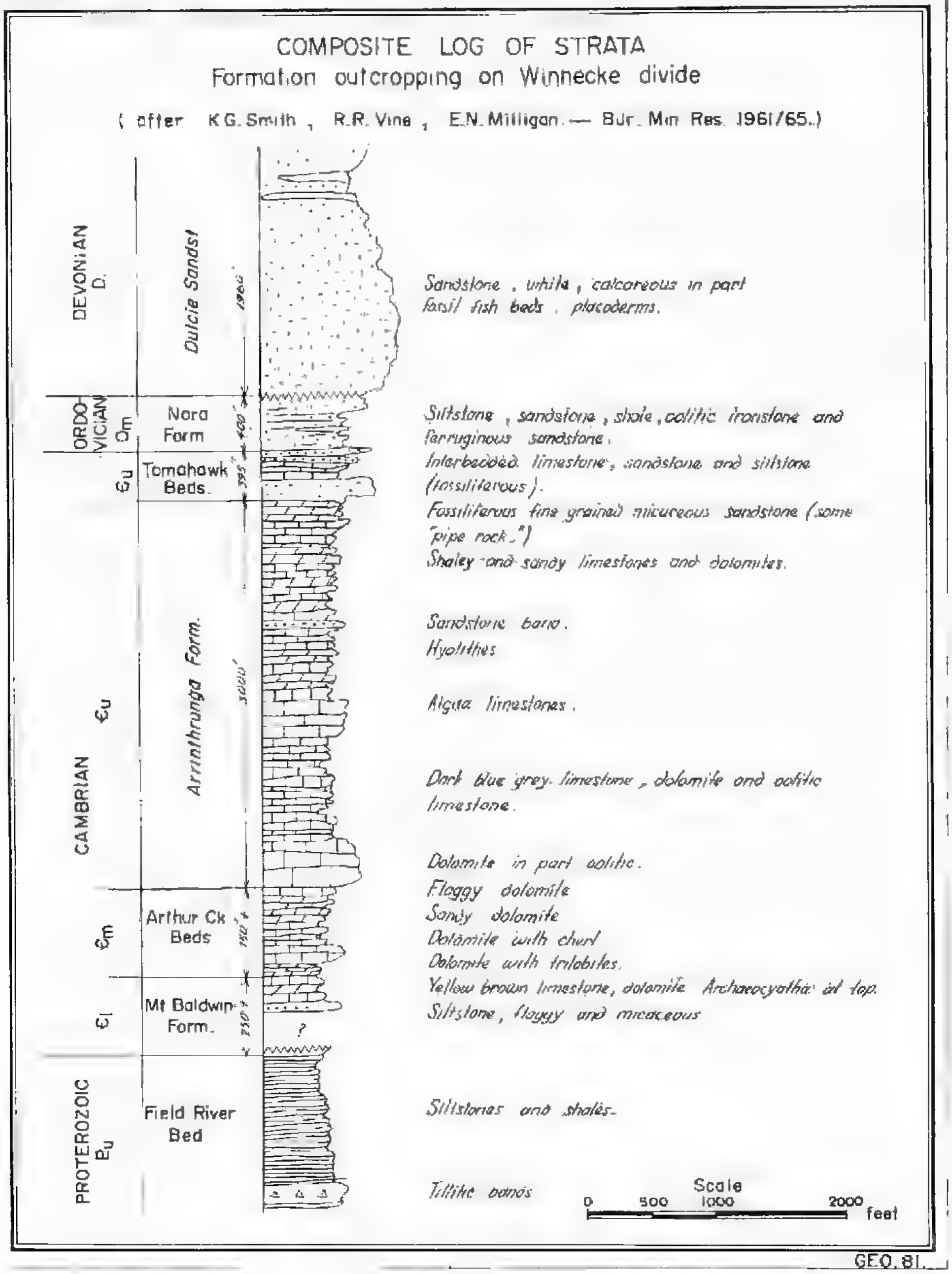


Fig. 3

In the Toko syncline (southern Georgina Basin) rich fossil assemblages include trilobites, nautiloids, pelecypods, gastropods, sponges and bryozoa.

South of the Musgrave Ranges in the Officer Basin massive sandstones characterised by "pipe rock" are coarsely cross-bedded and slump-bedded; they appear to be broken only by thin red and grey limestones and grey shales near the base. This formation overlies the uppermost Proterozoic red shales section with strong angular unconformity; its Cambro-Ordovician age requires verification.

East of the Musgrave Ranges, Ordovician sandstones with rich molluscan fauna have been found in the Mt. Kingston Range north-east of Kulgera. These appear to be coextensive with the "pipe rock" sandstones recorded by Opik and Sullivan (1951) at Rumbalara. These Ordovician strata, flat-lying, appear to dip gently beneath the Simpson Desert from this direction. In the last outcrop at the edge of the alluvial plains near Granite Downs, to the south, they are tilted to 45 degrees to the north. Much of the deeper seismic reflections below Andado in the desert area may be from these beds. None of the local water bores in this Andado area have penetrated below the flat-lying Permian.

b. *Upper Palaeozoic*

Detailed regional mapping by the Bureau of Mineral Resources (Smith *et al.*, 1959, 1960 and 1961) and geological reconnaissance by Frome Broken Hill Company and by Geosurveys, have disclosed the presence of considerable developments of Upper Palaeozoic sediments about the margins of the Simpson Desert. These give the strong impression that Upper Palaeozoic sections, (?)Upper Carboniferous to (?)Permian, beneath the desert may be not inconsequential.

Whereas (?)Permian sections in these marginal outcrop areas are all continental, recent checking of bore cores by the South Australian Mines Department (Ludbrook, 1961) demonstrate that Permian sections buried beneath Mesozoic cover, south of the Peake and Denison Ranges, include also marine developments. It is not unreasonable, therefore, to suspect an increasing marine element in any or all Upper Palaeozoic successions as they pass into the structurally more "negative" zones of the Simpson Desert area that had developed at that time. Dullingari Well near Innamincka (Delhi-Santos) has disclosed several thousand feet of continental to marine Permian in a sub-basin immediately east of the desert.

Prior to World War II, presumed (?)Permian "tillites" and conglomerates had been recognised in the Missionary Plain (west of Alice Springs, Madigan, 1932), and at Crown Point (near Finke; David and Howchin, 1923), but otherwise the Upper Palaeozoic was considered to be represented by an extensive geological hiatus.

Devonian fish beds have recently been reported from a deep synclinal "basin" on the immediate northern margin of the desert, and possibly also (?)Carboniferous leaf beds. These appear to be comparable with similar developments in the Dulcie Ranges of the southern Georgina. Within the Simpson Desert, in Malcolms Bore (30 miles N.-E. of Andado) Lower Permian (Artinskian) shales rich in pollen were encountered below about 600 feet to the bottom of the hole at approximately 1,800 feet.

There is now reason to suspect that a reasonably complete Palaeozoic succession may indeed be present beneath some parts of the Simpson Desert.

(i) (?)*Silurian to Devonian*: Fish beds of undoubted Devonian age (Hills, 1959) are reported (Smith, 1960 and 1961) in the south-western Georgina Basin.

They occur in thick sandstones deposited in fresh water as the thick Dulcie Sandstone.

In the Amadeus Basin the Mereenie Sandstone, 900-2,000 feet thick and overlying the Ordovician section in Ellery Creek west of Alice Springs, may possibly be of this age (Quinlan, 1962). Wells *et al.* (1961) recognise a disconformity separating the Mereenie Sandstone from the underlying (Ordovician) upper portion of the Larapintine Group. The Mereenie Sandstone is overlain unconformably by massive "flysch" conglomerates (8,000-21,500 feet thick according to various estimates) of the Missionary Plains syncline. Early writers (David and Brown, 1950) referred these "Post-Ordovician" Pertnjara conglomerates to possible Permian. Quinlan (1962) places them in the Upper Palaeozoic. The Pertnjara are the accumulations of a tectonic environment (Sprigg, *et al.*, 1960; Quinlan, 1962; Wells, *et al.*, 1962). The boulders are of unsorted mixed types that were rapidly accumulated. Metamorphic and igneous rocks from Archaean basement predominate in the uppermost conglomerates, whereas successively younger (Proterozoic to Ordovician) rock fragments predominate in the lower horizons. The rapid erosional stripping of an actively uplifting lower Palaeozoic landscape suggests itself. No fossils have yet been found in these sediments. The beds are described by Madigan (1932), Chewings (1935) and Pritchard and Quinlan (1960), Quinlan (1962), Wells *et al.* (1961).

The large diapiric Mt. Goss structure (two to three miles in diameter) of the Missionary Plains syncline has presumably penetrated a great thickness of Pertnjara beds, but its vertical walls, and also the horizontal cap strata, are of Ordovician sediments. The origin of the structure is undetermined but is presumed to be a salt, gypsum, or mobile clay plug from the deeply buried Cambrian or Upper Proterozoic, both of which are known to include red beds of saliferous affinities.

It is possible that similar incompetent strata have permitted extensive slippage (décollement formation) in the northern Simpson Desert area, the cores of the folds of which may also be diapiric. (See under subsequent discussion of structure.)

In the extreme south-eastern Georgina Basin, and immediately across the basement divide from the Simpson Desert, the Dulcie Sandstone (1,690 + feet) is of Upper Devonian age. Smith *et al.* (1961) report that "fragments of fossil fish were obtained from a bed 1,640 feet above the base. The fossiliferous horizon, about 60 feet thick, is a unit of white calcareous sandstone which also underlies the horizon where Upper Devonian placoderms were obtained in 1958. They were described by Hills (1959)." Disconformable relations with the underlying Ordovician are apparent. It is possible that comparable synclinal infillings lying immediately north of the Simpson Desert, are of this Devonian age and association.

(ii) *Permian*: Presumed continental and glaciofluvial sediments referred to this age have been recorded occurring widely about the northern and western perimeters of the Simpson Desert. These have been described from the Peake and Denison Ranges (Chewings, 1928; Reyner, 1955; Parkin, 1956), from Finke (David and Howchin, 1924; Ward, 1925; Sprigg and Brunnschweiler, 1958; Sprigg, Johnson and Audley-Charles, 1960), and from the Hay and Field River Headwaters (Condon and Smith, 1959; Smith *et al.*, 1960).

Undoubted (fossiliferous) Lower Permian have been recorded from the north central Simpson Desert in Malcolms Bore (on Andado Station) below about 600 feet of Cretaceous shales (Sprigg, Johnson and Audley-Charles, 1960; Balme, 1960). More recently (Ludbrook, 1961) has shown the Permian to be in part marine in the adjoining Stuart Range Area.

Ludbrook (1961) has provided the following stratigraphic sequence for these beds (principally from L. Phillipson Bore):

(a) Lower Artinskian to Upper Sakmarian fresh water mudstones with coal and fine sandstones	264 feet
(b) Sakmarian fresh water carbonaceous siltstones and mudstones with some sandstone	1,830 feet
(c) Lower Sakmarian marine mudstone and siltstones	280 feet
(d) Glacigene boulder clays of presumed lowermost Sakmarian age	766 feet
Total	3,140 feet

Much confusion has surrounded the assessment of Permian glacigenes in Central Australia. Tectonic (piedmont) breccia-conglomerates of the Missionary Plains have been tentatively included in this category, and there is high probability that many of the "tillitic" sands in marginal desert areas are rewashed (remanie) concentrations from earlier (Upper Proterozoic) fluvioglacial boulder beds. The confusion carries into the Cretaceous where "glaciofluvial" tillites have been described widely to occur about the south-western Artesian Basin. Here the pebbles could be re-eroded from neighbouring Proterozoic tillites, or Permian glaciofluvial deposits.

Near Tarlton Downs Homestead on the northern margin of the desert, thin presumed ground moraines, considered to be Permian (Condon and Smith, 1959), have since been found to carry a flora (*Linguifolium denmeadi*, etc.), indicating a Triassic or Lower Jurassic age (Smith *et al.*, 1961).

It is not unlikely that a number of so-called Permian glacigenes in the periphery area will be of these or other ages, and that the glacial impression has been misinterpreted or exaggerated.

The beds are generally conglomeratic sandstones, often with obvious cut-and-fill structures and slump- and cross-bedding attesting to fluviatile deposition. Doubt as to the "tillitic" interpretation has long existed in many localities because of the local outcrop of Upper Proterozoic tillites and glaciofluvial deposits from which some of the striated and facetted boulders could equally well have been derived by erosion. There is also good evidence (Sprigg *et al.*, 1960) that many of the boulders at best are likely to be products of periglacial activity beyond mountain glaciers, as could have developed in the higher and more distant ancestral Musgrave Ranges. Mostly the matrix of the "conglomerates" is sandy and not comparable with the "rock flour" or normal tillites. In the Finke-Crown Point localities the boulders are principally locally-derived quartzites; occasional granite and felspar porphyry pebbles indicate more distant origins, or they may be remanie from locally outcropping Upper Proterozoic. Pebbles of red limestones similar to beds within the (?)Ordovician near Granite Downs verify the post-(?)Ordovician age of these Finke occurrences.

(iii) *General Observations*: Uncertainty continues to surround the understanding of the stratigraphy of a number of sandstone formations descending gently below the desert from the vicinity of Finke and Oodnadatta (Glaessner and Parkin, 1958). About Finke, at Horseshoe Bend, the incomplete succession measures several hundred feet in thickness. It is as follows:

Sandstone, current bedded and micaceous; some interbedded red shale.

Conglomerate, intraformational, with cut-and-fill structure.

Disconformity

Shales, red or chocolate; micaceous.
Sandstones, current bedded, pebbly and gritty in part; locally argillaceous; severe local slumping.
Basal conglomerates.

Unconformity (on U. Proterozoic)

To the east of Pollys Corner, near Horseshoe Bend on Finke River, conglomerates occurring at higher levels appear to pass below the De Souza Sandstone (Opik, 1954) of Rumbalara. Fossil leaves reported to have been discovered in this vicinity by Frome Broken Hill Co. geologists are believed to have indicated a Lower Permian or Carboniferous age. Further to the east in the Simpson Desert, sands encountered in the Yardhole Bore (100 miles distant) beneath 600 feet of Mesozoic sediments are typically garnetiferous and lignitiferous Artinskian developments (Ludbrook, 1960). Grey shales were also well developed, and the formation was not penetrated at the cessation of drilling at 1,800 feet.

Beds possibly of the Finke sequence are also exposed about Mt. Ticyon and Umbearra, and eastwards to the Finke River between Lilla and Goyder Creeks. Where these overlap granites, boulder conglomerates are developed. They are capped by Cretaceous shales with siliceous and/or lateritic cappings.

A single sub-circular outcrop of hard siliceous conglomerate forming Mt. Alice and dipping outwardly occurs 50 miles NNW. of Oodnadatta. The outcrop is surrounded by low, outwardly-dipping Lower Cretaceous shales, and the sediments are dubiously related to the Permian. Brunnschweiler (1957), in a Santos Ltd. company report, has suggested correlation with the Algebuckina Sandstone bordering the Peake Ranges on their north.

Of particular interest was the encountering in the base of the Santos Oodnadatta Bore No. 1 of steeply dipping porous sandstones of unknown age. A single core taken at 1,292 feet revealed a steeply dipping (55 degrees) clean, very white sandstone, notable for its high mica content. The sediment was only lightly lithified, but otherwise there was no clue to its age which could be anywhere in the range from uppermost Palaeozoic down to Upper Proterozoic. Lithologically, similar sandstones occur locally in the Finke sequence and also in the (?)Ordovician, and in the Upper Proterozoic (the latter along the northern margin of the Indulkina Ranges).

c. *Trias-Jura*

Until recently sediments of these ages had not been recognised in the desert environs. Previously-presumed "Permian glacials" occurring immediately south of Tarlton Downs Homestead (at the north end of the desert), have now been found to contain a probable Triassic or Lower Jurassic flora (Smith *et al.*, 1961). A collection of plants examined by Mary White (1961) notes the presence of *Linguifolium denmeadi*, *Dicroidium odontopteroides* and *Elatacladus* sp., etc. The preservation of the impressions is not good, but the weight of the evidence favours the foregoing early-middle Mesozoic ages.

d. *Cretaceous*

The Simpson Desert depression forms part of the Great Artesian Basin or epeirogenic downwarp. Westward tilting of the basin during Mesozoic times led to progressive westerly overlap onto the Pre-Cambrian shield, with the result that early Mesozoic sediments do not appear to underlie the Cretaceous shales in extreme westerly areas to any significant extent.

Roma-Tambo (Aptian-Albian) marine shales blanket all earlier deposits in the desert area. They lap onto the "Permian beds" about Finke and Algebuckina, either disconformably, or with gentle non-conformity.

(i) *Blythesdale Sandstone*: Unconsolidated and highly permeable sands are present in bores about Oodnadatta where they aggregate 310 feet in thickness in Santos Ltd. Oodnadatta No. 1 well, and rest on steeply dipping micaceous sandstones of probable Palaeozoic age (see above). A chert band was encountered at the unconformity. The aquifer sands presumably thicken to the east in the direction of the Simpson Desert, but the available bore information in this direction is limited and unreliable.

(ii) *Roma-Tambo Formations*: Typically monotonous shale sections of these beds are relieved only by thin limestones, and sandy glauconitic silty developments. They are highly fossiliferous in the Oodnadatta region. Sand stringers and gravels have developed only in basal overlap, in contact with granites in the extreme west. In outcrop the shales bleach white, or are mottled white, yellow, mauve, reddish or brownish by laterization. At Rumbalara, near Finke, the shales are yellow with ochre developments.

About Mt. Dare and Dalhousie the shale section has been deeply eroded at the top of a broad fold-arch. Nodular limestones in grey shales and gypseous beds are exposed.

The deepest well to penetrate the Roma-Tambo is at Mt. Dare just inside South Australia. A thickness of about 1,000 feet of shales was cut, becoming sandy and glauconitic towards the base. They rested on porous sands of indeterminate age.

At the Rumbalara ochre mine the shales overlie the De Souza Sandstone of Opik and Sullivan (1954) which is variously reported as of Mesozoic or Palaeozoic age. Twelve miles south of the ochre mine a bore hole penetrated several hundred feet of shale, presumed to be Cretaceous, before entering a sandstone aquifer.

Shallow water sandy and glauconitic shales have been intersected in drilling for water on New Crown Station from where the Cretaceous shale boundary swings west to about 10 miles north of Lilla Creek. Presumed Cretaceous shales overlie the Finke River sandstones immediately north of Bloodwood bore. The shale boundary continues south-east past Tieyon to Mt. Irwin and disappears beneath the edge of the desert, and is last seen trending south towards and just east of Mt. John. These shales carry occasional *Maccoyella* valves as shells or casts. They can be traced at intervals in outcrop north about the margins of the Simpson Desert into Queensland.

The Santos Ltd. Oodnadatta No. 1 stratigraphic bore put down three miles NNE. of Oodnadatta township cored a fairly complete section of the Roma-Tambo. Ammonite fauna (R. O. Brunnschweiler in a Santos Ltd. company report) indicated the Aptian-Albian boundary at 400 feet, and the (?)Aptian-Neocomian at 960 feet. The well entered the artesian aquifer at 1,292 feet. Ludbrook (1958) confirmed these findings in the microfauna.

The succession proved to be lithologically rather uniform throughout the Aptian and Albian, with highly carbonaceous mudstones dominating the section. The sediments are typically marine shallow water, in which a rich foraminiferal fauna existed. Mollusca, brachiopods (particularly in the sandier bands), echinoids, ostracods, and fish teeth were all very abundant. Inoceramus and

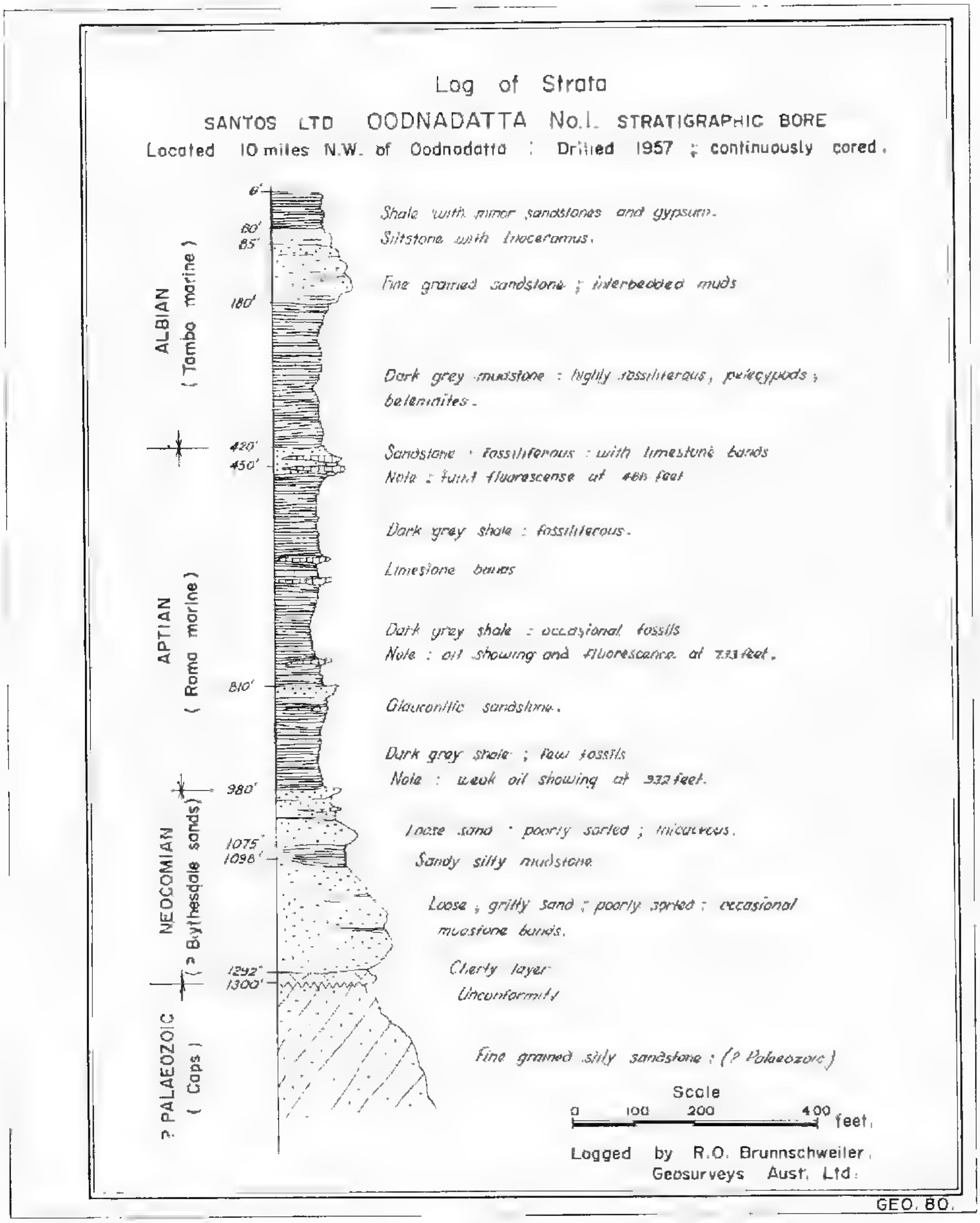


Fig. 4

ammonites were common. Brunnschweiler's log of the Santos Ltd. Oodnadatta No. 1 well is as follows:

0- 182 feet	Siltstones, silty sandstones and argillaceous limestones.
182- 422 feet	Dark grey mudstones.
422- 450 feet	Dark grey sandstone with limestone bands.
450- 981 feet	Dark grey mudstone with siltstone then limestone and sandy mudstone.
981-1,007 feet	Interbedded tight limestones, shale and sand.
1,007-1,292 feet	Principally unconsolidated water sands with some shaley partings and silty section (age uncertain; (?) Blythesdale).
1,292-1,330 feet	Pre-Mesozoic micaceous, soft white, sandstones dipping at 55 degrees ((?)Palaeozoic . . . R.C.S.).

The Yardhole bore on Andado Station drilled in 1959 indicated a middle Albian fauna at 660 to 680 feet equivalent to that at 260-300 feet in Oodnadatta bore (Ludbrook, 1960). This suggests a total Cretaceous shale depth of the order of 1,300 feet in this vicinity (see later).

An outcrop of bleached sandy shale beneath a "duricrust" (silcrete) capping 90 miles due east of Andado, and named "Geosurveys Hill", appears to be of Lower Cretaceous affinities. It is the only known outcrop in the central desert area.

e. *Tertiary*

Pebble conglomerates, claystone beds and sandstones as veneers are distributed widely about the margins of the Simpson Desert in Northern Territory. The pebbles are small (up to 1 inch), well-rounded and polished. Cementing material is usually siliceous or lateritic. These are commonly "duricrusted" by advent of silica, and form protective cappings to mesas. About Mt. Tieyon on the S.A.-N.T. border these beds may attain 30 to 40 feet in thickness. They include clay lenses interbedded with sands, and cut-and-fill conglomerates. The sediments are presumed to be Lower Tertiary in age, but the evidence is inconclusive. Denudation has stranded many of the deposits high on mesa pedestals.

Thicker Tertiary accumulations are expected to be present in the lower-lying desert areas. In this connection recent drilling carried out by the South Australian Department of Mines in the Lake Eyre region (Johns, 1962) is of interest; an early Tertiary sequence of Carbonaceous sands and silts is overlain disconformably by (?)Miocene dolomites, dolomitic mudstone and clays (Etadunna Formation).

f. *Quaternary*

Alluvial "drift" forms the floor of much of the desert area. Sand concentrated from the shallow soil layers in the process of wind deflation has formed the striking parallel dune system for which this desert is famous, and the finer silty products have been winnowed out and removed as dust.

Crocodilian teeth ((?)*Pallimnarchus*) were found in deep alluvial clays of this association in Mothers Well south of Mt. Tieyon.

B. STRUCTURE

The Simpson Desert is a continuing structurally and geomorphically "negative" section of the Australian continent of great antiquity. It coincides with the intersection, or meeting, of several ancient basin and geosynclinal trends. Several prominent crustal shear lineaments trend into the desert area from border regions, and these have exercised a decided influence in structural deformation from time to time throughout geological history. Crustal readjustments were facilitated by movement along the weaknesses.

1. *Archaean Structure Bordering the Simpson Desert*

The Westralian Shield attains the northern and western edge of the desert in the geomorphically depressed easterly extensions of the Musgrave and the MacDonnell Range mountain belts. In both cases the Archaean geanticlinal cores pitch gently eastwards with the result that Proterozoic, Cambrian and/or Ordovician sediments tend to nose around them.

The Musgrave mountain belt is one of greatest antiquity. It has provided a major source of sediments supplying surrounding relatively depressed areas during and since Upper Proterozoic times. Fold structures within this basement complex range from E.-W. to N.-S., but it is evident that the principal geomorphic control has been maintained by movements (vertical and/or horizontal) along major fault shear lineaments which confront the Mann and Musgrave Ranges along their southern margins for at least 300 miles. Near the W.A. border they are loci of ultrabasic intrusion and extrusion of the magnitude of a "Buschveldt Complex" (Sprigg and Wilson, 1959).

Despite the dominating east-west expression of the Musgrave mountain belt and parallelism of Proterozoic-Palaeozoic intra-cratonic basins, the fold-axial trends within the gneissic complexes lie in marked contrast in eastern outcrop area. At Mt. Tieyon, the folds preserve N.-S. trends, whereas near Umbearra the trend is N.E.-S.W. Further to the west, near Ernabella, isoclines are still aligned north-south.

The Arunta Complex near Alice Springs is, by contrast, a latitudinally aligned "raft" of ancient igneous-intruded metasediments that has only subsequently been extensively stripped of its Proterozoic and early Palaeozoic cover. (By comparison much of the Musgrave belt is a far more ancient geanticlinal zone, and has been the dominating source of sediments feeding into Central Australian basins). A major E.-W. crustal lineament confronts the MacDonnell Ranges in the south. This is a complicated fault and monoclinal fold zone, and a locus of a steep gravity gradient (Sprigg, 1961a).

As in the Musgrave Ranges, fold axes in more westerly areas trend east-westerly, but become irregular in the extreme east to the north of the Simpson Desert. (A comparable change is noticeable also in the Amadeus Palaeozoic fold pattern: see later.) The Arunta complex shelves gradually below the Simpson Desert.

South of Oodnadatta, Archaean complexes form inliers within the Great Artesian Basin principally as the Peake and Denison Ranges. Their positive geomorphic expression is again a consequence of uplift movement along a fault lineament (Sprigg, 1961a) or geosuture. Archaean structural trends in this area run broadly east-west. At one time the Upper Proterozoic sediments completely enveloped the presently exposed "raft" of basement rocks in this zone.

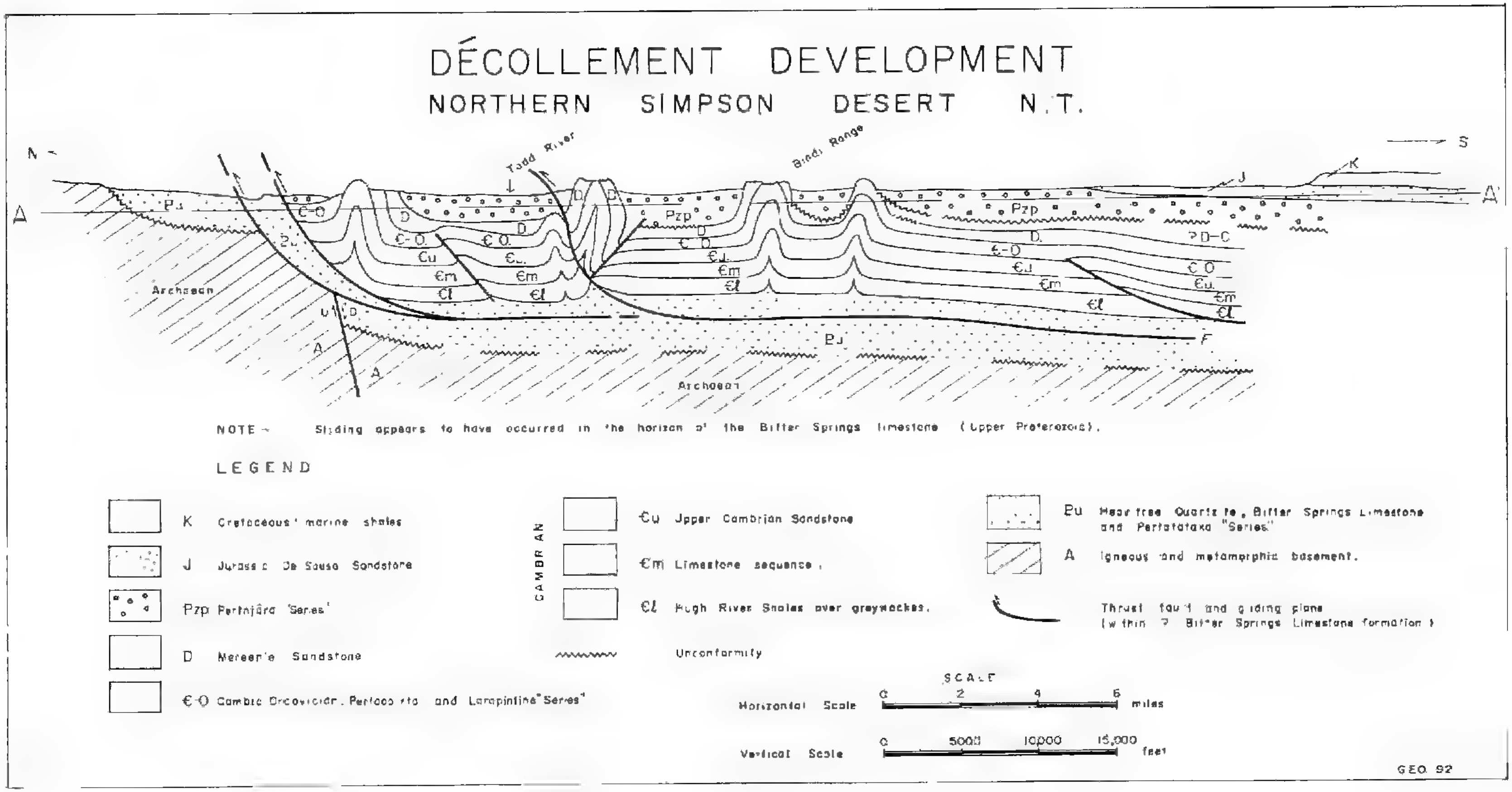
2. *Proterozoic to Palaeozoic Structure*

Elongate basinal belts that flank the Musgrave geanticline accumulated many thousands of feet of Upper Proterozoic, Cambrian, Ordovician and later sediments prior to extensive structural deformation. Cambrian sediments that could have been present in the southern or Officer Basin were extensively eroded and removed prior to Ordovician deposition. To the north, in the Amadeus Basin, by comparison the succession is practically complete, and still younger Palaeozoic sediments are extensively infolded with them.

The Upper Proterozoic to Ordovician section of the Amadeus Basin in the extreme north lacks marked internal unconformities, although gentle breaks are recognised near the top of the Cambrian. These became accentuated in the south in the approaches to the active Musgrave geanticlinal zone. (?)Devonian sandstones (Mereenie Sandstone) follow with little more than a disconformity break. The overlying Pertnjara formation, however, includes flysch-type sedimentary conglomerates that evidence marked instability at this time, principally in the newly developing MacDonnell geanticline along the northern side of the MacDonnell lineament. This was the first major Palaeozoic orogeny in this zone and developed across (E.W.) the trend of the main depositional belt. The large Missionary Plains syncline sagged to perhaps 20,000 feet or more in the MacDonnell frontal zone, further to accommodate the latest piedmont-like deposits. Possibly due to these superencumbent loadings the diapiric Mt. Gosse structure developed by salt, gypsum or mobile shale intrusion. Considered broadly, the older Palaeozoic structures in the Amadeus zone, west of the Alice Springs railway, display strongly east-west alignment, the individual fold axes trending N.N.W. in an *en echelon* arrangement. To the east, folding across N.-S. and E.-W. axes has introduced a centripetal tendency (basins and domes). This is the zone which lies north-west of the Simpson Desert, but the structure returns to more decidedly "east-west" in the low ranges immediately abutting the northern desert margins.

The latter folds are mostly of the "Jura-type", but sharp pinch-folding and tendencies to thrusting against the Arunta block, point also to block faulting and shear faulting in the basement. The nature of folding in the Amadeus Basin is still a matter for conjecture. Although the basin is relatively deeply sedimented, its sediments are well sorted, and are of platform type.

Rapid accumulation has occurred only in restricted zones that are related to localised uplift and erosional stripping. There is no evidence of volcanicity. Folds tend to be symmetrical and broad in many areas, but elsewhere the anticlines in particular appear to be sharp and separated by broad flat synclines. A measure of diapirism seems indicated in these latter instances. Fold axes may pass into faults along the crests. This is nowhere better illustrated than about the northern Simpson Desert (Fig. 5). It would appear that in these areas a measure of gliding along preferred layers has taken place by décollement formation. The energy for this gliding presumably would be gravitational and caused by uplift in zones of the north and/or south. The gliding undoubtedly has taken place low in the sedimentary section, possibly at about the level of the Bitter Springs limestone where interbedded saliferous formations are suspected. In typical cases the anticlines which have 60 to 90 degree limb-dips are separated by broad flat synclines. The anticlinal fold planes pass into high-angle thrusts.



DÉCOLLEMENT DEVELOPMENT
NORTHERN SIMPSON DESERT N.T.

NOTE – Sliding appears to have occurred in the horizon of the Bitter Springs limestone (Upper Proterozoic).

LEGEND

	K	Cretaceous marine shales
	J	Jurassic De Souza Sandstone
●	Pzp	Pertnjara 'Series'
	D	Mereenie Sandstone
	€-O	Cambro Ordovician, Pertaoorrta and Larapintine "Series"
CAMBRIAN	€u	Upper Cambrian Sandstone
CAMBRIAN	€m	Limestone sequence.
CAMBRIAN	€l	Hugh River Shales over greywackes.
		Unconformity
	Pu	Heavitree Quartzite, Bitter Springs Limestone and Pertatataka "Series"
▨	A	Igneous and metamorphic basement.
		Thrust fault and gliding plane (within ? Bitter Springs Limestone formation)

SCALE

Horizontal Scale 0 2 4 6 miles

Vertical Scale 0 5000 10,000 15,000 feet

GEO. 92

Fig. 5.

In the southern portions of the Amadeus Basin, repetition of the basal Proterozoic sandstones about the Western Australian border (Joklik, 1959) has been referred to as thrusting against the Musgrave mountain belt. They conform to a pattern of probable imbricate faulting. Comparable movements appear to have taken place in the Deep Well zone bordering the Simpson Desert, and in which case an upper- or epi-Cambrian age may be assigned to these movements.

In the immediate Simpson Desert border regions between Deep Well and Finke, the Cambrian is more strongly folded than the Ordovician, and has been extensively removed by pene-contemporaneous erosion before Ordovician deposition. Extensive unconformities, as a consequence, were developed on the Upper Proterozoic and Cambrian in this situation. This state of affairs extends into the eastern Officer Trough. In both regions the Proterozoic sequences ("Sturtian" to "Marinoan") were relatively steeply folded (40 to 80 degrees) in the Musgrave piedmont zone, prior to deposition of the thick Ordovician sands across well-developed erosion surfaces. The Ordovician also was subsequently folded, but the fold patterns appear to depart considerably from the earlier imprints in the region south of the Indulkina Ranges and Granite Downs. The Mt. John syncline in Ordovician sediments, for example, is 20 miles across, whereas the local Proterozoic exposed on either flank is tightly folded, exhibiting a number of fold axes in comparable widths.

The most easterly evidence of folding of the Proterozoic at the desert margin is observed in the Mt. Kingston Ranges (west of Finke). Here a resistant sandstone formation forms the north limb of a regional anticline. Dips of 60-70 degrees in the west flatten to 20 degrees in the east as the formation occupies the nose of a flat-pitching (5 degrees) anticline plunging beneath the desert at Horseshoe Bend. This rather sharp fold may be a décollement expression. Overlying Permian beds are unaffected by the folding.

Proterozoic sediments north-east of the desert are influenced strongly by basement faulting (principally striking N.W.-S.E. or N.N.W.-E.S.E.). Fold axes which are gentle approximate these directions.

In the Peake and Dension Ranges the rather broad folding of the exposed Upper Proterozoic sediments display N.N.W. trending axes, aligned sympathetically with and in genetic relation to the N.N.W. lineament on the eastern margin of the Ranges.

The pattern of Palaeozoic folding beneath the desert is known indirectly in the north-west. Just over 100 line miles of discontinuous seismic reflection traversing has been completed in the Mt. Dare-Andado-Camel Flat area in Northern Territory, and an incomplete traverse has been carried across the northern end of Lake Eyre where the sediments are probably shallower. Reconnaissance gravity surveys have been completed in these same areas, and airborne magnetometer surveys have subsequently covered most of the desert area in S.A. and N.T. The results of these surveys remain the property of private oil exploration companies for the present, but some general information has been released.

Airborne magnetometer surveys carried out on behalf of Delhi Australian Petroleum Company suggest deep magnetic basement in the south-eastern portion of the desert (ten to fifteen thousand feet), and the trend is continuing into Northern Territory east of the Finke.

In the Andado area (N.T.) gravity surveys (Denton and Sprigg, 1962) indicate medium low gradients for much of the area (0·5 to 1 milligal per mile or less) except in the New Crown and Malcolms Bore vicinities, where steeper gradients and more complex patterns reflect shallowing bedrock. Reconnaissance seismic traverses in this region confirm the indication of deeper basement underlying Andado and extending to the S.A.-N.T. border. A shallowing of bedrock towards Malcolms bore (region of lat. 25°00' and long. 123°30') is also evident. Eight to twelve thousand feet of sediments are indicated in the Andado zone, but depths appear to be less near Malcolms bore. This appreciation of rather flat-lying and moderately deep section (5,000-10,000 feet plus) carries into the more northern limits of the desert (by courtesy of Flamingo Petroleum Co. Ltd.) where broader sections of only gently undulating sedimentary succession occupy the flats between the sharp anticlines that protrude abruptly along the general desert area in the region of Camel Flat.

The impression, now fortified, is that the Proterozoic-Palaeozoic section shelves gently southwardly off the Arunta divide (dips of only a few degrees near the Hale headwaters), but that gliding of the main mass of the section has resulted in development of Jura-type (and/or diapiric) anticlines at intervals where the succession passes beneath the desert. A series of re-opened N.W.-S.E. faults have complicated the pattern somewhat but may have also initiated or assisted décollement development.

To recapitulate: the Palaeozoic era witnessed several somewhat localised episodes of orogenic deformation. Erosional truncation of deformed pre-Ordovician strata in the eastern foothill regions of the Musgrave mountain belt indicates diastrophism associated with uplift in those regions. The Ordovician appears to have been an interval of broader stability with the evolution of great sandy platforms. Late in Ordovician times diastrophism developed the MacDonnell Ranges as a regional platform uplifted in the north, and which was accompanied locally by piedmont (flysch-type) sedimentation into deepening synclines to the south. A measure of décollement formation may have occurred at this time or subsequently by gravitationally induced gliding. The principal deformation of the Amadeus geosyncline appears not to have occurred before Middle Palaeozoic times. Dating of this episode remains uncertain, but may be epi-Devonian. Post-Ordovician orogeny in the Officer Trough lying south of the Musgraves superimposed a new degree of folding over the (?)epi-Cambrian developments also in this region. Folding in the two deep sedimentary basins developed on either side of the Musgraves was not necessarily contemporaneous, nor was that of the northern and southern portions of the Amadeus Basin.

3. *Permian-Mesozoic Structure*

Permian and Cretaceous sediments outcropping in and about the Simpson Desert, everywhere are flat-lying, or they dip at low angles. Permian strata extend beyond the Cretaceous cover principally to the north and north-west. Dips are predominantly regional and gently desert or basin-ward.

Cretaceous strata outcrop practically continuously along the Simpson Desert margin. Dips are gently basin-ward for the most part and define a sub-basin (200 wide by 400 miles long) within the Great Artesian Basin as a whole. Stratal dips in outcrop west of the Georgina are directed gently westward so that the Cretaceous shales disappear beneath alluvial cover, not to re-appear until beyond the desert segment of the Finke River almost 300 miles to the west.

Warping and folding within the Cretaceous is apparent principally from bore data (Jack, 1930) and from the deposition of Tertiary "duricrusted" (silcrete or fossil soil) surfaces upon them (Sprigg, 1958). These ancient surfaces clearly have been deformed, and have developed gentle, but undoubted fold patterns along zones of pre-existing folding and/or along lines of reactivated crustal lineamental faulting. The silicified surfaces are not stratigraphic in a depositional sense, but are mappable surfaces of flat unconformity. East of the Simpson the surface is developed on Winton shales; to the west it passes from Tambo down onto Roma, and eventually onto the Permian and older beds.

The distribution of the surface indicates that basining, coincident with the Simpson Desert depression, has continued during the late Tertiary. Uplift and concomitant erosion has occurred about the margins, particularly on the west. Deposition of the erosional products has transferred centrally into the desert region.

Structural deformation climaxed during the early mid-Tertiary period, when gentle arching and folding developed groups of low, arch-like anticlines along either margin of the principal desert depression. The western group represents in part the northern extension of the Peake and Denison Ranges in the direction of the circular Mt. Alice. These structures appear to be in the nature of buried anticlines that are "baldheaded" at the Palaeozoic or older interface. At Oodnadatta, core-rocks of steeply dipping (?)Palaeozoic sandstones were encountered at 1,380 feet, immediately below the Mesozoic. This lines up generally with the projected Denison Range fault lineament.

A secondary structural trend diverges more or less due northerly from the nor'-nor'-westerly Dennison line. This incorporates the Mt. John and Dalhousie structures. Limb dips at the surface average 1 to 3 or 4 degrees; numerous artesian water mound springs escape at the culmination of the Dalhousie domal structure. This latter broad "arch" also diverts the Finke River into the margining Simpson Desert, and is responsible for the sharp elbow in the course of the Finke at the N.T.-S.A. border. To the north and east the "silcrete" surface developed on the Cretaceous plunges gently below the desert level.

To the north, repetitive upwarping in Cretaceous shales has developed the low-lying Andado "ridge", from which the silcrete layer has been extensively stripped. To the south-east of this ridge the duricrust dips gently basin-ward in a curving line of low cuestas. Remnant mesas preserved by silcrete form a secondary line of hills still further to the west (Rumbalara). To the east the silcrete is last seen in the desert at Geosurveys Hill 90 miles due west of Andado where it is gently south dipping.

Thirty miles north of Andado the full Cretaceous section is only 600 feet thick (Malcolms Bore). At Yardhole Bore, 12 miles west of Andado, the Cretaceous shales are probably thicker than 1,000 feet, whereas on the Rumbalara ridge still further to the west the shales are preserved merely as cappings on mesas. A broad syncline may be present between Andado and Rumbalara, but seismic evidence indicates a general regional dip south-easterly beneath the desert (Denton and Sprigg, 1962).

The Peake and Denison Ranges possess marked fault escarpments along their east borders, and these faults have been re-opened during Mesozoic and Tertiary times. This is evidenced by stratal drag and escarpment formation. Horizontal and/or vertical movements along such faults buried beneath the Mesozoic cover would readily develop *en echelon* and/or monoclinal folds in the latter.

Along the latter projected strike the Mt. Alice structure appears to be plug-like in that Cretaceous dips radially away from a (?)Permian core. Otherwise the nature of the structure is not known.

It is not improbable that gentle fold warping in the Andado area trends to centripetal development as this overlies the intersection of two older folding tendencies (viz. post-Cretaceous superimposed on Palaeozoic).

East of the southern Simpson Desert the silcrete again displays upwarping over the Kopperamanna-Gason Arch. Dips in the sector are all low (1 to 3 degrees).

4. *Late Cainozoic Warping*

Crustal sagging in the zone of the elongated Simpson Desert continued into late Cainozoic and modern times. In the extreme south (Lake Eyre) zone, tilting has brought the desert to below sea-level with the development of great playa lakes lacking drainage outlets. Rivers entering these depressed areas form part of a highly asymmetric drainage net. Lake Eyre extends 40 feet below sea-level, and is itself still tilting to the south where flood waters now concentrate.

Locally intensified sinking near Poeppels Corner (S.E. Northern Territory) is suspected. Anomalous creek patterns are obvious in this zone. The Diamentina and deserted segments deflect strongly N.W. towards this depression before deflecting back finally into Lake Eyre.

HYDRODYNAMICS

Investigation of the hydrodynamics of the principal reservoir formations within the Simpson Desert sub-basin of the Great Artesian Basin will undoubtedly have increasingly important bearing on the search for commercial oil.

R. L. Jack (1930) and F. W. Whitehouse (1954) and others have previously demonstrated the south-westerly and westerly flow of artesian waters within the principal Mesozoic aquifers of the Great Artesian Basin. Jack was also able to show that the two principal generations of these waters, namely, the carbonate waters from the intake areas in Queensland and New South Wales, and the sulphate waters from the western basin margin, in central South Australia and Northern Territory actually mixed somewhere in the Lake Eyre line of depression.

Jack and others also summarised data concerning the highly saline waters (at times brines) in the Cretaceous marine shale sections. These were believed to be extensively "connate" waters, but concentrations of the order of brines presumably indicate a large degree of stagnation within the sands concerned or the retention and filtering by semi-permeable formation "membranes". Many of the sands are thin and lenticular.

Jack and Whitehouse both noted escape outlets in the form of mound springs about the southern and western basin margins. The outlets always occur in low-lying areas, and mostly within 200 feet or so of sea level, and extend to 40 or more feet below sea-level on Lake Eyre. Attention was drawn by Jack to the fact that many of the outlets are now extinct, and that the older mounds are generally considerably more elevated than those now functioning.

The whole problem of investigation of artesian waters is now complicated by the development of more than 5,000 flowing or subartesian bores principally within Queensland and northern N.S.W. These have greatly lowered and modified the principal hydraulic surface and reduced artesian flows. Pressure head data in new drilling situations, consequently is hard to relate to the earlier defined and/or predicted hydraulic surfaces. In the Simpson Desert area of present interest, few bores are available for reference, and a central area of about 40,000 square miles is devoid of bores of any description.

In that the Simpson Desert is a zone of continuing sinking, it is not improbable that a pressure "sink" has developed in this zone, and as such is a potential trap for hydrocarbons, even though the area is presumed to be broadly synclinal.

In this respect the observation of minor amounts of hydrocarbon gases emitted along with artesian water flows in many of the bores along the Maree-Birdsville track, and east into Queensland, becomes significant when it is recognised that no such escaping gases are observed at the mound spring outlets in the direction of dominating westerly flow. The most probable explanation seems to be that hydrocarbons are being retained and concentrated in presumed low pressure and synclinal areas coincident with the central Lake Eyre-Simpson Desert depression. Investigation of this phenomena can be pursued only if all possible water-bearing horizons in new bore holes are accurately gauged for fluid pressures and salinity.

Recent investigations, particularly in the United States, demonstrate that single bore holes, if accurately gauged at all reservoir fluid-bearing levels, can provide invaluable leads for the prediction of hydrocarbon concentrations. "Subgradient" pressure-differences in depth, and in particular pressure-reversals, have great significance where fluids are traversing semi-permeable barriers. These aids must be applied increasingly to the investigation of the Great Artesian Basin, and particularly in relation to deeper formations, and in the search for hydrodynamic and combination traps.

In the Simpson Desert. the non-escape of detectable hydrocarbons via marginal mound springs lying in the direction of flow provides valuable leads to possible hydrocarbon accumulation in the central desert depression that must be pursued seriously.

GEOPHYSICAL EVIDENCE

Gravity and seismic surveys of the Andado area carried out by Geosurveys of Australia Limited in 1960-1961 were the first serious geophysical exploration carried out in the Simpson Desert. Associated Freney Oilfields N.L. undertook helicopter gravity surveys in early 1961 in the extreme south-east corner of Northern Territory, and seismic surveys by Flamingo Petroleum Co. Ltd. were completed to the north of Andado late in 1961. In northern South Australia the Mines Department has partially completed a reconnaissance seismic line from Oodnadatta across the north of Lake Eyre to Cowarie to link with previous reconnaissance surveys along the Bedourie-Birdsville-Maree Track. Delhi Australian Petroleum Co. Ltd. have completed several phases of a comprehensive airborne magnetometer survey of the central Great Artesian Basin across to Lake Eyre in South Australia, extending into Queensland. This work is being extended westward via South Australia almost to the foot of the Musgrave Ranges. The private company surveys have all been subsidised by the Commonwealth Government.

At the present time little of the basic geophysical data is yet available in reduced form. Gravity Bouger anomaly plans by Geoseismic (Australia) Ltd. have been prepared for the Andado area and also reflection seismic sections. The gravity data indicates sedimentary depths of the order of 10,000 or more feet and this is also borne out by the results of the seismic reflection surveys.

North-east of Andado station a well-developed "positive" gravity Bouger anomaly has been defined, suggesting a shallowing bedrock in this vicinity. Preliminary seismic investigations indicate that this is the case, and that sediments plunge steeply to the south and to the south-east.

In the direction of New Crown Homestead (viz. south-west) increasing Bouger gravity values and narrower anomalies confirm shallowing (rising) bedrock in this direction.

OIL AND GAS PROSPECTS

Several alleged oil seepages have been reported within the Simpson Desert. One was reported downstream along the Finke River from Finke siding, another in the Hay or Mulligan River near the Queensland-Northern Territory border, and a third in the canegrass "Mickri" country near the north-west corner of Lake Eyre. All were brought to the attention of white men by nomadic aborigines earlier in the century. None have been positively identified as the localities are all relatively inaccessible and difficult to pin-point.

If any credence can be given to these reports, principal interest is in that the locations all are about the edge of the Great Artesian Basin where escape of fluids under pressure could be reasonably expected.

A. POTENTIAL PETROLEUM SOURCE-BEDS AND RESERVOIR STORAGE POTENTIAL

Source-beds for petroleum in the Simpson Desert environment are predicted to occur in the Cambro-Ordovician and Cretaceous and possibly also in Devonian and Permian. The Upper Proterozoic Bitter Springs Limestones are potentially petroliferous and the possibility will only be mentioned here. The zone of ancient crustal sag that now constitutes the Simpson Desert is expected to have been more prone to marine invasion than may appear from marginal sedimentary outcrops. Such tendencies to marineness within the Permian in Central Australia have only recently been recorded from drill cores examined by the Mines Department in South Australia from the Lake Phillipson-Anna Creek area, and more recently in the Delhi-Santos Dullingari No. 1 Well on the S.A.-N.S.W. border.

1. *Cambrian*

Cambrian sediments, gently to moderately strongly folded, but quite unmetamorphosed, are widely distributed throughout the Amadeus Basin extending through to the Simpson Desert margin. In the nearby Georgina Basin they are flatter-lying, possibly thicker, and containing rather more marine organic matter.

Cambrian seas in Australia enveloped the continent more extensively than during any other interval in geological history. The seas were shallow, epeiric, warm and favourable to rich organic life. Extensive thicknesses of sediments were deposited in some areas (e.g. 15,000 + feet near Wirrealpa in the Flinders Ranges of South Australia; Mawson, 1939). Early Cambrian seas followed still earlier Upper Proterozoic marine trends in many areas that had developed great sand platforms (the "Pound" formation and its equivalents). Cambrian biohermal limestone accumulations of the primitive sponge-like *Archaeocyatha* simulated coral reefs and meadows, and south of the Simpson Desert (in the Flinders Ranges) limestones of this association attained 3,000 feet in thickness over areas of several thousand square miles. North-west of the desert *Archaeocyatha* limestone accumulations were considerably thinner (Pritchard and Quinlan, 1959).

Limestones that developed higher in the Cambrian sequences were mostly still richer in organic matter. Black foetid limestones which provide bituminous chemical reactions are particularly prevalent in Middle and Upper

Cambrian of the Amadeus and Georgina Basins. Limestone facies generally increase to the east.

Both the Lower and Middle Cambrian in the central longitudinal belt extending through South Australia and Northern Territory have produced showings of oil and/or petroliferous gas in the few deeper bores that have been drilled into them. At Wilkatana (Lake Torrens Basin, South Australia) ozokerites and paraffinic oils were encountered by Santos Ltd. in drilling dolomitised and porous Lower Cambrian *Archaeocyatha* limestone (Sprigg, 1959). At Minlaton (Yorke Peninsula, S.A.) the Mines Department drilled the comparable horizons with the discovery of oil and gas traces (Johnson, 1960). At Wirrealpa (Mawson and Dalwitz, 1939) acidised free oil from *Redlichia* (Middle Cambrian) limestones. In a water bore on Ammaroo Station in the south-western Georgina Basin, Middle Cambrian limestones produced small amounts of petroliferous gas (MacKay and Jones, 1956), and, allegedly, also traces of free oil from Middle Cambrian limestones.

Cambrian sediments are undoubtedly rich in organic proto-bituminous organic matter in Central Australia. In view of their widespread development about the Simpson Desert, and the considerable thicknesses known to be present, these sediments must rank prominently for petroleum potential.

Reservoir developments within the Cambrian are likely to take the form of dolomitised zones within limestones; porous clear white sands are extensively developed at some higher horizons.

2. *Ordovician*

Ordovician sediments are widely distributed beyond the north-western margin of the Simpson Desert and particularly in the southern Georgina Basin to the north and north-east across the upwarped basement divide. They are also well developed north and south of the Musgrave Ranges striking into the desert. They are not known in outcrop in Central Australia south of about the latitude of Oodnadatta.

Ordovician sediments in the Amadeus Basin tend to be finer-grained and more calcareous to the east, but westward grade into extremely thick and widespread sands. Sand development also dominate the known section in the Officer Basin and the upper section of Georgina sequence in the more south-easterly areas.

Finer-grained Ordovician sediments are mostly dark coloured, organic limestones, dolomitic limestones and shaley limestones. The beds are fossiliferous and they are frequently rich in organic material; as such they constitute promising source-beds for hydrocarbons. Thicknesses of several thousands of feet of these sediments are developed in the Georgina and eastern Amadeus Basins, and if present beneath the Simpson Desert would constitute excellent source material for the generation of petroleum.

In the Queensland area (Boulia) investigations by the Bureau of Mineral Resources have revealed Ordovician limestones to be bituminous through considerable thicknesses and these strata plunge beneath the Great Artesian Basin along the eastern margins of the Simpson Desert.

The great platform sands that make up most of the sedimentary section in the central Amadeus Basin and also in the outcropping portion of the Officer Basin appear to offer ideal storage potential for hydrocarbons. The (?)*Scolithes* (pipe rock) sandstones of the Waterhouse Ranges (south-east of Alice Springs, N.T.) and also about Mt. John (near Granite Downs, S.A.) similarly tend to be locally highly permeable. Sandstone developments in the Upper Ordovician of the Toko Ranges likewise offer promising reservoir storage potential. Superposition of these more easterly sands over thick and richly organic Cambro-Ordovician limestones and shale developments would appear ideal for the accumulation of petroleum if and where these beds are suitably capped. This may be the case beneath the Great Artesian Basin in the zone of the Simpson Desert.

3. *Upper Palaeozoic*

No Upper Palaeozoic marine deposits have been located in the immediate Simpson Desert environment. Considerable thicknesses of Devonian fresh water beds have recently been mapped immediately north-west of the desert, and also in the southern Georgina. Permian fresh water beds about the northern desert margin are also known to be widespread (Smith *et al.*, 1960, 1961).

Following the discovery of traces of foraminifera in the Lake Phillipson Bore by Mr. J. Harrison of Delhi Australian Petroleum Ltd., systematic work by Ludbrook (1961) on this and several other bores has established the presence of marine Permian in the area west and south of the Peake and Denison Ranges. This is the first record of marine Permian in Central Australia.

It is now reasonable to predict that marine Permian may be present in some zones beneath the the central Simpson Desert. The reported occurrence of a thick grey shale section below pollen-bearing, fresh-water sands of Lower Permian (Artinskian) age in Malcolms Bore, 30 miles north-east of Andado homestead, is promising in these regards. There is good reason to believe that these will pass below into Sakmarian marine developments.

Similar predictions of facies changes from continental into open marine conditions are equally permissible in relation to Devonian deposition that certainly has extension into the northern Simpson Desert.

With the possible exception of the above-mentioned shales in Malcolms Bore, sediments of Upper Palaeozoic age outcropping about the Simpson Desert margins are predominantly siliceous, porous sands. They appear to be excellent reservoir media for accumulation of hydrocarbons migrating across underlying unconformities, or up-dip from marine source beds which occur in lateral continuity beneath the desert.

4. *Lower Mesozoic*

Trias-Jura sediments may well extend beneath much of the Simpson Desert below the marine Cretaceous (Roma-Tambo) shale formation. Nowhere have they yet been intersected in drilling for artesian water, for practically all successful water bores are completed within the highly permeable (?)Blythesdale (Lower Cretaceous) water sands. Trias-Jura sands do not appear to extend far beyond the Cretaceous limits as occurs in eastern Australia. There has been progressive westerly tilting of the basin during deposition. Younger sediments tend to overlap more extensively to the west. Trias-Jura sands do, however, extend onto bedrock to the north near Tarlton Downs and possibly also Rumbalara (north-west).

5. *Cretaceous*

Cretaceous seas occupied most of the Simpson Desert area. Roma-Tambo (Aptian-Albian) shales and minor limestones in the better known westerly areas were completely marine and/or estuarine. Locally they are highly fossiliferous (Oodnadatta Bore; Ludbrook, 1959). They are fine-grained deposits of shallow epeiric seas. There is scope for considerable thicknesses of these sediments beneath the central sag of the desert, and, as this sub-basin may have been variously cut off from time to time during the Cretaceous, a variety of marine depositional environments can be postulated. Where shaley and organic marine sediments are buried deeper than about 2,000 feet they must constitute potential source beds for petroleum.

Sands within the Roma-Tambo are usually thin and lenticular and as such are not particularly attractive as reservoirs for commercial oil or gas. These sands commonly carry strong brine concentrations suggesting restricted circulation or osmotic filtering via semi-permeable barriers, a condition presumed to be favourable to oil accumulation in hydrodynamic traps. In the Oodnadatta region the sediments have produced showings of oil (fluorescence in cores).

Sand beds are more prevalent towards the base of the Roma Formation, and eventually dominate in the underlying Blythesdale Formation. These latter constitute the major artesian aquifer over much of the Great Artesian Basin.

Oil and gas showings are not infrequently encountered within the uppermost transition members of the Blythesdale Formation. Traces of petroliferous gas accompany flowing bore water tapped on the Mt. Gason and other structures along the eastern margin of the desert (north-east of Lake Eyre).

A geologist of Delhi Australian Petroleum Ltd. has drawn attention to the prominent "fish scale" horizon near the Aptian-Albian boundary in Oodnadatta well (see also Ludbrook, 1959), which in the Mornington Island drill holes (1961) far to the north-east revealed traces of hydrocarbons and may be worth investigating in this region.

B. THE POTENTIAL FOR STRUCTURAL AND STRATIGRAPHIC TRAPS

Cambro-Ordovician sediments outcropping about the north-western Simpson Desert margins are moderately to strongly folded along localised zones and are also faulted. These tendencies almost certainly continue beneath the desert.

(?)Devonian sediments at the north-west edge of the desert evidence comparable deformation, being infolded with the Cambro-Ordovician.

Permian sediments appear to post-date the principal fold cycles that have deformed earlier strata. The sediments lie flatly but dip desertward. Principally, they will have been affected by the gentle fold-warp movements that have also deformed the Cretaceous. Gently-warped, deep, sediments that also enclose internal unconformities are indicated seismically to be present below Andado. They provide scope for Permian developments suitably deformed to produce structural traps for oil.

Cretaceous sediments are gently deformed along certain well-defined zones about either desert margin. The fold structures appear to be quite attractive to oil exploration and the thick shale developments form ideal "cap rock" to deeper reservoirs. On the west, the Mt. John and Dalhousie anticlinal upwarps appear to be "closed" domally in outcrop, although the former is breached by mound springs. The Mt. Gason anticlinal warp along the south-east desert margin is punctured by several water bores (3,500-4,000 feet deep) which also bleed small amounts of petroliferous gas from the Lower Cretaceous artesian water-bearing sands.

The Andado region is viewed favourably in the structural sense as occupying the zone of intersection of the older Palaeozoic E.-W. fold trends with the foregoing younger Cretaceous-Tertiary N.-S. trends.

The western Artesian Basin is a region of Cretaceous overlap from the east. Cretaceous shales consequently blanket earlier (?)Mesozoic and Palaeozoic development progressively and there is marked tendency to stratigraphic wedging and/or erosional truncation to westward.

CONCLUSIONS

The Simpson Desert is an ancient "negative" geomorphic structural element of the Australian continent. It is a continuing repository of sediments and an area where deep sedimentary sections are postulated, much of them likely to be more marine than in areas marginal to the Basin.

Petroleum source-bed potential is predicted particularly within the marine Cambrian, Ordovician and Cretaceous, but may well hold for Devonian and Permian developments in the structurally more "negative" reaches of the desert basin which are likely also to be more "marine".

Potential reservoir beds are expected to be widespread in depth. Structural deformation and stratigraphic variation is likely to provide a wide range of traps for hydrocarbon accumulations.

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Warm appreciation is expressed to geologists R. O. Brunnschweiler, M. Audley-Charles, J. Johnson and H. Wopfner of Geosurveys of Australia Limited who carried out much of the more detailed geological exploration on behalf of Geosurveys of Australia Limited and Santos Ltd. in the western Simpson Desert marginal areas. Geophysicists, E. R. Denton, R. G. Dennison and F. de Castillejo of Geoseismic (Australia) Limited, supervised seismic and gravity geophysical operations and interpreted data.

The Northern Territory Department of Mines staff have assisted wholeheartedly in supplying water-bore drilling data, and Mr. C. Pritchard has been particularly helpful in discussing Amadeus Basin stratigraphy.

The Bureau of Mineral Resources have at all times made the results of their extensive "4-mile" mapping programme freely available, and the preliminary reports of Mr. K. G. Smith's parties have been an invaluable assistance to regional investigations. The work of C. E. Pritchard and T. Quinlan in the Amadeus area have been particularly helpful.

The Commonwealth Government, in supplying generous aid by way of subsidy for geophysical operations carried out by Geosurveys of Australia Limited in the Andado vicinity, and by Flamingo Petroleum Co. Ltd. to the north, are currently greatly aiding the preliminary investigations of the Simpson Desert potential for oil.

The results of geological mapping published by the South Australian Department of Mines in the Peake and Denison Ranges has been of great assistance, as have also been the preliminary reports of the Bureau of Mineral Resources describing the geology of the Hay River and other 4-mile areas in the extreme north.

K. E. Balme, Palaeobotanist of the University of Western Australia, and N. H. Ludbrook, Palaeontologist of the South Australian Mines Department, have assisted by examining bore samples collected from Andado Station.

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COASTAL BITUMEN IN SOUTHERN AUSTRALIA, WITH SPECIAL REFERENCE TO OBSERVATIONS AT GELTWOOD BEACH, SOUTH-EAST SOUTH AUSTRALIA

BY R. C. SPRIGG AND J. B. WOOLLEY

Summary

"Coastal bitumen" is stranded annually at a number of well-known centres along the southern Australian coast. This mostly accompanies and follows winter storm activity, but lesser standing may continue at intervals throughout the year. These natural bitumens mostly originate in shallow ocean coastal waters within reach of storm wave turbulence and/or near shore rip-current activity. The weathered crudes which constitute coastal bitumen, upon stranding appear to include both naphthene and paraffin-based oils of low A.P.I. gravity and moderately high sulphur. They are inspissated and varyingly weathered. They include ozokerites. Associated light chocolate-brown coloured and highly oxidised crudes also come ashore from time to time in these localities. It is thought to be eroding from flat-lying sea floor fossil seepage deposits that way have been subaerially exposed during the low sea-level periods of the Pleistocene. Care must be exercised to separate these crudes from tanker spillage which is a more recent complication. The crudes of interest are locally derived. Evidence is cited to demonstrate that the oils, which strand during storms, are not far-travelled, nor are they the products of ocean-going tankers. The crudes have certainly not originated in the vicinity of Antarctica or South America as has previously been widely claimed. Association with localised storms which stir up the immediate subcoastal shallow sea-bottom, and alternatively, with recorded earthquakes epicentred in the sea near Beachport, is considered to demonstrate local origin quite conclusively. Although superficially, the stranded crudes look almost identical, spectrographic investigation of the minor element constitution of a series of samples has indicated that the crudes from the Geltwood area are distinctively different from those from Sleaford Bay (Eyre Peninsula) or from Cape Northumberland. More data, however, is required. Geltwood Beach, approximately 20 miles south of Beachport, South Australia, has long been recognised by local residents as a favoured site for the stranding of coastal bitumen. The locality is now being closely investigated and seepage activity was extensively investigated and documented during much of 1961. The crude oil is believed to seep via deep-seated faults from marine Tertiary and Cretaceous sediments wedging in from the Continental Shelf. Evidence indicates that the more pronounced seepage occurs following the active erosion of submarine outcrops of bituminous material which seals fault fissures, or by superficial breaching of diapiric bituminous plugs and/or other seafloor deposits. Temporarily greatly increased stranding of bitumen after the recorded Beachport submarine earthquakes of 1898, 1915 and 1948, accords with the theory of invasion of the crude oil along fault planes, or via fractured anticlinal structures. A major fault or monoclinal (Beachport-Kalangadoo) hingeline trending W.N.W. trends out to sea beyond Beachport in the direction of the earthquake epicentres of 1898 and 1948, which were estimated to lie 10 miles N.W. of that town. Several other related fault lines cut the coast in this vicinity. The Gambier sub-basin which is co-extensive with the continental shelf in this region, is one of deep Tertiary and Mesozoic sedimentary deposition.

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Temporarily greatly increased stranding of bitumen after the recorded Beachport submarine earthquakes of 1898, 1915 and 1948, accords with the theory of invasion of the crude oil along fault planes, or via fractured anticlinal structures. A major fault or monoclinal (Beachport-Kalangadoo) hinge-line trending W.N.W. trends out to sea beyond Beachport in the direction of the earthquake epicentres of 1898 and 1948, which were estimated to lie 10 miles N.W. of that town. Several other related fault lines cut the coast in this vicinity.

The Gambier sub-basin which is co-extensive with the continental shelf in this region, is one of deep Tertiary and Mesozoic sedimentary deposition.

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Much of the sedimentation is marine. Petroliferous (gas) accumulations have recently been demonstrated in more easterly extensions of the basin. Similar sediments probably make up much of the wide continental shelves of the southern Australian coast. It is concluded that these may constitute one of the great "Tarbelts" of the world.

INTRODUCTION

The frequent stranding of crude bitumen and ozokerite along the southern coasts of Australia from Southwest Cape in Tasmania and Lorne in Victoria in the east, across to Fremantle in the extreme west has raised and maintained a long-standing controversy amongst Australian geologists.

Bitumen in lumps, blocks and sheets, mostly sticky with heavy crude oil, has been reported from high tide level on open sandy beaches and from rocky headlands, almost since the white man first arrived in southern Australia. The first published record was in 1869 in Victoria.

Fishermen, farmers and other local residents have frequently reported discoveries of fresh coastal bitumen and forwarded samples to Government agencies for determination. Surprisingly little serious scientific investigation of these phenomena has resulted.

From time to time local interest has been excited to the extent that locations for drilling have been proposed; in a few instances shallow drilling has been carried out.

Most of these local observers became convinced that there was an oil seepage nearby, and not infrequently fishermen have declared positively that they had seen oil "erupting" a short distance off-shore; while others asserted that they had seen it "oozing" from the base of sea cliffs.

For instance, Mr. T. W. V. Bates, of Penneshaw, Kangaroo Island, wrote in the Adelaide "Advertiser" (March, 1961) as follows:

> "It is a well known fact, that in the early days of Kangaroo Island, a family by the name of Thomas, and several other old pioneers, who lived at Antechamber Bay, made yearly pilgrimage by boat to a small beach at the mouth of what is now known as Hog Bay River. Here they would collect lumps of bitumen that were strewn along the beach. This was melted down, and the boats given several coats of this tarry substance, which made them quite watertight. I remember Mrs. Seymour, who was a daughter of Mr. Nat Thomas, telling me that the thick, oily substance used to bubble up from the sea bed from a depth of several feet. On calm days, this substance used to form lumps on top of the water; and when the weather became rough these would break away, and be cast up on the beach."

Where official investigators subsequently visited various of the alleged seepages further reliable evidence was rarely forthcoming; the discoverer expressed the view that the seepages were temporarily inactive, and the visitors were left to ponder the situation, to theorise, and generally to caution against drilling without further evidence. No effort was made systematically to observe these areas continuously and over a period of time, and to document the phenomena scientifically. Too often visits were made during fine weather, and for reasons which will be appreciated later, much compelling evidence was never gathered.

A. *Coastal Bitumen Localities*

Coastal bitumen has been reported very widely along the southern Australian coast (Fig. 1). Some of the earliest reports came from near Nelson (Victoria); from the west coast of Tasmania and King Island; from Cape Leeuwin (Western Australia), from Neptune Island; and from Hog Bay on Kangaroo Island (South Australia).

The known examples are listed as follows:

Tasmania:

West Coast: From Cape Sorell to Point Hibbs prolific stranding was observed in 1913; also New River to S.E. Cape.

East Coast: King Island; officially recorded near Pass River mouth (1929); frequent strandings are believed to continue to the present day.

Victoria:

Otway Peninsula: Lorne and Cape Otway, various reportings.

Portland Vicinity: Cape Nelson and Cape Bridgewater: frequent stranding of bitumen on the headlands. Reported seaward "eruptions" together with big artesian water flows approximately two miles S.S.E. of Cape Nelson.

Nelson Vicinity: Mt. Richmond, Swan Lake, etc. (E. of Nelson); Glenelg River (upstream from Nelson). In 1908 a spectacular "eruption" was reported in this river.

South Australia:

Extreme South-east Province: Haines Landing seepage (on Glenelg River, 4 miles upstream from Nelson) considered probably authentic by F. Reeves, and 2 miles upstream from that reported in 1908 at Nelson. Cape Banks and Cape Douglas (near Pt. MacDonnell) frequent reportings, including 1960 and 1961. Carpenters Rocks and Pelican Point: almost annual occurrence reported by old identities; certainly operative in 1961. Principal activity reported to have stopped following the 1898 Beachport earthquake, resumed again after that of 1915, and greatly increased temporarily after that of 1948.

Beachport Vicinity: Devils Gap (south-west of Millicent) northwards via Geltwood Beach to South End, semi-continuous activity throughout the year, with principal activity during storms. Greatly heightened stranding of crude immediately following the Beachport earthquakes of 1898, 1915 and 1948.

Encounter Bay: Port Elliot (1920, 1962) and Victor Harbor (1920).

Kangaroo Island: Hog Bay, 1½ miles to west of Hog Bay River mouth: in earlier days local fishermen made annual visits to waterproof their boats, infrequent strandings still recorded. Also Penneshaw, Nobby Island: West Bay; Middle River.

Yorke Peninsula: Stenhouse Bay (recently sampled by Mines Department; Pt. Vincent (2 miles north of). Cape Spencer (1961).

Eyre Peninsula and Adjacent Islands: Neptune Island several reportings this century; Mt. Greenley (1873, 1926, 1961). Coffin Bay and Sleaford Bay (1961, and probably annually since earliest occupation).

Western Australia:

Cape Leeuwin: Mandurah (Fremantle): Bunbury, Cheyenne Beach (1929, 1941).

B. *The Nature of the Material Investigated*

The material is most commonly a brown-black bitumen, varying in consistency from a soft, viscous or pasty semi-solid, to a brittle solid with conchoidal fracture. The S.G. of different samples has been recorded (L. K. Ward, 1913, Bulletin No. 2, Geological Survey of South Australia) as ranging from 1·0041 for the softer, pasty specimens, to values between 1·075 for the harder specimens. The softer specimens may give off a volatile substance, smelling like gasoline. A piece of medium density was distilled and yielded 0·6 per cent. of a kerosene product and 11·7 per cent. of an oil of the consistency of kerosene. The analyses suggests that the material was a mixture of bitumen and heavy oil that had been extensively weathered.

As seen by the writers on Geltwood Beach (south of Beachport, South Australia) the fresh material strands in several forms. The most spectacular is brownish-black lumpy crude bitumen usually rolled and somewhat incorporated with beach sand on the outer surface. This waxy bitumen when broken open contains "pockets" of liquid oil and may ooze sea water. When dried out it may develop an imperfect conchoidal fracture. Blocks of 50 lbs. or more have been reported and some have pedicular barnacles attached. Almost half a ton of this material was collected by the writers and friends following a single storm during 1961. The lumpy material all appears to be weathered and extensively inspissated with the loss of lighter hydrocarbon fractions. By far the greater proportion of the "lumpy" crude is thrown on to the local beaches during winter storms, or during periods of high rip-current activity.

Semi-liquid (tacky) black bitumen has been noted (1961) to deposit near Devils Gap and along Geltwood Beach (and also at Cape Northumberland, although less is known of this) during periods of somewhat more moderate seas following storms. This material collapses and flows under its own weight when freshly stranded. Light brown, extensively oxidised and "flakey" crude also strands during these periods. Another association of the Geltwood Beach occurrence is brownish ozokerite.

PREVIOUS INVESTIGATION

In view of the frequency of reports of coastal bitumen stranding and the fact that samples are usually supplied, it is a matter of concern that so little serious attention was previously awakened in scientific and exploration circles in these phenomena.

A prime problem in the past has undoubtedly been the relative inaccessibility of the seeps and their intermittent character (to be described later). Visits by trained observers have been few, and have usually coincided with fine summer weather. Material that has stranded on rocks and subsequently melted in the sun has mistakenly been described as "oozing"; when the rock is volcanic or metamorphic, scepticism has understandably been aroused. Dr. Ward's remarks (1913) when referring to various accounts of asphaltic springs near Hog Bay (Kangaroo Island) and Mt. Greenly (Eyre Peninsula) are typical.

> "The old residents of Kangaroo Island and Eyre Peninsula responsible for these statements are undoubtedly honestly convinced that their interpretation of the facts is correct; but their failure to convince scientific observers of the genuine character of their claim and geological features presented by the localities at which these discoveries are said to have been made, are more than sufficient to discount the value of the statements made."

However, the presence of stranded bitumen was mostly attested by samples, so that Ward, who had always rejected the evidence for local seepage, was led (1913) to develop the theory of distant sources in Antarctica or South America and involvement of ocean currents. In this he was followed by Loftus Hills in discussing Tasmanian occurrences in 1914, and by Twelvetrees (1915) in discussing Western Australian reportings. Sprigg and Boutakoff more recently (1951) repeated these views without serious questioning.

Dr. Arthur Wade (1915), the Commonwealth Government Geologist, first suggested local submarine origin, and was followed by Dr. McIntosh Reid (1931), who was convinced that the point of origin was local. These two men were the first geologists to devote serious attention to the investigation in the field.

Samples of bitumen were collected by the South Australian Mines Department in 1920 at Victor Harbor, where considerable amounts were found stranded between tide levels. The results of analysis are given in Appendix 1 (Part 1) and it was concluded that—

> "there can be no doubt that the oil is a crude petroleum oil. It may be, therefore, that (this) oil found on the beach at Victor Harbor has come ashore from some vessel, but looking at the question only from the chemical point of view, it is just as possible that the oil is derived from a natural source not very far away."

Dr. Ward then stated his opinion that it was not possible with any certainty to decide the sources of any of the stranded bitumen along the southern coasts of Australia. He continued:

> "By plotting the positions of all known sources of petroleum and asphaltum on a map of the world, showing also the surface ocean currents, no certain solution of this problem is yet obtainable. The main drift of the oceanic waters is known to be from west to east in the Southern Ocean; and this easterly drift is modified by an eddy which produces a current moving from south-east to north-west along the South Australian coast. Hence jetsam having a source to the westward of any point on the coast of this State may in turn be brought eastwards until near the shore, to be caught in the return current and swept along in a north-westerly direction until stranded. The position at which any material finds a resting place is dependent not merely on its place of origin, but also on the ever varying meteorological changes which affect the currents."

Dr. A. Wade, however, was not so convinced of the need to invoke distant sources. His conclusions are worth quoting:

> "The fact that it (asphaltum) comes ashore at times in a viscous condition suggests that it had not travelled any great distances: I am firmly convinced by the evidence that the material originates from beds now covered by the sea, beds thrown down by the great fault system, known to exist, protected to some extent by the deep sea deposits and lying south of the continental shelf. As a surmise, I should say that, just as the great trough faults of the Dead Sea area have exuded bitumen in places seen by myself, so the bitumen found on these coasts may be at present escaping from similar fault planes mentioned. It would be interesting and useful to discover whether the presence of asphaltum in these becomes more pronounced after the earthquake shocks which sometimes affect them. Rumour has said that there is a connection, but scientific observations have not confirmed it as yet."

Dr. McIntosh Reid (1931) was the leading geological proponent on the local origin. Despite the strong criticism he has received for his outspoken opinions, he appears to have been by far the most realistic, and presumably has suffered by being "ahead of the times". His case for local seepage along fissures (faults) on the local continental platform, and also for escape via fracturing associated with volcanic outpourings was strongly made.

McIntosh Reid noted that during winter, stranding of asphaltum is a more or less weekly occurrence in restricted segments of some beaches, particularly along Discovery Bay (between Nelson and Portland — for analysis of these crudes see Appendix A, Parts 2 and 3). He collected much material and noted that—

> "the viscous asphaltum is a shedding from pre-Tertiary beds through the marginal faults of the southern coast, and the stranding at two places only on the shore of Discovery Bay is due indirectly to the effects of transverse faulting or to fractured domes."

He records that S. Jenkins and J. Vance of Portland (Victoria) declared that in the early 1920's, they saw oil issuing from the bed of Bridgewater Bay in large quantities. Also that on August 12th, 1931, he received from S. Johnson of

Richmond settlement, large blocks of hard asphaltum which had only recently been cast up on the shore of Discovery Bay—

> "this find of asphaltum of greater density than sea water suggests that the material had been broken off from the fissure in that condition, and that it had not been transported far from its source."

He then quotes and agrees with Wade (1915)—

> "The fresh condition of the material at the time of its arrival at the shore, and its viscous condition indicate a short period of exposure and a short distance of travel. Winter and summer the fresh asphaltum possesses similar qualities. Exposed on the beach a few days the material becomes hard and brittle."

Finally, McIntosh Reid conjectured with surprising insight, as only now is being proved by drilling twenty years later, that south of the Robe bore—

> "it is possible and even likely that marine Cretaceous will intervene between Tertiary and the Jurassic formations . . . and be the source of these crude petroleums. . . ."

Undoubted marine Cretaceous was located on drilling in the area only a few years ago, and practically all wells which have cut it have produced flows or showings of condensate gas.

Loftus Hills (1914) provides a description of the material occurring along the coast of Tasmania from Cape Sorel to Point Hibbs, which is fairly typical—

> "Along practically the whole of the sea coast of this region there are found fragments of black bituminous substance. These fragments vary in size from about three feet long by two feet square down to small fragments a few inches in diameter. The shape varies, some lumps being roughly cubical with rounded edges, but the greater number being quite flat. One piece, for example, measured about three feet by two feet with a thickness of about two inches.
>
> "The bitumen or asphaltum is jet black in colour. Some fragments are hard and brittle, while other blocks, although hard on the outside, are soft and plastic in the centre. A fresh fracture gives the odour of gasoline and kerosene. Those fragments which have been exposed to the sun develop a series of cracks on the surface. Sometimes, also, there occur water-worn pebbles of the brittle variety."

To this should be added the experience of other observers (and the writers) that in very localised areas, fresh seepage material (as compared with solid material presumed torn from seals to fissures) is more of the nature of a very viscous fluid.

CHARACTERISTICS OF OIL SEEPAGES IN OTHER PARTS OF THE WORLD

Walter Link (1952) has provided the most exhaustive study of oil and gas seeps throughout the world in relation to oilfields that has yet been published. According to him—

> "A look at the exploration history of the important oil areas of the world proves conclusively that oil and gas seeps gave the first clues to most oil-producing regions. Many great oilfields are the direct result of seepage drilling. . . . Oil and gas seeps fill one of the pre-requisites of a region if it is to produce oil, namely, source rocks, since large seeps generally result from pool destruction, they also indicate reservoir rocks and structure."

He also noted that—

> "Depending on the type, location and size of the seepages, a good guess can also be made concerning the possibility of reservoir rocks and suitable oil traps."

Natural bitumen may occur at the surface of the earth in one of four ways:

1. As the inspissated product of large seeps of heavy crude oil;
2. as diapiric cores;
3. as tar sands;
4. as fillings in joints or faults.

The mode of occurrence of "Coastal Bitumen" of the south coasts of Australia may be compared with the famous "bitumen fishery" of the Dead Sea, the two sets of phenomena appear to have much in common. In neither case is it clear from what formation the slabs seen in the water are derived, although this is a question of the utmost importance in the search for oil.

A good account of the Dead Sea occurrence is given by Ball and Ball (1953) who quote two writers of antiquity who both describe very vividly the foul smell and tarnishing of metal vessels which heralded the discharge of the bitumen. No eruptions of sour gases have been reported in modern times.

One of the largest—and best known—examples of the inspissated heavy oil seep is the Pitch Lake of Guanoco, in eastern Venezuela. Before exploitation, the lake covered an area of about 340 acres, but was nowhere more than 12 feet deep. A striking feature is the wholesale contamination of the surrounding area by heavy oil. Streams of heavy oil feed into the lake and gouts of unsolidified oil float in the surface waters. Like most very heavy crudes, the Guanoco crude is very sour, and the odour is extremely strong.

We can quite safely rule out this type of occurrence at Geltwood Beach. Sea and beach would be a sticky, tarry mess; and the smell of sulphur would be quite strong with an onshore wind. No smell has been noticed.

The Great Pitch Lake at Brighton in Trinidad is a diapiric core of bitumen. It was very probably formed by the burial of a lake of Guanoco type; followed by piercement and ascent of the bitumen in a manner analogous to that of the salt in a salt dome. In plan, the lake is quite circular and covers an area of about 42 acres; the depth (proved by drilling) exceeds 250 feet.

The lake smells strongly of bitumen but does not smell sour. Sulphurous gases and waters were apparently discharged into sands during the ascent, for in parts of the nearby Brighton Field, and at Point D'Or, very sour conditions were encountered and a number of fatal accidents occurred.

The surface of the Guanoco Lake is featureless, but the Brighton Lake is covered by circular structures in the asphalt, some tens of feet in diameter. The centre of each circle is soft and sticky bitumen, the bitumen gradually becomes harder as one approaches the periphery. Each circle is ringed with a peculiar brownish bitumen, which does not soil the fingers, and is almost as elastic as rubber.

A comparison with the diminution of the volume of the lakes with the amounts of asphalt extracted, showed that seepage into the Brighton lake is at least seven times as fast as into the Guanoco lake. Activity varies greatly at Brighton, both in space and time; on one occasion a large fossil tree trunk appeared from the depths and later sunk away again.

The absence of sourness, and especially the variation in activity, accord well with the way in which bitumen has been reported in Australia. If there are, in fact, a number of diapiric bitumen cores (possibly distributed along lines of major faulting) then the origin of the bitumen must probably be sought in the Cretaceous, for a certain depth of burial is necessary before ascent and piercement take place.

It is not known if the "rubber bitumen" is an essential feature of this type of occurrence. Certainly such rings of the Brighton lake as were observed all possessed it; it has never been reported in Australia.

Tar sands can originate in three ways. Manjak can be deposited in a sandstone; sand can be drifted into a bitumen lake, either by water or wind action (the latter is supposed by some to have caused the McMurray sands); a sandstone can be impregnated by tar in the subsurface, as in the sands of the tar belt of northern South America, and the Morne l'Enfer tar sands of Trinidad. The distinction is quite easily made: tar as grains; sand grains separated by tar, or all in contact, with interstitial tar only.

The Morne l'Enfer tar sands show occasional activity, which may be violent. At one place, an accumulation of heavy oil was found, several commercial wells were obtained, one of which blew out. Half a mile away, slightly higher beds were being quarried for road metal.

In another place, between two visits about three weeks apart by one of us (J. Woolley), a stream of tar about ten yards wide and three feet thick issued from a hilltop and rolled for several hundred yards through the scrub overwhelming saplings and blocking an old road.

On another occasion, an eruption of bitumen took place on a newly-graded location. In the course of a few days after the first movements, a ridge of bitumen about five feet high built up and after a few weeks the whole location and the access road had been overwhelmed.

In both these cases, the mass which issued was almost pure bitumen, not tar sand.

At the location, either the excavation operations or the vibration of heavy earthmoving machinery, or both, started the eruption. The flow from the hilltop may have been started by the passage of a car over the old road, which was very seldom used.

In the southern Australian occurrences, it could be that eruptions of coastal bitumen were from tar sands in the shallow subsurface, and that very slight tremor along faults might set off the larger flows. The tar sands would then probably be Tertiary (at least in the Geltwood area), but the original source of the oil could also be Cretaceous. (The Morne l'Enfer is certainly not a mother formation, and the tar sands lie a thousand feet stratigraphically above the main commercial oilsands of the area.)

Joint, fissure and/or fault in-fillings could provide the considerable volume of material, only if the asphalt was actually ascending, when it would be classed as a diapiric occurrence. Static asphalt or ozokerites cemented in fissures could only become free through erosion or breaking away of the containing rock. This possibility cannot be ruled out.

The evidence would appear to favour fissure eruptions or diapiric intrusions along structural weaknesses, perhaps with some invasion of sea-floor sediments. Movements along faults causing earthquakes are presumed to temporarily trigger accelerated extrusion. Coastal bitumen would be the product of both sea-floor erosion of diapiric cores or fissures infillings and/or sea-floor deposits.

THE GELTWOOD BEACH SEEPAGES (South-East South Australia)

According to residents of the Millicent-Rendelsham district, evidence of submarine oil seepages off the Canunda, Geltwood and Devils Gap Beaches (extending 15 to 20 miles south of Beachport, S.A.), has been recognised since well before this century. Visiting experts had, however, displayed little interest in this phenomena until recently.

Stranded bituminous crude oils and ozokerites have been collected from about Canunda Rocks intermittently for many years despite the fact that this coast, until the recent advent of jeep-type vehicles, has been isolated and little visited. Recent investigations have been complicated in turn by the, at times, spectacular upwelling of "brown water" in these zones, that has been shown to involve "floods" of micro-plankton (Ludbrook, 1961). This presumably fortuitous relationship is discussed later.

Geltwood Beach is so named because of the foundering of the ship Geltwood a few miles south of Canunda Rocks. It is a windswept ocean sand beach terminating in the north against outcropping aeolianite (consolidated dune lime sand). It lies several miles north of a more accessible beach at Devils Gap.

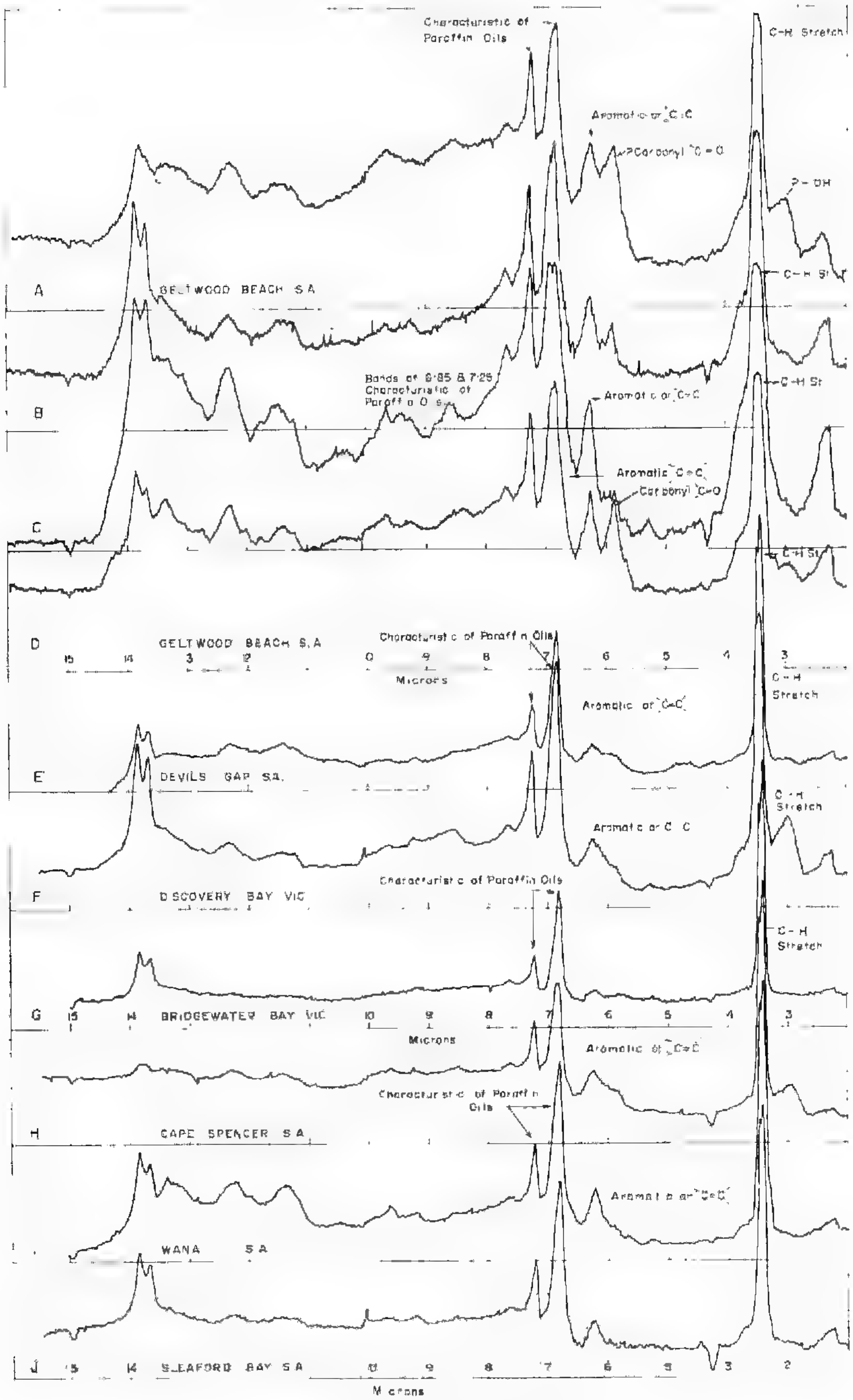
In July, 1960, geologist R. Twist, of Geosurveys of Australia Limited was detailed to visit Geltwood beach following requests from Messrs. D. Schultz and M. Schinkel. Fresh oil was collected from the beach that appeared to be a natural crude.

The presently detailed investigations commenced during March, 1961, when the customary small amounts of bitumen were collected on the beach and the "brown-water flows" (phytoplankton) were first investigated. Over a length of beach extending almost a mile south of Canunda Rocks honey-yellow to almost brown-black discolouration of water (Plate 1) was observed for periods of a day or more at a time during the first autumn months. As many as fifteen, or more, localised "points of origin" were documented and the varying activity plotted. The "brown-water" was eventually successfully sampled over the most northerly "centre" within 50 yards south of Canunda Rocks. A small amount of what was then felt to be possibly "lignic" material (? peaty or lignitic) was sampled and the filtrate sent for analysis to the Microchemical section of C.S.I.R.O. in Melbourne (Appendix D). Only carbon, hydrogen and ash were determined. The analysis was not that of lignin or petroleum substance, although certainly organic (see later section).

At the time of sampling a gallon of sea water was skimmed from immediately above the brown water "point of origin" (in about 10 feet of turbulent surf) and sent for analysis. A very considerable (45 per cent.) dilution below normal oceanic salinity was indicated (see later). A subsequent sample from another "brown-water" area 200 yards south, however, indicated no such dilution.

During these and subsequent visits to these beaches an inspection of the strandline for several miles to the north and south was carried out as a routine measure. Small amounts of fresh crude oil (a few pounds) was found to be stranded in preferred situations, the most persistent being opposite two of the more pronounced "brown-water" areas, viz., "Old Faithful" about 200 yards south of Canunda Rocks, and at Devils Gap, four miles further to the south, and due south-west of Millicent.

Other than the increasing brown-water (phytoplankton) activity in restricted zones, as winter approached, no significant increase in bitumen stranding was noted until on May 30, 1961, immediately following the first storm of the winter season. D. Schultz (and later with C. A. Sprigg) collected several hundred pounds of freshly stranded crude bitumen from the beach extending a few hundred yards to the south from "Old Faithful". During the next few weeks several hundred pounds more of such material, generally becoming increasingly "weathered" due to exposure on the beach, were collected by one of the writers (R.C.S.) accompanied by J. M. Dwyer, H. LeMessurier, L. Ackland and numerous other helpers. L. W. Parkin, Acting Director of Mines, then made a short visit to the area and also sampled some of the stranded crude and also the brown-water.



BITUMEN SEEPAGES
FROM
COASTAL REGIONS OF SOUTH AUSTRALIA AND VICTORIA
(ABCD) SAMPLES TAKEN JULY 1961 BY R.C. SPRIGG
(EFGHIJ) SAMPLES TAKEN NOV 196 BY R.C. SPRIGG 682

Periodic encampments at the beach have since resulted in considerable new data. Particular attention was directed to the incidence of rough seas, and due in no small measure to the co-operation of D. Schultz of Rendelsham, an understanding of the rôle and importance of local storms in the overall phenomena of "coastal bitumen" has emerged. At the same time, one of the writers took the opportunity to delay a visit to another reported occurrence of coastal bitumen at Sleaford Bay near Port Lincoln (300 miles north-west) until immediately following a local winter storm. In this case, a local beach that had been relatively free of lumpy crude on Saturday, 12th August, was found to be littered with it on Thursday, 17th, following the storm of the intervening Tuesday. Much older material was also noted that had melted in to the beach sand at extreme storm tide level. The rôle of storms and/or rough seas also in this instance was again demonstrated.

Also following the season's first storm, Mr. and Mrs. J. Altorfer, of Port MacDonnell, on 12th June brought in several pounds of viscous oil from Cape Banks. This they claimed was part of a recurring phenomena in this situation since about 1905 to their knowledge.

Once this storm factor was clearly established, local fishermen and various old identities verified this to be the only notable association of "coastal bitumen" beyond the occurrence of earthquake shocks, of which there had been several within living memory in this district. A search of the literature disclosed that McIntosh Reid was also fully aware of this relationship with storms, as was also the late R. Altorfer, senior, of Mt. Gambier, who was one of the proponents of "oil in the south-east".

A point of concern that arose was that no sizeable deposits of stranded bitumen had accumulated on the local sea coasts in these south-east areas. The explanation was not hard to find. The beaches of interest are all storm beaches, the back-shore dune accumulations of which are breached by wind-lane "blow outs". In winter time seas flood through the gaps and spread flotsam for several hundred yards inland. Drift bitumen can be collected in most of these situations. From here, as the material dries out, winds may transport it onto and over dune sand accumulations 100 to 200 feet high and extending a mile or more inland. "Fragments" of bitumen have, in fact, been observed buried in sand accumulations for more than half a mile inland. The fate of drift bitumen, ending in burial, is clear.

Continued observation of Geltwood Beach has permitted documentation of the stranding of "oxidised" light brown crude, and of fresh "tarry" black viscous bitumen during periods of moderate seas. Along the four miles of beach between the "Old Faithful" locality (of "brown-water") and Devils Gap, at least six or eight locations have favoured deposition of chocolate brown "oxidised" crude and a lesser number also of the viscous fresh black crudes. These crudes have been observed in the process of stranding low to high on the beach during a range of tides.

Stranding of the fresh black crude has been observed mostly during periods of moderate sea. In most cases "brown-water" (phytoplankton) activity has been observed nearby, and this usually in relation to very obvious rip-currents. It is noted, for example, that moderate to heavy seas may temporarily impound many hundreds of tons of excess water shoreward of the innermost sandbars, locally to increase the depth of water on the beach by as much as five or six feet and for periods of a minute or more. It is during these intervals that most of the fishing accidents occur along this coast, and some rather alarming situations developed even during the local sampling operations.

Once massive volumes of water have been thrown on to the beach in this way, rip-currents carrying water back via channels through intervening sandbars become greatly accelerated and turbulent. "Brown-water" floods frequently "surface" spectacularly under these conditions. It is evident that the phytoplankton responsible for this discolouration wells up from the bottom under these disturbed conditions and appears as outpourings to the surface, particularly in the neighbourhood of the more obvious current-rips. Some of these undoubtedly powerful currents also erode bituminous sea floor deposits by tearing off the brown "oxidised" veneers to sea-floor deposits, or to outcropping bituminous seals or ozokerite veins, thereby also facilitating the seepage of less viscous oil from below. This phenomena will be discussed in more detail later.

Another observation worthy of note is that at a few minutes to 5 p.m. on Friday, March 31st, 1961, while observing "brown-water" activity from about 800 yards south of Canunda Rocks (R.C.S.) a large "block" of black material appeared suddenly in the centre of one "brown-water" area, several hundred yards out to sea. This is one of the few occasions on which such "brown-water" activity was observed so far out. The tide was high at this time. The material floated partly submerged and appeared through binoculars to possess blocky edges. The block moved northwards several hundred yards by nightfall. Next morning several large lumps (several pounds) were found stranded at high tide level in this same direction near Canunda Rocks. This was the first massive piece of coastal bitumen found by the writer (R.C.S.) during 1961 and was definitely not present in this area on the previous day when this strand-line had been searched diligently by a party of four.

One final observation is that, without prompting, Mr. Syd. Smith of Rendelsham, volunteered the information that following the 1948 earthquake epicentred in the sea off Beachport (Sprigg, 1952, 1959), abnormally large quantities of bitumen were washed ashore south of Cape Buffon (a few miles north of Canunda Rocks). He also remarked that stranding of coastal bitumen declined almost completely thereafter. This is an important observation and one which answers Dr. Wade's question (see above) that activity should climax following an earthquake. Other local residents have also confirmed this. It brings to mind that such earthquake relationships have been observed elsewhere in the world in the great oil provinces. Edward Hitchcock, an American geologist, reported in 1840 that after the earthquake of 1834 and 1837 about the Dead Sea, large quantities of asphalt drifted ashore, and one mass, "like an island or house rose to the surface", and drifted in (Ball and Ball, 1953).

A. *The Composition of Coastal Bitumen with Particular Reference to the Geltwood Crude*

A number of analyses have been carried out on bitumen crudes found stranded on southern Australian ocean beaches. Some of the analytic data and conclusions have been published (Appendix A, Parts 1 to 6 inclusive). Undoubtedly a range of crude bitumen and ozokerites is represented, but mostly the analyses are incomplete and lack standards for comparison. They are all classed as natural crudes.

In most cases it is conceded that it is extremely difficult to distinguish by analytical methods natural seepage bitumens from industrial waste products. For example, one of the most widely used bitumens, "Trinidad Lake Asphalt", is simply dug out of the lake, melted by as gentle a heating as will induce flow and poured into drums. At Oxnard, east of Ventura, California, very heavy oil is raised by steam lift and flowed directly onto rock chips. Even a wide range of boiling points would not be conclusive; for a small topping plant on a heavy oilfield might do little more than take off the lightest fractions.

The possibility that coastal bitumen is not of "mineral" origin is distinctly remote. Metabolic waste products of large animal colonies can resemble bitumen in appearance, but on heating they char rather than burn and melt with great difficulty. In the process they give off a foul foetid odour quite unlike the smell of oil. Distinction can be made in the laboratory by determining oxygen, nitrogen, phosphorous and acid number, but the simple heating test is just as conclusive. Analyses of Geltwood crude made by the Shell Company (Appendix A, Part 6) reveal that its saponification value, high sulphur content, characteristic appearance, odour and burning qualities clearly exclude animal and vegetable oils as well as coal products. Ludbrook (1961; see later), on the other hand, has attempted to relate the coastal bitumen to phytoplankton "floods" that appear spectacularly in local nearshore waters, particularly during winter time. The evidence is admitted to be weak. The fact that the living diatoms concerned contain minute oil globules in their protoplasmic make-up (like most other organisms) cannot be used as evidence for the formation of massive amounts of natural crude oil devoid of all the other substances present in these organisms. The phytoplankton swarms are definitely not oily in themselves. They sink in standing sea water, they do not give the normal solvent reactions for petroleum, nor do they adhere to objects in the manner of oil.

Analyses of the oil (see appendices) all point to the coastal bitumen being natural crudes and to their being short-travelled. Understandable caution has led some analysts to draw inferences that the oils may, therefore, be from tankers, jettisoned during cleaning operations at sea. The opinion expressed by the Director of Chemistry in Adelaide (see Appendix A, Part 1; 1920) is quite typical:

> "It may be, therefore, that the oil found on the beach near Victor Harbor, South Australia, has come ashore from some vessel, but looking at the question from the chemical point of view, it is just as probable that the oil is derived from a natural source not very far away."

Coastal bitumen has been stranding along the southern sea coasts since long before ocean-going tankers were developed. Direct relationships of coastal bitumen "stranding" with the action of storms that effectively stir up and erode the local sea bottom does away with the necessity for oils to originate about Antarctica or South America, as suggested by Ward (1913). Marine biologists have expressed the opinion that marine organisms destroy seaborne oil far too rapidly to allow of long distance ocean transport via slow-moving ocean currents.

The analyses quoted (Appendices) are undoubtedly those of natural crude petroleum, varyingly weathered and inspissated. They range from paraffin-based to naphthene-based mineral oils with medium to high sulphur content. The oils are reported by oil company laboratories to be specifically different from any of the crudes regularly imported into the country. As a consequence, the crudes must be from a very extensive southern Australian oil province, immediately under and beyond the sea coast

B. *Comparison of the Geltwood Crudes with those of Port Lincoln and Port MacDonnell*

An attempt has been made by trace element analysis to establish relationships between oils found along various parts of the South Australian coasts. The analyses (Appendix E) were carried out by K. Norrish and T. B. Sweatman of the Council for Scientific and Industrial Research Organisation, Division of Soils.

Relative figures representing spectrographic analysis of five oil samples for eleven trace elements have been determined. The samples included three from the Geltwood Beach vicinity (i.e., Geltwood Beach, Canunda Rocks and Rivoli Bay), one from Cape Northumberland lying 30 miles to the south-east, and one from Pt. Lincoln, 300 miles to the north-west:

The analysts report that:

> "The results indicate that the oils from Geltwood Beach, Canunda Rocks and Rivoli Bay are similar. The oil from Cape Northumberland is distinctly higher in S. & V. and lower in Cl, Ca, Fe, Ni, Cu, and Zn than the above three samples. The other sample, from Port Lincoln, appears to have an intermediate composition."

It is further noted by the analysts that Cr and Mo were not detected in any of the oils. The scatter results were also given since they showed differences in the oils. The scatter is probably dependent on the density and hydrogen content of the oils. These support the previous inferences as to possible relationships of the oils.

Undoubtedly more such analyses (in time and locality) are required before definite conclusions can be drawn, but it appears that the oils from immediately south of Beachport are of a particular suite, and may be distinct from those stranding near Port MacDonnell, southern Yorke Peninsula or Port Lincoln. This certainly is in direct conflict with the theory of distant origin across the ocean. A number of distinctive sources are suggested lying close by the respective coasts.

C. *Associated Phenomena*

In coastal bitumen localities other processes are operative that may in some way be interrelated. These include the activity of fresh-water submarine springs and the possible association of "brown-water" (phytoplankton) flooding.

1. *Submarine Fresh-water Springs: Possible Relationships with Oil Seepage*

Deep-seated submarine springs have previously been suggested as a possible mechanism for escape of hydrocarbons from Tertiary and/or older sediments along the continental shelf in southern Australia.

Enormous volumes of fresh-water are known to issue via low-lying spring outlets from the Gambier Basin in coastal and sub-coastal zones principally in South Australia. At the foot of the Mt. Burr (marine erosional) escarpment, for example, spring flow has been gauged at about 20 million gallons per day. The outlets represent erosional "nick points" cutting the local ground-water table within the highly permeable Gambier Limestone. Similarly, surface springs debouching into the "Fifteen-mile" peat swamps (east of Port MacDonnell) issue from the cavernous Gambier Limestones. Others are known or suspected immediately across the border in Victoria.

A number of submarine fresh-water springs have also been reported. The most spectacular appears to be one lying approximately two miles off Cape Nelson (Portland, Victoria) which appears on fine days as an area of peculiarly calm water. According to the Portland Lighthousekeeper (Sprigg and Boutakoff, 1949), local fishermen have replenished their fresh-water supplies from these springs even though the sea is thereabouts probably 200 feet deep. Fishermen have reported "eruptions" of oil along with these spring water flows, and the area is one of frequent reporting of coastal bitumen.

In South Australia, E. P. O'Driscoll (1961), Senior Geologist with the South Australian Mines Department, recently reported on similar phenomena at Southend (six miles north of Canunda Rocks). He records that S. S. Smith of Rendelsham had observed numerous fresh-water springs at the base of aeolianite cliffs along this stretch of coast; others have been reported in shallow water by spear-fishermen. Mr. Smith reported that it is possible to drink from some of them, and some appear to flow quite strongly and to carry entrained gases. It is claimed that oil slicks have been noted in some cases. O'Driscoll observed the lanes of smooth water extending out to sea from near the bases of the cliffs, but was unable to sample them. He concluded that from the "knowledge of the groundwater hydrology of the area, and from local reports there is no doubt that they do exist, although it is not possible to say with absolute certainty whether they have their source in the deep pressure waters or the higher non-pressure waters".

He added that the evidence favours a non-pressure water origin, as the static water level of the Gambier Limestones and younger sediments is slightly above sea-level and, therefore, only to be expected to form springs in the coastal zone. The possibility that such waters could contain traces of oily material is considered unlikely but not impossible.

These problems are complicated in the immediate beach vicinity by the presence of downward and outward percolating rain waters representing a low head of groundwater within the adjacent highly porous dune sands and aeolianite. Springs of the nature described can be readily observed at the immediate west end of Port MacDonnell Bay beach. Water issues quite freely from the bases of aeolianite cliffs in this situation and has been reported as carrying oil slicks. The writers have not seen the latter, but the springs are genuine. Almost certainly they represent escaping of water from local swamps and/or the saturated Gambier Limestones which outcrop at sea-level hereabouts.

It is considered unlikely that waters in these situations will be sufficiently uncontaminated and diagnostic upon analysis to allow demonstration of their origin from one or other more deeply buried sedimentary formation; however, at least four or five classes of water can be predicted in the province which justify recapitulation in so far as any of them may eventually be detected escaping via outlets along the coast. They are:

1. Contaminated rainwater from the dune systems and backswamps
2. Non-pressure "carbonate" waters from the ubiquitous and shallow-lying Gambier Limestones, which have "high level" intakes concentrated in the Dismal Swamp and Mt. Burr Ranges.
3. Pressure waters from the Knight Formation. These are also "carbonate" waters in the lower south-east, but extensively will have a more distant origin in the Casterton area of western Victoria.
4. Pressure waters from the Cretaceous; these are predicted to be more saline and consequently of "chloride" type.*
5. Formational waters from the "Jurassic" likely to be saline because of known low permeability of the formations concerned.

It is felt that there is insufficient evidence to reject the possibility of submarine escape of deeper pressure waters at the coast at this juncture. The evidence of differing hydraulic surfaces for the various waters suggests otherwise. O'Driscoll (1960), for example, has demonstrated quite clearly that the hydraulic surface for the Knight Formation waters does not conform to the free groundwater surface of the overlying Gambier Limestones. He notes (negative)

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* Formation water recovered from the Cretaceous at 9,200 feet in Mt. Salt No. 1 Well west of Mt. Schank (1962) analyzed 3·2 per cent. salt, and consequently is a brine.

discrepancies relative to the Gambier Limestones hydraulic surface in the Mt. Gambier area that point clearly to separate intakes and the obvious separation of the respective water horizons by intervening impermeable (?clay) layers. Despite this, the hydraulic surface for the Knight Sands also reaches the coast almost at sea-level, suggesting pressure loss by escape in the immediate coastal zone

It is expected that faults would greatly facilitate localized escape of pressure waters from deeper sedimentary horizons. In this respect the Tartwarp fault, passing E.S.E.-W.N.W. immediately to the north of Mt. Gambier, would eventually strike out to sea beneath about Beachport. (The Beachport earthquake epicentre also lies along this W.N.W. trend to seaward.) In parallel fashion the Nelson en echelon system of folds and faults passes W.N.W. beneath the coast at about Cape Banks, and E.S.E. approximately along the Victorian coast in the general direction of Swan Lake. Another W.N.W.-E.S.E. line of disturbance coincides with the coast about Cape Douglas. Seismic surveys (1962) have recently demonstrated a (?)line of anticlines extending E.S.E.-W.N.W. beneath Geltwood Beach. The presence of reputed oil seeps and submarine springs in zones where lines of structural disturbances (G.E.A. 38A) cross the coastline consequently cannot be disregarded. A direct relationship may well exist. Wade (1915) and others have also stressed this possibility.

2. *Phytoplankton Floods*

Patches of "brown-water", sometimes many acres in extent and almost invariably close inshore, have been reported in areas of coastal bitumen stranding down through the years almost since the white man first settled in southern Australia. They have been broadly described in the literature by McIntosh Reid (1932), but seem never to have been seriously investigated. They are known to have been observed by N. Osborne of Frome Broken Hill Company as far back as 1934, and were sighted at the Head of the Bight by R. Sprigg and R. Brunnschweiler from low-flying aircraft in 1956. They appear to be well-known to fishermen and local residents mostly along relatively uninhabited sandy ocean beaches certainly from Bridgewater Bay in Western Victoria to the Head of the Bight. They are also reported along the west coast of New Zealand and elsewhere in the world. McIntosh Reid (1932), discussing the local examples, reasoned that the brown colouring matter came from lignitic lake material (? peaty).

Samples were taken from Geltwood Beach in April, 1961, by R. Sprigg and again during July, 1961, when the phenomenon was more pronounced, in company with L. W. Parkin, Deputy Director of the South Australian Mines Department. The later samples were found to contain "floods" of phytoplankton; N. H. Ludbrook (1961) who examined the samples reported that—

> "the discolouration is due to phytoplankton, mainly a rectangular-shaped diatom with conspicuous chloroplasts which is present in great numbers. Other diatoms, dinoflagellates, and various planktonic organisms are also present."

When this material strands on the beach it leaves a yellowish to brownish-black stain in summer time, but in winter time may be quite greenish to greenish-brown.

"Brown-water" or phytoplankton "floods" have been noted throughout the year at Geltwood, but are far more prominent and persistent during the winter. The floods wax and wane over intervals of a few minutes to many hours. On occasions, a score of such "flows" have been observed flooding in from a few tens of yards out to sea to rarely several hundred yards out, along a single mile of beach. Practically without exception the beaches are sandy and the most pronounced activity appears to be associated with current-rips. Mostly the swarms appear to well-up out of deeper channels (10 to 20 feet deep) between the shore and the first off-shore bar. Mostly the material moves rapidly shoreward to the beach in spectacular floods that are maintained and intensified in the surf, although remarkably little phytoplankton actually strands. Even where prominent current-rips are operating, little phytoplankton remains at the surface beyond the first sand bar. This is despite the fact that the rips are travelling seaward. Presumably the plankton slowly sinks and the floods are dissipated in deeper water.

Not unreasonably, local opinion has tended to associate the swarms with the coastal bitumen phenomena. Regions of pronounced brown-water activity are not infrequently also situations of pronounced coastal bitumen stranding, and the rather foreboding brownish-black water in itself suggests oil with its quite spectacular and apparently (at a distance) "greasy" frothing (Plate 1).

Contrary to this latter suggestion of oily character, the brown suspension does not stick to the body, and being denser than sea water, it settles out on standing. The material rather more resembles humic acid in peat swamps, or other lignic material in suspension. The material does not readily give the standard solvent tests for oil, although Ludbrook has described "waxy" products along with it (the phytoplankton) that are "partially soluble in carbon tetrachloride".

The present writers have now viewed these planktonic floods frequently and under many conditions. They have never considered them to be directly related to coastal bitumen, although originally it was felt that the material may be "lignic", possibly having been carried up by ascending spring waters from the underlying Tertiary. This hypothesis advanced independently also by McIntosh Reid (1932) is no longer tenable.

Microanalysis of the plankton by C.S.I.R.O. (Appendix D) indicates a high hydrogen content in relation to carbon—viz. Carbon 13·6 per cent; Hydrogen 2·5 per cent. This gives a C:H ratio 100:18·5 which compares with-

	C:H
Protoplasm	100: 18
Phytoplankton (Celtwood)	100: 18·5
Average paraffin-based oils	100: 16
Average mixed or naphthene-base oils	100: 14
Wood	100: 12·5
Peat	100: 11·3
Lignite	100: 7·2
Bituminous coal	100: 6·6
Anthracite	100: 3·0

There seems no reason to suggest genetic relationships of the phytoplankton with the present coastal bitumen as inferred by Ludbrook (1961). The latter are quite normal oilfield crudes, whereas the phytoplankton is living material in no way behaving like oil other than in its very superficial resemblance in discolouring sea water. This opinion is borne out in examinations carried out by Shell Company of Australia Ltd. (Appendix A, Part 7) which "exclude animal and vegetable oils as well as coal products".

The phytoplankton "brown-water" activity and the coastal bitumen phenomena do bear certain casual relationships. It is presumed that the same currents which stir up the phytoplankton may also erode the local sea bottom. Any bituminous deposits present in these zones will be subjected to this same erosive action.

These phenomena call for further investigation out of scientific interest and in relation to fishery research. It is not entirely unlikely that the local seas are enriched in nutrient solutions either from spring waters or other sources that could help proliferate phytoplankton. On the other hand, ocean-facing coasts in temperate latitudes are known to facilitate upwelling of deeper oceanic waters during the cold winter season (i.e., temperature-density inversion) that replenish the nutrients in shallower waters in which most of the microscopic plant life must exist.

A PROBABLE MECHANISM OF "COASTAL BITUMEN" ESCAPE FROM SUBMARINE SOURCES

Documentation of coastal bitumen activity in a "sample locality" during late summer through to spring in 1961 has provided an understanding of the phenomenon not previously possible. Several important factors now stand out:

1. Specific relationship with local storm activity.
2. Apparent concentration of seepage points in ocean surf zones.
3. Possible association of seepages in some cases with coastal fresh-water springs.
4. Apparent relationship with predicted faults.
5. Direct relationships with earthquakes.
6. Possible casual relationship with phytoplankton flooding.
7. Presence of highly "oxidised" (light chocolate brown) crudes amongst stranded bitumen suggesting previous sub-aerial exposure of bitumen "lakes", that now lie beneath the sea.

The stranding of natural crudes during and immediately following local storms is undoubtedly a dominating characteristic of the coastal bitumen phenomenon. This relationship has now been observed specifically in the case of particular storms that hit both the Port Lincoln and Geltwood localities during 1961. The arrival of any excessively rough seas against these coasts apparently may bring its harvest of "coastal bitumen". The first violent storm of the season normally strands more than others later in the season, because there would be more seafloor exudations to be eroded or plucked off at the earlier stage.

The local storm relationship demonstrates fairly conclusively that the crudes originate locally and in relatively shallow water. Depths of less than 100 feet (possibly 35 feet or less) are considered to be the probable limit of effective scouring and/or wave disturbance in an average winter storm. While wave motion undoubtedly may carry to still greater depths, the erosive power would be severely limited.

Refraction of waves is the first indication of transfer of wave energy to the bottom and the beginning of appreciable geological work by the waves. Deitz and Menard (1951) have pointed out that since refraction of waves occurs only where the water depth is considerably less than half of the wave length, then the effective wave base must be less than 10 metres off most coasts. Between this depth and the highest shore level reached by the waves, nearly all wave erosion and most transportation and deposition of sediment takes place. It is concluded then that erodable oil seeps likely to be affected by storm activity will lie in water depths less than about 40 foot depth, which in the Geltwood beach restricts the zone to a few hundred yards from the beach.

Fresh-water spring seepages are believed to occur plentifully along the south-east coast of South Australia. Hydraulic surfaces of both the Gambier Limestones ground waters and the Knight Formation pressure waters both descend to sea-level in the immediate coastal zone. This points strongly to escape outlets in this zone for both these aquifers. Diluted sea water sampled against Canunda Rocks (Appendix C) and other reports confirm this activity. Where pressure waters are escaping it is also possible that these will include seepage points for petroleum.

Geltwood Beach and Devils Gap overlies a N.W.-S.E. line of seismically demonstrated anticlinal structures as it passes beneath the local coast. Another (Nelson) line of (en echelon) faulting and folding would cross the coast near Carpenters Rocks, and a third coincides with the coast about Capes Douglas and Northumberland. The latter are W.N.W.-E.S.E. structures and where they pass beneath the sea coast are also preferred points of coastal bitumen activity. These relationships with geological structure are unlikely all to be fortuitous.

Local earthquakes are known to have greatly stimulated the temporarily increased stranding of bitumen. The earthquakes of 1898, 1915 and 1948 all epicentred offshore from Beachport along the projected extension of the Beachport-Kalangadoo hinge-line greatly stimulated local stranding, and it is reported that activity declined to insignificance in the Carpenters Rocks vicinity following on the 1898 earthquake, but re-appeared after that of 1915. The association of earthquakes with faulting and with temporarily accelerated coastal bitumen activity seems inescapable.

The relationship of coastal bitumen deposition with phytoplankton "flooding" if other than casual is unexplained. The resulting "brown-water" appears particularly frequent in the Geltwood (and Swan Lake and Port Lincoln) areas of preferred oil stranding. Although only a circumstantial relationship is suspected, this sometimes spectacular biological phenomenon could be usefully further investigated. It is remotely possible that the diatoms and other organisms are feeding on nutrient-enriched spring waters or seepage solutions in these situations, and in which case the resulting "brown-water" may constitute an exploration aid. Dilution of the sea water has been noted in the New Zealand example also (Cassie, 1960). It is considered more likely, however, that the prolific blooming of phytoplankton is a consequence of the upwelling of mineral-rich ocean waters during winter times by convection, as is commonly the case along exposed ocean coasts in middle and lower latitudes.

The appearance of light brown "oxidised" crude, as "flake-like" fragments stranding on Geltwood beaches at intervals over several miles, and more noticeably during intervals of moderate winter seas may have important implications. The material appears to have been subaerially oxidised at some stage; it is usually observed to be stranding opposite some of the more powerful nearshore current-rips. It appears also to be relatively widespread in the Geltwood Beach vicinity. By comparison the more "lumpy" crude found on these beaches is relatively fresh, and not uncommonly carries pedicular barnacles. This latter is viewed rather to indicate "secretion" or oozing of viscous material above sea floor level, whether sand or rock, from where it may be broken off during accentuated wave or rip-current activity. Such action would in turn rupture local seals and temporarily release the less viscous bitumen fractions that appear for some time after storms. The lighter brown "oxidised", and more "flaky", material would appear to be from flat-lying crusts on sea floor deposits.

Some important deductions now seem justified in relation to coastal bitumen. These are:

1. A shallow submarine "origin" in coastal waters less than 40 feet deep.
2. Association with lines of structural weaknesses (faults, folds and earthquake zones).
3. Possible relationships with submarine springs.
4. Secretion of viscous bitumen.
5. Possible presence of flat-lying submarine bituminous deposits that were subaerially exposed at some time during Quaternary geological history (glacial low and sea-level phases); during which times exposed sea floor deposits were more deeply weathered and oxidised.

It would seem from these deductions that coastal bitumen is likely to be principally a seepage product emanating via deep-seated fractures and/or faults. The deposits are viewed as possibly diapiric, and as such their submarine outcrops would be being continually, but intermittently, eroded in zones of shallow marine wave and rip-current activity. In the case of the Geltwood example, the spread of activity for several miles along the local beaches which lie obliquely across the projected line of the Devils Gap line of anticlines, suggests a number of outlets or extensive sea floor deposits or outcrops. Observations by the Thomas family at Hog Bay on Kangaroo Island, that pitch deposits have been observed building up above sea-level during calm weather may provide an additional clue to the probable seepage pressures and the vent-like nature of outlets.

The appearance of brown "oxidised" oil suggests that some of the sea floor deposits may have been subaerially exposed during the last Quaternary low sea-level (c. 30,000 years B.P.). It is not impossible that the relatively increased formational hydraulic head under conditions of reduced sea-level would have facilitated crude oil seepage into subaerial pools or lakes that were subsequently inundated by rising modern sea-level.

CONCLUSIONS

The stranding of weathered natural crude oil as "coastal bitumen" is a continuing and important phenomenon along the southern coast of Australia possibly for more than 2,000 miles. The crudes include both paraffinic and naphthanic types, but spectrographic investigations have demonstrated wide variations in trace element constitutions, possibly characterising different provinces which require further study. Special precautions must be taken to avoid confusion with tanker spillage.

Maximum stranding accompanies local storm activity, when wave action in shallow water and rip-currents in the surf zone most actively erode the local sea bottom. Tons of crude may strand annually along the coasts, but greatly increased quantities appeared following the Beachport earthquakes of 1898, 1915 and 1948. Disturbance of fracture infillings and other deposits presumably occurred on these occasions.

Fault fracturing is believed to have channelled and otherwise facilitated much of the oil seepage escape. In this and other respects the weight of the evidence now favours diapirism of bitumen in these zones.

Brown "oxidised" crudes also stranding along with the fresher bitumen suggest a degree of subaerial exposure of crude oil deposits in Quaternary times. The development of fossil pitch-lakes during periods of lowered sea-level is also implied.

The ultimate source of the petroleum is believed to be from the marine Tertiary or Cretaceous lying at depths of 2,000 feet or more below sea-level. The local sedimentary section is known to attain 10,000 feet deep locally.

The writers submit that the carefully documented observations which form the basis of this report provide grounds for accepting many of the previous observations of coastal bitumen by other witnesses. The regional spread of the coastal bitumen localities and also the frequency and persistence of stranding suggest that we are in the presence of one of the great "tar-belts" of the world, comparable in size to the McMurray Tar Sands of Canada or the tar belt of northern South America.

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APPENDIX A (PART 1).

Extract from "*Report on the Nature and Origin of Oil Matter Found on the Shore at Encounter Bay and Kangaroo Island*". Min. Rev. No. 32, 1920 (L. K. Ward). Report by Director of Chemistry:

Each of the samples consisted of sand, seaweed, water and black oil. The quantities of oil in the different samples varied from 8 per cent. to 14 per cent.

A portion of one of the samples distilled from a brine bath gave no distillate till the temperature of the boiling water was reached when water came over with a small quantity of oil similar in character to kerosene. By continuing the distillation from 100° C. up to 315° C. a further quantity of oil distilled over. This treatment "cracked" the petrolene and asphaltene bases. The whole of the oils thus obtained in this distillation were redistilled and fractioned, with the following results:

Distilling up to 150° C.	9·7 per cent.
150° C.-270° C.	49·2 per cent.
270° C.-290° C	20·8 per cent.
Residue and loss	20·3 per cent.
	100·0 per cent.

The flash point of one of the original samples was found to be over 100° C., but the exact flash point could not be determined owing to the presence of water.

The oil from a representative sample was extracted by solvents and the resulting solutions analysed. From the results obtained the following constituents of the oil are estimated:

Black Oil	Petrolene 85%	Naphtha	Nil
		Kerosene	26·6 per cent
		Lubricating Oil	27·8 per cent
		Paraffin Wax	2·8 per cent
		Pitch	21·5 per cent
		Undetermined & loss	6·3 per cent
	Asphaltene 15%	Asphaltum	15·0 per cent

The above analysis is to be regarded as only an approximate estimation and should be checked when larger and purer samples of the oil are available. From the results of the analyses there can be no doubt that the oil is a crude petroleum oil. Crude petroleum oils and petroleum residual oils are largely used nowadays as fuel, both for internal combustion engines of the Diesel type and for firing steamboilers in place of coal fuel. Many steamers now use oil fuel and most sailing vessels carry auxiliary engines, for which black oil is frequently used. It may be, therefore, that the oil found on the beach near Victor has come ashore from some vessel, but looking at the question from the chemical point of view, it is just as probable that the oil is derived from a natural source not very far away.

APPENDIX A (Part 2).

ANALYSES OF COASTAL BITUMEN

Sample No. 828: *Bitumen Asphalt.*

Discovery Bay, Western Victoria.
Mines Department, Melbourne: May 21st, 1931.
Analysis by J. C. Watson.

Properties

Colour: Black.
Lustre (outer exposed portion): Brilliant.
Lustre (minor portion): Dull.
Hardness: Less than I.
Odour: Petroliferous, characteristic of asphaltic petroleum.
Condition (outer exposed portion): Brittle, hardened.

Condition (inner portion): Soft plastic.

Inorganic impurities: Sand, calcium carbonate.

Behaviour on heating: Melts readily, burns with long luminous flame.

Fractural Distillation

Fraction	Boiling Point	Per Cent	Remarks
A. Water		Trace	
B. Light Oil	to 150° C.	Nil	
C. Intermediate Oil	150-230° C.	Nil	
D. Heavy Oil	over 230° C.	20·8	Brownish yellow viscous
E. Bitumen	residue	79·0	Black brittle
	Total	99·8	

SM Sample is classed as a Petroleum Bitumen.

APPENDIX A (PART 3).

ANALYSES OF COASTAL BITUMEN

Sample No. 829: *Waxy Material.*

Discovery Bay, Western Victoria.

Mines Department, Melbourne: May 21st, 1931.

Analysis by J. C. Watson.

Properties

Colour: Dark brown.

Lustre: Dull, waxy.

Hardness: Under 1.

Odour: Characteristic suggesting that of petroleum.

Consistency: Soft, waxy.

Behaviour when heated: Crackles, melts and burns with long luminous flames.

This material consists mainly of unsaponifiable hydrocarbons.

The sample contains only a slight amount of inorganic impurities, such as sand, ash, etc. It is classed as a mineral wax, which contains moisture and a heavy, dark brown oil.

APPENDIX A (PART 4).

ANALYSES OF COASTAL BITUMEN – GELTWOOD BEACH

Samples collected by R. Twist, Geosurveys of Australia Limited, on Geltwood Beach, 8th July, 1960, in company with Mr. G. Crawford, South Australian Department of Mines.

Analysis by Avery and Anderson, Industrial Chemists, Collins House, Melbourne, 17th August, 1960.

"*Re Coastal Bitumen*".

Results of analysis indicate definitely that this very dark brown viscous material contains approximately 45 per cent. of heavy petroleum oil and 35 per cent. of water. The balance of the sample consisted of inorganic substances, mainly sodium chloride and other salts normally found in sea water. A small amount of mineral residue resembling fine sand was found to consist principally of calcium carbonate. Presumably this residue consists chiefly of shell fragments.

The results were as follows:

Percentage by Weight.

Sample collected near high tide mark Geltwood Beach, near Rendelsham, South-East South Australia, 8th June, 1960.

Water	35·0
Mineral Matter ...	19·6
Petroleum Oils ...	45·4

(completely soluble in carbon tetrachloride).

The residue obtained on extracting the dried material with carbon tetrachloride consisted wholly of inorganic matter. No carbonaceous matter remained. On evaporating the solvent a dark brown oily residue resembling crude petroleum remained. Tests applied to this residue showed that the oil was derived from petroleum. We were unable, however, to ascertain any definite information about its origin. The original matter was actually an emulsion containing sea-water and oil.

(Sgd.) V. G. Anderson, F.R.I.C., F.R.A.C.

APPENDIX A (PART 5).

ANALYSES OF COASTAL BITUMEN

SAMPLE FROM GELTWOOD BEACH, SOUTH AUSTRALIA

Ref. X10: July, 1960.

Analysis by courtesy of Vacuum Oil Company of Australia, Melbourne.

Appearance: Blackish-brown heterogeneous mixture of oil and inorganic matter.

Specific Gravity: 1·23.

U.V. Florescence: Positive.

Water Content: 28 per cent. (salt).

Solubility:

Hexane: 98 per cent. residue on evaporation of hexane gave a waxy material with ASTM melting point of 120° F. approximately. Also present, inorganic matter (salt) carried over with water present in the samples. Specific gravity 0·902.

Ethyl Alcohol: 1 per cent.

Isopropyl Alcohol/Benzene Mixture: 50/50.

Ninety-seven per cent. residue on evaporation of solvent giving a resinous material and inorganic matter (salt) carried over with water present in sample.

Neutralisation Number: 2·0 mgm.

Steam Distillation: 5 per cent. refractive index of material distilled 1·493.

Saponification No.: 4.

Organic matter extracted with chloroform compared with average natural petroleum.

	Chloroform Extract	Fuel Oil	Average Petroleum	
			(a) Paraffin Base	(b) Mixed or Naphthene Base
Carbon %	91·9	87·0	84·55	85·4
Hydrogen %	10·09	11·1	13·55	11·8
Nitrogen %	1·71	—	—	·84
Oxygen %	1·86	—	—	1·5
Sulphur %	1·70	—	—	1·2
H/C Atomic Ratio	1·48	1·53	1·92	1·66

Conclusions

The low saponification and neutralisation numbers together with the ultimate analyses indicates that product is of petroleum and possibly slightly oxidised. Hydrogen : carbon atomic ratio approached that of a fuel oil or naphthene base mineral oil.

These results when considered with the 5 per cent. volatile material indicate the sample submitted could be slightly oxidised heavy mineral oil or weathered crude oil together with solid inorganic material or water.

It is also possible that the oil could originate from oil residue obtained by the hot washing of crude oil tanks on board tankers, though regulations provide that such "slops" be discharged when the tanker is well out to sea.

APPENDIX A (Part 6).

ANALYSES OF COASTAL BITUMEN

GELTWOOD BEACH, SOUTH AUSTRALIA

Analysis by: E. W. Saybolt and Co. Inc., Inspectors of Petroleum, Wilmington, California: Signed J. E. Sheiman.

Date: 29th March, 1961.

Submitted by: General Exploration Company of California, 29th March, 1961.

Marked: Engler Distillation.

Initial Boiling Point	570° F.
Approximately 10 per cent. yield to ...	650° F.

Note: Mr. Clayton of Saybolt and Co. Inc., who performed the distillation, noted that the sample was very waxy, that it was derived from crude oil, and could very likely have come from a submarine oil seep. He considered it unlikely to be from residual clean-out of oil tankers due to the 10 per cent. content of the lighter ends which would be extremely high for such an occurrence when considering the effect of weathering.

APPENDIX A (Part 7).

ANALYSES OF COASTAL BITUMEN

SAMPLE FROM GELTWOOD BEACH, SOUTH AUSTRALIA

Analysis by courtesy of The Shell Company of Australia, Melbourne, April, 1961.

The following is the laboratory report on above.

A laboratory analysis of the black, heavy-oil deposit found at Geltwood Beach, South Australia, has been carried out and the following conclusions have been reached:—

The oil is the weathered residue of either a predominantly waxy-base, medium sulphur content mineral crude oil or that of waxy fuel oil. Its saponification value, high sulphur content, characteristic appearance, odour and burning qualities exclude animal and vegetable oils as well as coal products.

Since there are numerous possible sources of oil contamination of sea passages (particularly in the vicinity of harbour or industrial installations) which could lead to oil accumulations on adjacent beaches or shores, the origin of this deposit cannot be determined with any certainty on the basis of an analysis. However, the analysis may be of value as a basis for a local investigation.

Analytical Results:

Appearance	Black, waxy solid
Melting Point (deg. C.)	72 (sharply defined)
Sulphur Content D.1551 (% WT)	1·8
Paraffin Wax Content SMS. 1769 (% WT)	40
Congealing Point (deg. C.)	79
Burning Characteristics	Non-smoky, luminous flame
Asphaltenes (% WT)	Less than 1·4
Saponification Value IP MG KOH/GM	Less than 15

APPENDIX B (PART 1).

VICTORIAN CRUDE OILS

LAKES ENTRANCE CRUDE OIL

(*Extracted from N. Boutakoff*, 1956)

15·7 per cent. A.P.I. Gravity.

S.G. 0·961.

Asphaltic base crude devoid of gasoline or kerosene.

Distillation tests show 17·92 per cent. gas oil.

Remainder is heavy lubricating oil and petroleum residue.

Analysis by Canadian Oil Co., Petrolia, Ontario, is as follows:

	%	S.G.	A.P.I.	Viscosity at
Light gasoline	Nil			
Total gasoline or naphtha	Nil			
Kerosene	Nil			
Gas oil	17·9	0·902	25·4	
Non viscous lub. distillate	14·9	0·902-0·939	22·3-19·2	50-100
Viscous lub. distillate	11·8	0·939-0·954	19·2-16·3	100-200
Residium	23·8	0·954-0·984	16·3-12·3	above 200
Med. lub. distillate	31·6	1·010	8·6	—
Distillation loss	4·0	—	—	—

(PART 2).

WOODSIDE CRUDE OIL

(After Boutakoff, 1956)

The Woodside oil appears to be a mixed (paraffinic-asphaltic) base origin. Resembles Lakes Entrance oil greatly in that it lacks the gasoline and kerosene fractions.

S.G. 0·92-0·93.

It is a dark brown like Lakes Entrance oils and possesses the peculiar odour of those oils.

APPENDIX C (PART 1).

SEA AND SUBMARINE SPRING WATER ANALYSES

GELTWOOD BEACH, SOUTH AUSTRALIA

Normal Ocean Water

Location: Four miles south of Cape Buffon, South-East S.A.

Sample by: R. C. Sprigg.

Date: 4th April, 1961.

Analysis by: Australian Mineral Development Laboratory, T. R. Frost, Chief Analyst.

Analysis:

Radicle	Grains/gall.	p.p.m.
Chloride	1365·4	19,506
Sulphuric acid (radicle)	180·9	2,584
Carbonic acid (radicle)	4·8	69
Nitric acid (radicle)	Nil	—
Sodium (+potassium)	743·0	10,614
Calcium	30·2	1,490
Magnesium	104·3	1,490
Silica	—	—
Total saline matter	2428·6 g.p.g.	34,694 p.p.m.
Assumed Composition of Salts		
Calcium carbonate	7·0	100
Calcium sulphate	91·1	1,358
Calcium chloride	—	—
Magnesium carbonate	—	—
Magnesium sulphate	142·7	2,038
Magnesium chloride	295·3	4,218
Sodium carbonate	—	—
Sodium sulphate	—	—
Sodium chloride	1888·5	26,980
Sodium nitrate	—	—
Potassium chloride	—	—

APPENDIX C (PART 2).

"SEA WATER" ANALYSIS

Location: Geltwood Beach—50 yards south of Canunda Rocks in surf zone in area of intense phytoplankton activity.

Sample by: R. C. and G. A. F. Sprigg.

Date Collected: 2nd April, 1961—10 a.m.

Analysis by: Australian Mineral Development Laboratory, T. R. Frost, Chief Analyst.

Analysis:

Radicle	Grains/gall.	p.p.m.
Chloride	700·0	10,000
Sulphuric Acid	182·0	2,600
Carbonic Acid	7·5	107
Nitric Acid	Nil	Nil
Sodium	333·9	4,770
Potassium	N.D.	—
Calcium	32·1	460
Magnesium	93·2	1,331
Silica	N.D.	N.D.
Total saline matter	1348·7 g.p.g.	19,268 p.p.m.
Assumed Composition of Salts		
Calcium Carbonate	12·5	179
Calcium Sulphate	92·1	1,314
Calcium Chloride	—	—
Magnesium Carbonate	—	—
Magnesium Sulphate	146·6	2,094
Magnesium Chloride	248·8	3,555
Sodium Carbonate	—	—
Sodium Sulphate	—	—
Sodium Chloride	848·7	12,124
Sodium Nitrate	Nil	
Potassium Chloride	N.D.	

APPENDIX D.

GELTWOOD BEACH SAMPLE

MICRO-ANALYSIS OF PHYTOPLANKTON MATERIAL IN AQUEOUS SUSPENSION IN MIXED SPRING AND SEA WATER

(Sample labelled ?"lignic" or "humic" material)

Date Sampled: 2nd April, 1961—10 a.m.

Analytical Report—

Sample submitted by: Geosurveys of Australia Ltd.

Sample designated: Residue from Water off Geltwood Beach, S.A.

Our Number: M 1783.

Results:

Residue by drying at 90° C.		6·32%
We found in the dry-residue:		
	C	13·6%
	H	2·5%
	Ash	63·7%
The ash consists of	SiO_2	10·2%
	Al_2O_3 Fe_2O_3	3·5%
	Ca	1·4%
	Mg	2·2%
	Na	17·0%
	Cl	29·6%
	K S	Present, but very small amount

(Sgd.) R. W. Zimmerman,

27th April, 1961.

Australian Microanalytical Service,
Div. of Industrial Chemistry, C.S.I.R.O.
and University of Melbourne,
C/o Chemistry Department,
University of Melbourne,
Carlton N.3, Victoria.

APPENDIX E.

C.S.I.R.O., Division of Soils *Technical Memorandum* 3/61.

TRACE ELEMENT ANALYSES OF OILS

by K. Norrish and T. R. Sweatman

The aim of this work was to try and establish by trace element analyses the similarity or otherwise of crude oils found along various parts of the coast.

Normally, trace element analyses of oil are made on the ash. However, to obtain a reasonable amount of ash a large quantity of oil must be purified and ashed, and if there are not to be losses during ashing the comparatively tedious wet methods must be used.

It was therefore decided to analyse the oil direct. The sensitivity attainable could not compare with the ash, but if sufficient this method would be simple and quick.

Prior to analyses, to eliminate contamination, Mr. R. Grasso dissolved the oils in benzene and filtered the solution to remove solids. The oil was recovered by evaporation on a hot plate and final-drying at 110° C.

The accompanying table shows the results of analysing the five oil samples for eleven elements.

The figures in the table are relative only as no attempt was made to obtain absolute percentages. However, the data is sufficient to compare the oils. Two elements, Cr and Mo were not detected in any of the oils. The scatter results are given since they show differences in the oils. The scatter is probably dependent on the density and hydrogen content of the oils. The results indicate that the oils from Geltwood Beach, Canunda Rocks and Rivoli Bay are similar. The oil from Cape Northumberland is distinctly higher in S and V and lower in Cl, Ca, Fe, Ni, Cu, and Zn than the above three samples. The other sample, from Port Lincoln, appears to have an intermediate composition.

ANALYSES OF FIVE OILS

Relative values only.

	Canunda Rocks	Geltwood Beach	Cape Northumberland.	Rivoli Bay	Port Lincoln
S	11	11	160	11	63
Cl	20	11	2·5	13	1·3
K	8·7	6·7	6	7·7	2·0
Ca	59	48	23	42	29
V	1·3	9·5	21·2	1·1	9·9
Cr	0	0	0	0	0
Fe	42	19	3	22	0
Ni	96	88	19	85	77
Cu	21	45	4	34	0
Zn	146	114	25	112	9
Mo	0	0	0	0	0
Scatter	123	121	100	120	111
Ratio Ni/V	74	9·3	0·9	78	7·8

APPENDIX F (PART 1).

SOME CHARACTERISTIC PROPERTIES OF SAMPLES ANALYSED FROM GELTWOOD BEACH

Analysed by Shell Development (Aust.) Pty. Ltd., September 26th, 1961.

Test	Method	Unit	Sample 1 (Apr. 61)	Sample 2 (5 gall. drum)	Sample 3 (quart tins)
Appearance			Black, waxy solid	Black, waxy solid	Black, waxy solid
Pour point	ASTM D.97	°F.	160	115	125
Sulphur content	ASTM D.1551	%wt	1·8	0·25	0·50
Paraffin wax content	SMS.1769	%wt	40	—	—
Congealing point	SMS.1769	°C.	79	—	—
Burning characteristics			Non-smoky luminuous flame	Non-smoky luminous flame	Non-smoky luminous flame
Asphaltenes	IP.143/57	%wt	<1·4	—	—
Saponification value	IP.136/58mg	KOH/gm	<15	—	—

APPENDIX F (Part 2).

U.O.P. Distillation Analysis.

(1). *Sample ex 5 gall. drum.*

Yield (% vol.)	Temp. (°C.)	Press. (mmHg)	Temp. (corr. for atm. press)
5	130	6·5	277
10	150	6·6	302
20	192	6·7	351
30	226	6·8	390
40	254	7·0	424
50	284	6·2	463
55	310	7·4	489
(2). Sample ex quart tin			
5	148	5·2	306
10	168	7·3	321
20	220	7·6	380
30	228	7·6	390
40	268	8·0	436
47	304	7·5	480

Analysis of Sample ex 5 gall. drum

Analysis of Distillate boiling below 350° C. (TRP)

Aromatics	Griffiths Method	8	%vol.
Olefins	Griffiths Method	0·5	%vol.
Sulphur content	ASTM D.1551	0·15	%wt.
Alkly phenols	SMS 246	124	ppm

Analysis of Residue boiling above 350° C.

Sulphur content	ASTM D.1551	0·25	%wt.
Inorganic ash		0·98	%wt.

Analysis of Ash

Fe	2·52	%wt.	on ash
Ni	0·08	%wt.	on ash
Cu	0·05	%wt.	on ash
V	0·001	%wt.	on ash

APPENDIX F (PART 3).

T.B.P. CURVE FOR GELTWOOD BEACH DEPOSIT

Fractions	Temp °C.	Press mm Hg	Temp Corr. °C.	No. of Flask	wt. of Flask	Wt. τ	wt. of H_2O	wt. of Fract.	Accum. wt.	Acc. % wt. on no loss base	Reflux ratio.
I.P.B.											
+	$+\frac{3}{4}$										
1	162	92	238	5	90·60	106·50	0·0	6·90	6·90	0·93	10·1
2	173	92	252	6	80·30	95·35	0·1	14·95	21·85	2·95	10·1
3	169	51	266	7	78·60	93·75	—	15·25	37·10	5·01	10·1
4	190	45	294	8	80·25	96·35	1·1	15·00	52·10	7·04	10·1
5	187	38	296	9	78·45	94·00	0·2	15·35	67·45	9·11	10·1
6	196	38	306	10	88·05	103·60	0·2	15·35	82·80	11·18	10·1
7	206	38	317	11	83·85	99·10	—	15·25	98·05	13·24	10·1
8	214	38	326	12	88·20	103·60	0·3	15·10	113·15	15·28	10·1
9	205	18	340	13	91·70	107·05	—	15·35	128·15	17·30	10·1
10	212	18	346	14	84·25	99·50	—	15·25	143·75	19·41	10·1
11	211	13	355	15	83·25	98·60	—	15·35	159·10	21·21	10·1
12	220	13	366	16	90·75	106·00	—	15·25	174·35	23·54	10·1
13	229	13	376	17	82·40	97·95	—	15·55	189·90	25·64	10·1
14	252	26	384	18	77·75	93·05	—	15·30	205·20	27·71	10·1
15	261	25	394	19	86·50	102·15	—	15·65	220·85	29·82	10·1
16	267	25	401	20	81·90	97·35	—	15·45	236·30	31·91	10·1
17	263	19	405	21	77·65	92·75	—	15·10	251·40	33·95	10·1
18	267	18	412	22	80·60	95·75	—	15·15	266·55	35·99	10·1
19	255	9	418	23	76·65	92·05	—	15·40	281·95	38·07	10·1
20	252	9	415	24	86·60	90·20	—	3·60	285·55	38·56	10·1

Total Dist.	285·55
Residue	455
Loss	16·45
Intake	757

APPENDIX G

REPORT ON STRANDED CRUDE PETROLEUM

taken from tide level

RIVOLI BAY, SOUTH-EAST SOUTH AUSTRALIA

Sample Received: July, 1961.

Forwarded by: Mr. D. Schulz, Rendelsham, S.A.

Sample Description: "Pellets and balls of waxy crude petroleum ½-inch to two inches in diameter."

Results of Analysis:

Colour: Mostly black, but some pellets possess a brown exterior (due to oxidation) but black interior.

Odour: Slight petroliferous.

Microscope Characteristics: Shell fragments and other calcareous grains are abundant.

Solubility:

In chloroform: Readily soluble
In carbon tetrachloride: Readily soluble
In acetone: Only partly soluble
In benzene: Readily soluble
In sulphuric ether: Readily soluble
In carbon disulphide: Readily soluble.

Extraction of Hydrocarbons: The sand was separated from the hydrocarbons by using a soxhlet extraction. Less than 5 per cent. of the sample is made up of sand grains; the remainder being hydrocarbons.

Distillation: Approximately 72 per cent. of the bituminous material distils off in the following manner:

Fraction	Boiling Point	Percentage
1	90°-125° C.	13%
2	125°-155° C.	12%
3	155°-230° C.	24%
4	230°-260° C.	32%
5	260°-300° C.	19%

Aniline cloud points:

Fraction	Temperature
1	not tested
2	48·5° C.
3	62·8° C.
4	77·8° C.
5	86·0° C.

Coke residue: Approximately 20 per cent.

Wax residue: Approximately 8 per cent.

Remarks: The aniline cloud points show that the crude is paraffin base. The fact that 72 per cent. of the crude (which must have lost most of its light fraction due to exposure) is distillate at 300° C. makes it attractive as a source for petroleum products.

R. Grasso, M.Sc.,
Geologist-in-charge
of Laboratory Investigations.

Geosurveys of Australia Limited
15th September, 1961.

APPENDIX H.

REPORT ON OIL IMPREGNATED BEACH SAND

taken from

AVOID BAY, EYRE PENINSULA, SOUTH AUSTRALIA

Sample received: 13th August, 1961.

Supplied by: Mr. H. F. Blacker, Port Lincoln, S.A.

Sample description: "Beach sand impregnated with petroliferous material."

Results of Analysis:

Colour: Light greyish-brown.

Odour: Slight petroliferous.

Fluorescence: Under long ultra-violet rays (3660A) fluorescence is light fawn.

Microscopic characteristics: The sample is almost entirely composed of calcareous fragments coated with brown petroliferous matter. Grains, which are fossiliferous, are well rounded.

Solubility:

(a) In chloroform: Readily soluble
(b) In carbon tetrachloride: Readily soluble
(c) In acetone: Readily soluble.
(d) In benzene: Readily soluble
(e) In sulphuric ether: Readily soluble
(f) In carbon disulphide: Readily soluble.

Extraction of Hydrocarbons: Twelve soxhlet extractions were necessary to extract 45 grammes of hydrocarbons.

Specific Gravity: 0·95.

A.P.I. Gravity: 17·45 degrees.

Distillation: From the 45 grammes of crude a total of 11 grammes of distillate was produced at a final temperature of 240° C. Of this, approximately 60 per cent. is a low temperature fraction (kerosene-diesel), while the remainder is heavier oil and wax which distilled over in the absence of a fractionating column.

A second distillation was made using a fractionating column (A.S.T.M. specifications) and selecting the sand containing the most oil. The following fractions resulted:

Fraction	Boiling Point Range	Percentage
1	90°-125° C.	3
2	125°-230° C.	7
3	230°-250° C.	11
4	250°-300° C.	75
5	300°-310° C.	3

Aniline Cloud Point

Fraction	Temperature
1	not tested
2	59·9° C.
3	62·3° C.
4	70·5° C.
5	not tested

Coke residue: 55 per cent. of bituminous extraction.

Remarks: The aniline cloud points clearly show that the crude oil is a paraffin base one. The paraffin wax content of the petroliferous material is approximately 5 per cent. This was left as a rusty-coloured residue together with the coke after the distillation was completed.

R. Grasso, M.Sc.,
Geologist-in-charge
of Laboratory Investigations.

Geosurveys of Australia Limited.
15th September, 1961.

A TAXONOMIC STUDY OF AMPHIBIANS AND REPTILES OF THE CENTRAL HIGHLANDS OF NEW GUINEA, WITH NOTES ON THEIR ECOLOGY AND BIOLOGY
2. ANURA: RANIDAE AND HYLIDAE

BY MICHAEL J. TYLER

Summary

In the present paper two new species, *Hyla micromembrana* and *Hyla mintima,* are described and of the thirteen Hylidae included two additional species are new records for the Central Highlands of New Guinea. Observations on *Rana grisea* van Kampen, the only representative of the Ranidae found in this region, are also recorded. The tadpoles of *Hula angularis* Loveridge, *H. darlingtoni* Loveridge and *H. iris* Tyler are described, of which the first-mentioned is shown to be structurally adapted to montane conditions in a manner previously associated solely with *Nyctimystes* spp., and the spawn and early development of *H. iris* is reported. Notes on habitat, diet, call, parasites and habits are included, and native vernacular names listed. Distribution is discussed, and eight species are shown to be endemic to the Central Highlands. The record of N. *humeralis* (Boulenger) from this region is excluded from the check list prepared as it probably refers to another species; the current recognition of *N. flavomaculata* Forcart as a synonym of *H. darlingtoni* is supported, and *H. pratti* Boulenger is restored to specific status. It is tentatively suggested that the position of the proximal margin of the nuptial pad may provide a further method for distinguishing male *Nyctimystes* from *Hyla.*

A TAXONOMIC STUDY OF AMPHIBIANS AND REPTILES OF THE CENTRAL HIGHLANDS OF NEW GUINEA, WITH NOTES ON THEIR ECOLOGY AND BIOLOGY

2. ANURA : Ranidae and Hylidae

by MICHAEL J. TYLER*

[Read 12 April 1962]

SUMMARY

In the present paper two new species, *Hyla micromembrana* and *Hyla minima*, are described and of the thirteen Hylidae included two additional species are new records for the Central Highlands of New Guinea. Observations on *Rana grisea* van Kampen, the only representative of the Ranidae found in this region, are also recorded.

The tadpoles of *Hyla angularis* Loveridge, *H. darlingtoni* Loveridge and *H. iris* Tyler are described, of which the first-mentioned is shown to be structurally adapted to montane conditions in a manner previously associated solely with *Nyctimystes* spp., and the spawn and early development of *H. iris* is reported. Notes on habitat, diet, call, parasites and habits are included, and native vernacular names listed. Distribution is discussed, and eight species are shown to be endemic to the Central Highlands. The record of *N. humeralis* (Boulenger) from this region is excluded from the check list prepared as it probably refers to another species; the current recognition of *N. flavomaculata* Forcart as a synonym of *H. darlingtoni* is supported, and *H. pratti* Boulenger is restored to specific status.

It is tentatively suggested that the position of the proximal margin of the nuptial pad may provide a further method for distinguishing male *Nyctimystes* from *Hyla*.

INTRODUCTION

The amphibians of the Central Highlands of the Australian Trusteeship Territory of New Guinea represent the Anuran families Ranidae, Hylidae and Microhylidae. The first paper describing the herpetofauna of this isolated region was written by Loveridge and published as recently as 1945. Since that date the Microhylidae has been the subject of most attention (Zweifel, 1956, 1956a, 1962; Tyler, 1962d).

Of the six species of *Rana* currently recognised from New Guinea, only one, *R. grisea* van Kampen, has been found in the Central Highlands. Loveridge (1948) commented upon four specimens collected at Kundiawa in 1944, and Forcart (1953) stated that two had been taken at Mingende in 1949.

The Hylidae inhabiting the Central Highlands are members of the genera *Hyla* and *Nyctimystes*. Loveridge (1945) described *H. angularis*, *H. becki* and *H. darlingtoni*; Forcart (*loc. cit.*) listed *H. arfakiana* Peters and Doria, and *H. angiana* Boulenger, and described *N. flavomaculata*. More recently Zweifel (1958) in revising the genus *Nyctimystes* recorded *N. papua* (Boulenger) and

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[*] Department of Human Physiology and Pharmacology, the University of Adelaide.

N. humeralis (Boulenger), and described *N. kubori* and *N. narinosa*, whilst the writer has described *H. iris* (1962a).

The present paper is the second of a series on the herpetofauna of the Central Highlands of New Guinea. It is concerned with the results of a survey conducted in the vicinity of Nondugl in the Wahgi Valley, during the period January-July, 1960, and taxonomic studies at the British Museum (Natural History) during the corresponding period in the following year. Geographical and ecological notes, and a sketch map of the Wahgi Valley in the vicinity of Nondugl are included in the first paper in the present series (1962d). Details of the rainfall recorded at Nondugl are illustrated in the form of a graph in Fig. 1.

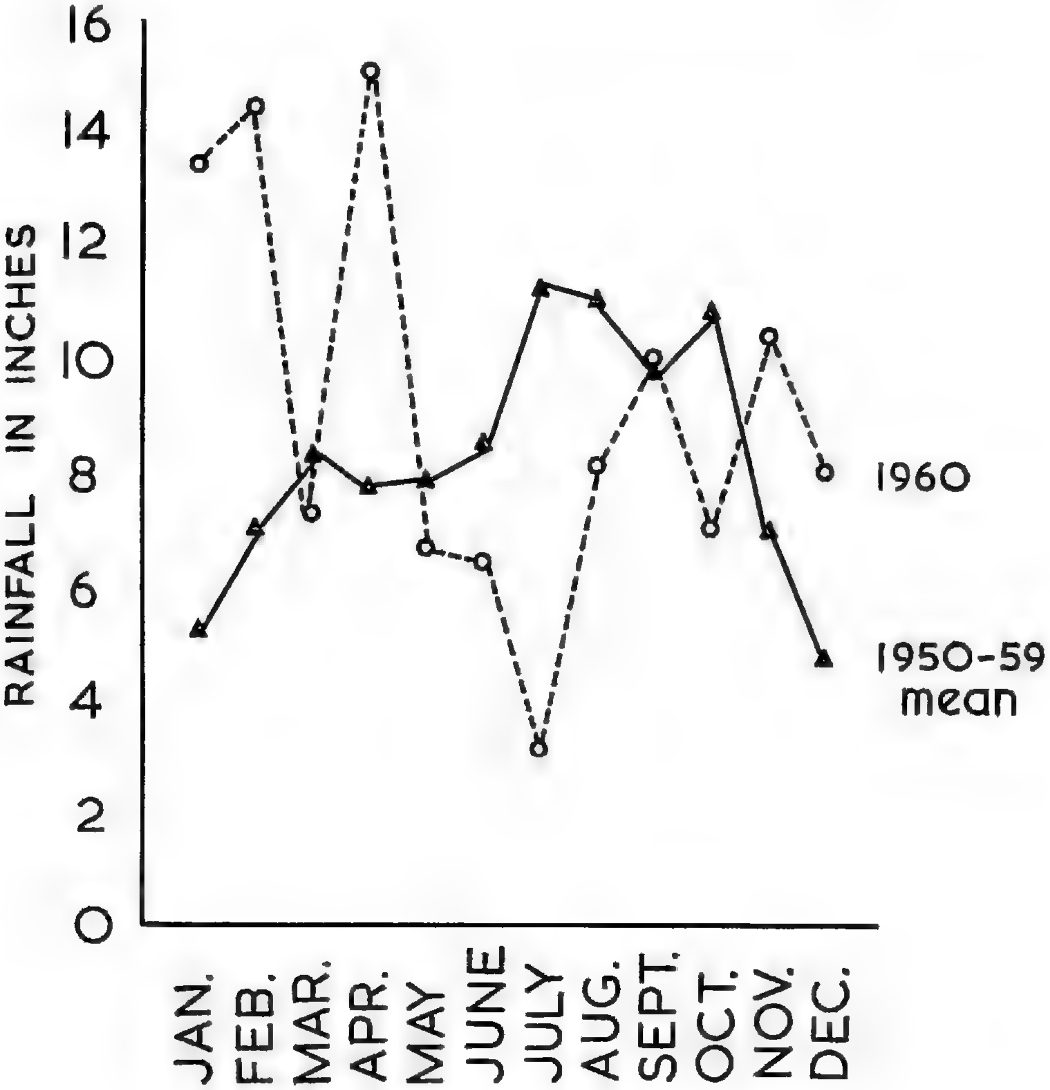

Fig. 1. Rainfall in Central Highlands. (Prepared from data obtained by the Hallstrom Livestock and Fauna Station, Nondugl.)

MATERIALS AND METHODS

Materials used and methods of measurement of specimens closely follow those previously employed for the Microhylidae. The ratio of the distance between eye and naris to internarial distance is abbreviated as E-N/IN, and tibia length to snout to vent length at TL/S-V.

Sex was determined by the presence of secondary sexual characters in males and by dissection in the case of females.

The abbreviations of the names of institutions where the collection has been lodged are as follows:

A.M.N.H. = American Museum of Natural History, New York.
Austral Mus. = Australian Museum, Sydney.
B.M. = British Museum (Natural History), London.
K.T.C. = Kingston Technical College, Kingston-upon-Thames, England.
S.A.M. = South Australian Museum, Adelaide.

SPECIES REPRESENTED

Family RANIDAE

Rana grisea van Kampen

Rana grisea van Kampen, 1913, *Nova Guinea*, 9, p. 460.

Material: 33 specimens (unsexed)—Austral. Mus. R.16808-16815, B.M. 1961.806-830.

Description: Distance between thickened dorso-lateral folds immediately behind eyes slightly greater than (19 specimens), or equal to (14), distance from external nares to posterior border of eye; tympanum approximately ¾ diameter of eye, from which it is separated by a distance of approximately ⅔ of its own diameter. Adpressed heel reaches external nares (7), between external nares and tip of snout (9), or beyond tip of snout (17); toes fully webbed except for fourth which has only a narrow fringe on terminal two joints.

Body length: 22·6-80·4 mm.

Colour in life: Dorsally and laterally a uniform pale brown with a metallic greenish-gold tint (14). A dark brown patch (24) extends from tip of snout to just posterior to tympanum, descending from canthus rostralis to margin of upper lip; tympanum obscured by this patch (28) or flecked with gold (5). A few clearly defined black spots above the eye and less prominent ones posterior to it. Dorso-lateral glandular folds paler than ground colour in juveniles, but merge with it in adults. Three or four bars on upper surface of thighs become darker, and assume a bluish tint in adults.

Ventral surface of body and forelimbs grey (3), cream (24), pale pink (4) or pale green (2), becoming obscured by chocolate patches as specimens reach sexual maturity. Ventral surface of hindlimbs pink in adults. In small juveniles abdomen and thighs are a brilliant yellow. By the time a body length of 40 mm. has been attained, the yellow has become much paler and less extensive anteriorly. At 50 mm. it is restricted to posterior 5 mm., and indistinct patches on thighs. By 60 mm. the yellow markings have completely disappeared.

Locality: Thirty-two specimens were collected between 26.3.60 and 24.4.60 in long grass beside ditches on the Hallstrom Livestock and Fauna Station at Nondugl, and one from a creek named Mingende, at a village of the same name, in the Chimbu region, on 1.6.60.

Remarks: Specimens of *R. grisea* have occasionally been mistaken for *R. papua* Lesson. A brief key to distinguish these species was prepared by Parker (1936), who stated that the distance between the dorso-lateral, glandular skin folds on the occiput of *R. papua* is, "scarcely, if at all, greater than the distance between the nostril and the posterior corner of the eye". In *R. grisea* the distance between the folds is "as great as the distance from the nostril to the tympanum".

The present series of specimens agrees with the above diagnosis of *grisea*, but none approach the maximum snout-vent lengths recorded: ♂ ♂ 80 mm., ♀ ♀ 120 mm.

Development: The number of ripe ova dissected from two gravid females totalled 620 and 622 respectively.

The mouthparts of tadpoles referred to *R. grisea* by Parker (*loc. cit.*) possess three upper rows and three lower rows of labial teeth, of which the innermost two of the upper are widely divided in the midline. The tadpoles of *R. papua* are described by Parker to have four or five rows of upper labial teeth, and three rows of lower labials.

Diet: Stomach contents included large beetles of the families Curculionidae and Carabidae; Orthoptera (Acrididae), Lepidopterous larvae and adult moths and millipedes.

Notes: The native name most commonly applied to this species is "*Gem-boogal*". Occasionally it is called "*Missil*".

Specimens of *Rana grisea* in the British Museum collection include a series collected at Minj in the Wahgi Valley by Mr. F. M. Shaw Mayer in 1952 (B.M. 1953.1.7.36-46).

Family HYLIDAE

Nyctimystes kubori Zweifel

Nyctimystes kubori Zweifel, 1958, *Amer. Mus. Novit.*, 1896, p. 18.

Material: 17 ♂ ♂, 1 ♀, 2 juveniles — A.M.N.H. 67616-67619; Austral. Mus. R.16831, 16853, 17589-17592; B.M. 1961. 1155-1164.

Description: The present series conform closely to the recent description. The TL/S-V and E-N/IN ratios of the males are tabulated in Table 1.

Body Length: Juveniles 19·8-21·1 mm.; ♂ ♂ 38·3-47·0 mm.; ♀ 56·0 mm.

In life the eyes are prominent, the iris is blue-black and the shape of the pupil circular, elliptical or vertical. Male with vocal sacs, which are apparently internal communicating with mouth by paired slits at side of tongue, and rugose nuptial pads. The nuptial pad of B.M. 1961. 1163 is illustrated in Fig. 2.

The colour of the dorsal surface of the body is pale brown with patches of grey, orange or black, or any combination of these colours, upon it. The ventral surface is pale pink.

Locality: Twelve specimens were taken from low herbage in moss-forest at 6,300 ft. near Bilikep, on the Wahgi-Sepik Divide on 26.3.60. A further six were collected at Bamna at the foot of the Divide on 16.4.60, and the remaining two specimens at the same locality on 24.4.60.

Remarks: *Nyctimystes kubori* shares certain similarities of proportions with *N. humeralis* (Boulenger), but the males lack the humeral spine which is characteristic of male *N. humeralis*, and do not exhibit immaculate green dorsal colouration of that species.

N. kubori has hitherto been known solely from the holotype and two paratypes, which are all gravid females, and a juvenile tentatively referred to it.

Notes: The native name of *N. kubori* is *"Deg-eh"*.

One of the juveniles (B.M. 1961. 1161) was found to be infested with a small leech, situated subcutaneously beneath the ventral surface in the pectoral region. A note on the endoparasitic infestations by leeches of this and other species of New Guinea frogs will be the subject of a future publication.

The specific name was based upon that of the type locality: the Kubor Mountains.

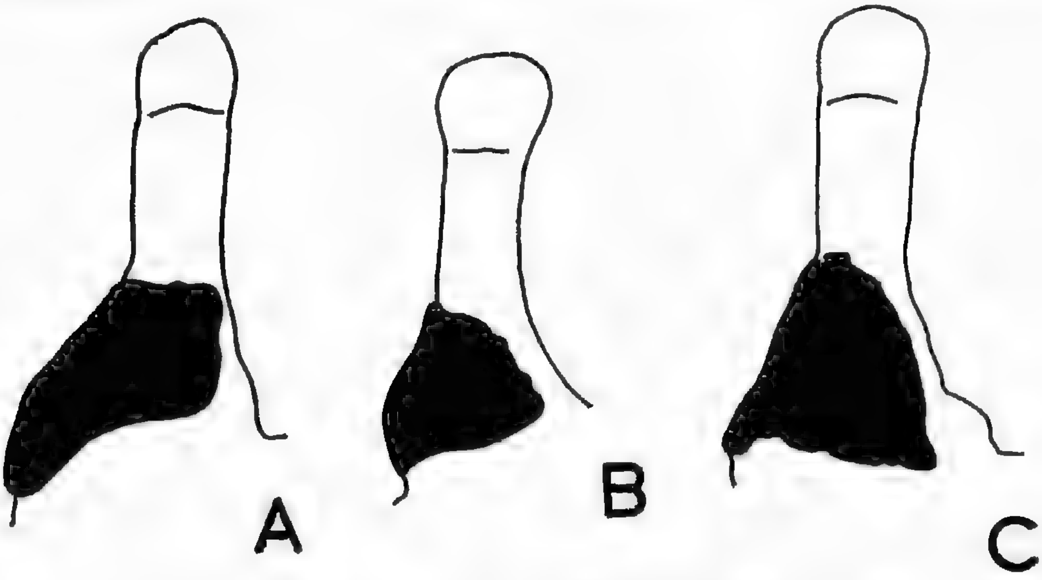

Fig. 2. Nuptial pads of *Nyctimystes*. A = *N. narinosa* (B.M. 1961.1151); B = *N. kubori* (B.M. 1961.1163); C = *N. papua* (B.M. 1961.1124).

Nyctimystes narinosa Zweifel

Nyctimystes narinosa Zweifel, 1958, *Amer. Mus. Novit.*, 1896, p. 26.

Material: 5 adult ♂♂, 2 adult ♀♀, Austral. Mus. R. 16830, 17635, 17636; B.M. 1961. 1151-1154.

Description: The present series agree so closely with the recent description by Zweifel (1958), that the inclusion of an account of their morphological characteristics would only be an unnecessary repetition. The E-N/IN and TL/S-V ratios are compared with those of the type series in Table 1. The male possesses a nuptial pad on the first finger as depicted in Fig. 2, the pupil shape is a horizontal slit in life.

Body Length: 55·5-59·8 mm., 54·0-69·8 mm.

Dorsal and lateral surfaces of body and limbs a dark grey, with large, irregularly shaped patches of cream upon them. Dorsal and lateral surface of limbs uniform grey, with small, white tubercles upon posterior surface of forearm.

Ventral surface of body and limbs a light shade of grey. Granular surface of lower abdomen and thighs stippled with black.

Locality: One specimen was taken from low herbage on the summit of a pass (9,500 ft.) on the Wahgi-Sepik Divide near Banz on 28.5.60. Five more were taken in dense moss-forest at 8,700 ft. on Mt. Odan, ten miles east, on 9.6.60, and a further specimen at 10,500 ft. on the same day.

Remarks: When comparing *N. narinosa* with other species, Zweifel pointed out that the shape of the snout and reduced webbing of the fingers was similar to *N. papua* (Boulenger) and *N. gularis* Parker, but stated that they could be differentiated from these species by the form of the palpebral venation. Although the writer's examination of the types of *N. gularis* confirm the distinction of *N. narinosa* from that species (Tyler, 1962c), the pattern of the palpebral venation of the former is quite unlike Zweifel's figure and definition, whilst the results of an examination of the types of *N. papua* indicate that not all the members of the type series are conspecific. (Discussed in the account of that species.)

TABLE 1.

A comparison of tibia length to snout to vent length (TL/S-V), and of eye to naris distance to internarial distance (E-N/IN) between the present series of *Nyctimystes* and the types.

	TL/S-V		E-N/IN	
Species	Mean	Range	Mean	Range
kubori	0·578	0·54-0·61	1·03	0·91-1·14
kubori types	0·539	0·51-0·57	1·05	0·94-1·14
narinosa	0·564	0·54-0·61	0·87	0·84-0·92
narinosa types	0·563	0·54-0·61	0·84	0·79-0·93
papua	0·550	0·51-0·58	0·93	0·86-0·98
papua types	0·567	0·56-0·58	0·89	0·85-0·96

In the British Museum collection are two specimens described as "*Nyctimystes* sp. near *gularis*" (B.M. 1953. 1.7.47-48), which the writer refers to *N. narinosa*. The specimens were collected at Tomba (8,000 ft.), at the southern end of the Mt. Hagen range, by F. M. Shaw Mayer in February, 1951.

Distribution: *Nyctimystes narinosa* has only been recorded from the Mt. Hagen region and the mountains bordering the Wahgi Valley.

Notes: The occurrence of an endoparasitic infestation of leeches was observed in two specimens.

The native name of this frog is "*Kork*".

Nyctimystes papua (Boulenger)

Nyctimantis papua Boulenger, 1897, *Ann. Mag. nat. Hist.*, 6, 19, p. 12.

Material: 16 adult ♂♂, 13 adult ♀♀ – Austral. Mus. R.16816-16821; B.M. 1961. 1103-1125.

Description: The present series agrees very well with the redescription of Zweifel (1958). The E-N/IN and TL/S-V ratios are tabulated in Table 1. The pupil is vertical in life.

Body Length: ♂♂ 57·8-66·9 mm.; ♀♀ 67·9-73·8 mm.

In life the dorsal and lateral surfaces of head, body and limbs are densely flecked with metallic greenish-gold and black (18 specimens), or with deep violet and black (11); ventral surfaces pale grey replaced by violet of a variety of shades, particularly upon the posterior portion of the body and hindlimbs. Throat crimson in three specimens. Palmar and plantar surfaces grey.

The appearance of the male nuptial pad is depicted in Fig. 2.

Locality: Collected on Wahgi-Sepik Divide at elevations between 6,300 ft. and 7,500 ft. within the vicinity of Nondugl during the period 28.3.60-24.4.60.

Examination of Type Specimens: The British Museum type series (B.M. 96.10.31.50-53) originally consisted of five specimens, but Parker (1936) excluded one which had quite distinctive characteristics and tentatively referred it to *N. semipalmata* Parker.

After an additional re-examination of the remaining cotypes, the writer is of the opinion that the series is still not conspecific. Since the cotypes are all females and have been catalogued as a series, it is necessary for purposes of comparison that each be readily identifiable as an individual specimen, and they are therefore referred to as A, B, C and D respectively. The measurements of these specimens are tabulated in Table 2.

TABLE 2.

Measurements of cotypes of *Nyctimystes papua* in the British Museum

Ref.	E-N	IN	E-N/IN	TL	S-V	TL/S-V
A	4·3	5·0	·860	31·0	53·9	·575
B	4·4	4·6	·957	30·8	54·0	·570
C	5·8	5·7	1·018	38·2	63·0	·606
D	4·4	5·2	·846	35·6	63·9	·556

Specimens A and B are almost identical in size and appearance and differ mainly in the E-N/IN ratios. They share with C and a cotype in the Museum of Comparative Zoology at Harvard (M.C.Z. 12838) a palpebral venation which, as defined by Parker, "is reduced to a few scattered dots and indefinite lines". Specimen D, however, possesses a well-developed palpebral venation, forming an almost complete reticulum whose orientation is almost horizontal. A further difference between D and the other British Museum cotypes is that the tympanum is completely free, whereas in the remainder the superior margin is hidden beneath the supra-tympanic fold. The latter characteristic is apparently common to all of the 75 specimens of this species in the British Museum and the American Museum of Natural History. On the basis of the above characteristics D is regarded as distinct from *N. papua* but, although possessing a dermal appendage on the heel it cannot be referred to *N. semipalmata*.

Specimen C is excluded on the grounds that whereas the dorsal surface of A, B and all other known specimens is deep slate and granular, that of C is pale brown and strongly rugose. A further difference between this specimen and the other cotypes is that the distance between eye and naris is greater than the internarial distance, as opposed to being less than it.

The position of the vomerine teeth in relation to the choanae is at variance in the remaining cotypes. In A they are directly between the choanae and on a level with them, but in B they are below and behind them.

Until A and B are directly compared with M.C.Z. 12838, designation of a lectotype is considered premature.

Notes: This species is called "*Aynak*" by natives throughout the entire Wahgi Valley.

Ova dissected from a gravid female measured up to 3·3 mm. in diameter and were unpigmented.

Hyla angiana Boulenger

Hyla angiana Boulenger, 1915, *Ann. Mag. nat. Hist.*, 8, 16, p. 402.

Material: 8 adult ♂♂, 8 adult ♀♀—Austral. Mus. R.17638-17641; B.M. 1961. 1165-1175.

Description: Head depressed, breadth greater than length; snout rounded; canthus rostralis distinct; loreal region concave; length of snout greater than diameter of eye; tympanum distinct, but superior border hidden by pronounced supra-tympanic fold extending from corner of eye to shoulder; tympanic diameter less than half that of eye. Vomerine teeth in two oblique series between posterior margins of choanae. Fingers one-third webbed, fourth toe webbed to sub-articular tubercle of penultimate phalanx, continuing to disc as a fringe; other toes fully webbed to discs; sub-articular tubercles prominent. Tibio-tarsal articulation of adpressed hind limb reaches tip of snout. Skin of dorsal surface smooth, ventral surface coarsely granular. Males possess vocal sacs and nuptial pads. Pupil horizontal in life.

Body length: ♂♂ 43·7-56·0 mm. (mean, 48·3 mm.); ♀♀ 66·8-77·5 mm. (mean, 72·3 mm.).

Colour in life of dorsal surface green (two specimens), green blotched with black (7), or green with black markings concentrated upon head and mid-dorsal regions (9). Canthus rostralis and side of head green (3), canthus rostralis brown and side of head green (8), or both brown (7). Upper lip bordered by broken white line. Lateral body surfaces green, becoming obscured by violet spots on ventro-laterals. Thorax and abdomen violet (5); lilac (7) or cream (6), throat of latter violet. Limbs green above, similar to colour of thorax beneath. Upper surfaces of discs pale green above, grey beneath. Above anus is a broad cream line (11), and white tubercles are situated beneath the anus of all specimens. Posterior surfaces of limbs are bordered with white (11).

Locality: Series taken from leaves of bushes near streams on Wahgi-Sepik Divide, within a five-mile radius of Nondugl, during the period 26.3.60-28.5.60. Altitude range from 6,300 ft. to 7,500 ft.

The present series compare favourably with the five cotypes in the British Museum collection (1915.9.10.11-15 = 1947.2.30.95-98), but show greater variation in the colour pattern.

Boulenger (1915) described the toes to be "webbed to the discs", as indicated in the figure accompanying his description, but examination of the cotypes revealed that the webbing of the penultimate phalanx of the fourth toe is only a narrow fringe.

Boulenger mentioned the apparent affinities of *H. angiana* to the group of *Hyla* species that he had previously allied to *H. caerulea* White, and drew attention to the small size of the tympanum shared by *H. humeralis* Boulenger. The last-mentioned species has subsequently been transferred to the genus *Nyctimystes* on the grounds of its possession of a vertical pupil and palpebral venation (Zweifel, 1958), and their affinities appear more remote.

Comparison of the present series with an account of the morphological characteristics of *H. arfakiana* Peters and Doria by Loveridge (1948), led to an initial supposition that the present series included representatives of that species. Examination of the British Museum cotypes of *H. arfakiana* (B.M. 82.10.3.3-5) and the original description (1878), enabled their distinction from that species to be more readily determined.

Amplexus: Three pairs were found in amplexus:

Austral. Mus. R.17630 ♂	x	B.M. 1961.1165 ♀	(28.3.60)
B.M. 1961.1170 ♂	x	B.M. 1961.1171 ♀	(24.4.60)
B.M. 1961.1175 ♂	x	B.M. 1961.1174 ♀	(24.4.60)

The male amplexal grasp was supra-axillary, with the fourth finger upon the superior surface of the humerus, and the remaining fingers pressed against its posterior surface.

A male *H. angiana* was also take in amplexus with a female *Rana grisea* (Austral. Mus. R.16810). The pair were collected on 26.3.60, and remained in this position for eight days. Ovulation was not induced during this period.

Distribution. This species is known from specimens on and around the Arfak Mountains in Dutch New Guinea, and has previously been recorded in the Wahgi Valley by Forcart (1953). Altitude range: 5,000-8,000 ft.

Notes: Food items recovered from stomachs consisted of Diptera, Orthoptera and moss.

The bladders of two specimens were found to be infested with Trematodes.

The specific name was based upon the name of the type locality: the Angi Lakes in the Arfak Mountains, whilst the native vernacular name is "*Kowuar*".

Hyla angularis Loveridge

Hyla angularis Loveridge, 1945, *Proc. biol. Soc., Wash.*, 58, p. 54.

Material: 16 ♂♂, 3 ♀♀, 1 tadpole — Austral Mus. R.16857-16859; B.M. 1961.1228-1242, 1243 (tadpole).

Description: Vomerine teeth in two short, oblique series directly between the oval choanae, separated from each other by a distance slightly greater than the length of one series; tongue slightly more than half the width of mouth opening, oval, its posterior border free and slightly notched; snout elongated and depressed, pointed or rounded when viewed from above, tip slightly concave in profile, the upper jaw extending beyond lower; nostrils more lateral than superior, considerably projecting, their distance from end of snout very slightly less than that from eye. Canthus rostralis angular and extremely prominent; loreal region concave and oblique, the upper lip flaring out strongly below it. Eye large, its diameter slightly greater than its distance from naris, inter-orbital distance greater than the width of upper eyelid, and less than internarial distance. Pupil horizontal in life. Tympanum distinct, its superior border hidden beneath strong supratympanic fold which extends from posterior

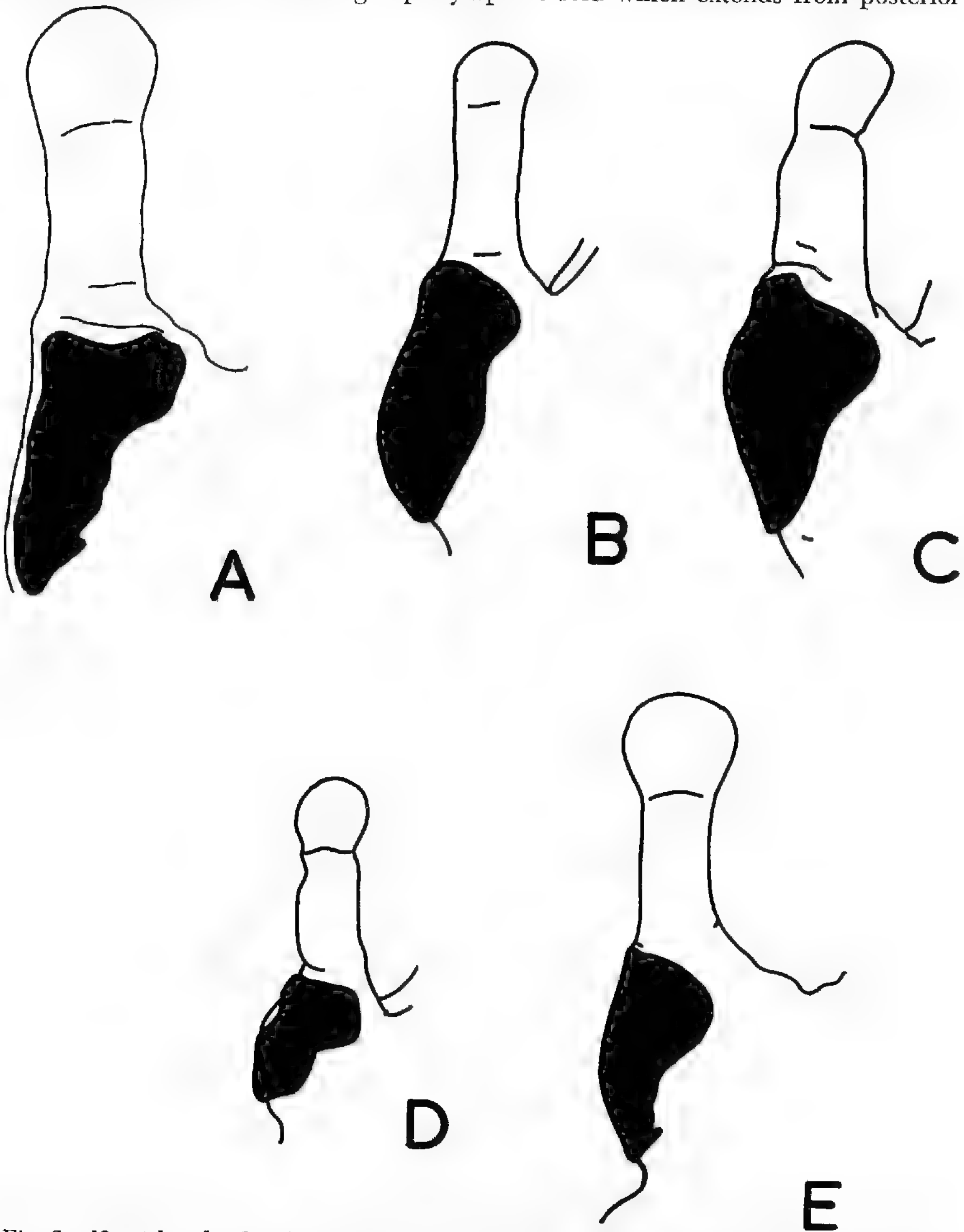

Fig. 3. Nuptial pads of *Hyla*. A = *H. angularis* (B.M. 1961.1242); B = *H. montana* (B.M. 1962.152); C = *H. mintima* Holotype S.A.M. R.4151); D = *H. becki* (S.A.M. R.4142); E = *H. darlingtoni* (B.M. 1961.1134).

corner of eye to shoulder; tympanum separated from eye by a distance nearly equal to its own diameter. First two fingers webbed at base or one-third webbed, fourth considerably longer than second, just reaching to disc of third which is almost equal to size of tympanum; distinct oval inner metacarpal tubercle. First, second and fifth toes webbed to disc, fourth to sub-articular tubercle of penultimate phalanx, and third to point midway between penultimate phalanx and disc; disc of fourth slightly smaller than tympanum. Inner but no outer metatarsal tubercle; no tarsal ridge; very small, conical, dermal appendanges on heel, usually two in number.

Body not elongate, in post-axillary region a little narrower than greatest width of head; when hind limbs adpressed, heel reaches beyond tip of snout; when limbs are laid along the sides, knee and elbow considerably overlap; when limbs are bent at right angles to body, heels overlap greatly. A narrow patagium extends from the back of the upper arm to the side of the body. Skin of upper parts non-glandular, with few scattered conical tubercles on dorsolateral surfaces of body, and on posterior half of upper eyelid; large tubercles around anus; skin of thorax smooth, throat lightly granular, abdomen and lower femur coarsely granular; skin of head not co-ossified with skull, roof of skull not exostosed. Male with vocal sac which is apparently internal, with paired openings in floor of mouth at angles of jaws; nuptial pad on inner surface of first finger as depicted in Fig. 3. TL/S-V = ·569-·664 (mean = ·616).

Body length: 33·1-42·1 mm. ♂♂; 47·6-52·9 mm. ♀♀.

Dorsal surface of head, body and limbs grey or pale brown, very lightly flecked with small black spots; lateral body surfaces and thighs slightly paler than ground colour. Ventral surface white or cream marbled or variegated with grey or black. Tubercles around anus white. No appreciable change between colour in life and that in alcohol.

Locality: The series was collected at various localities on the Wahgi-Sepik Divide, during the period 26.3.60-4.4.60 at altitudes of 6,000 ft. to 6,500 ft.

Remarks: Miss A. G. C. Grandison of the British Museum (Natural History) kindly compared the present series with a paratype lent by the Museum of Comparative Zoology, Harvard, and reported that the majority differ from it in few respects. The skin of *H. angularis* is described as smooth, but low power microscopic examination revealed small tubercles. The skin of the present series is sparsely tuberculose, and the tubercles are prominent macroscopically. It has been suggested that large tubercles might be a characteristic associated with the breeding season.

The description of the colouration of the type series differs markedly from the present series. Loveridge described the colour in preservative as blue-black dorsally, and referred to a broad rostro-lateral stripe. These features are not exhibited by the Wahgi-Sepik Divide material.

When mentioning the affinities of *H. angularis*, Loveridge stated that in van Kampen's key (1923) it came near to *H. everetti* Boulenger of the Dutch East Indies, but differed from it in many respects. The cotypes of *H. everetti* lodged in the British Museum (B.M. 97.6.21. 104-111 = 1947.2.23. 60-67) have been examined by the writer and the distinction from *H. angularis* confirmed.

Development: The early stages of development are unknown, but large tadpoles, clearly referable to this species by the characteristic shape of the angular canthus rostralis and tip of the snout, were collected from beneath

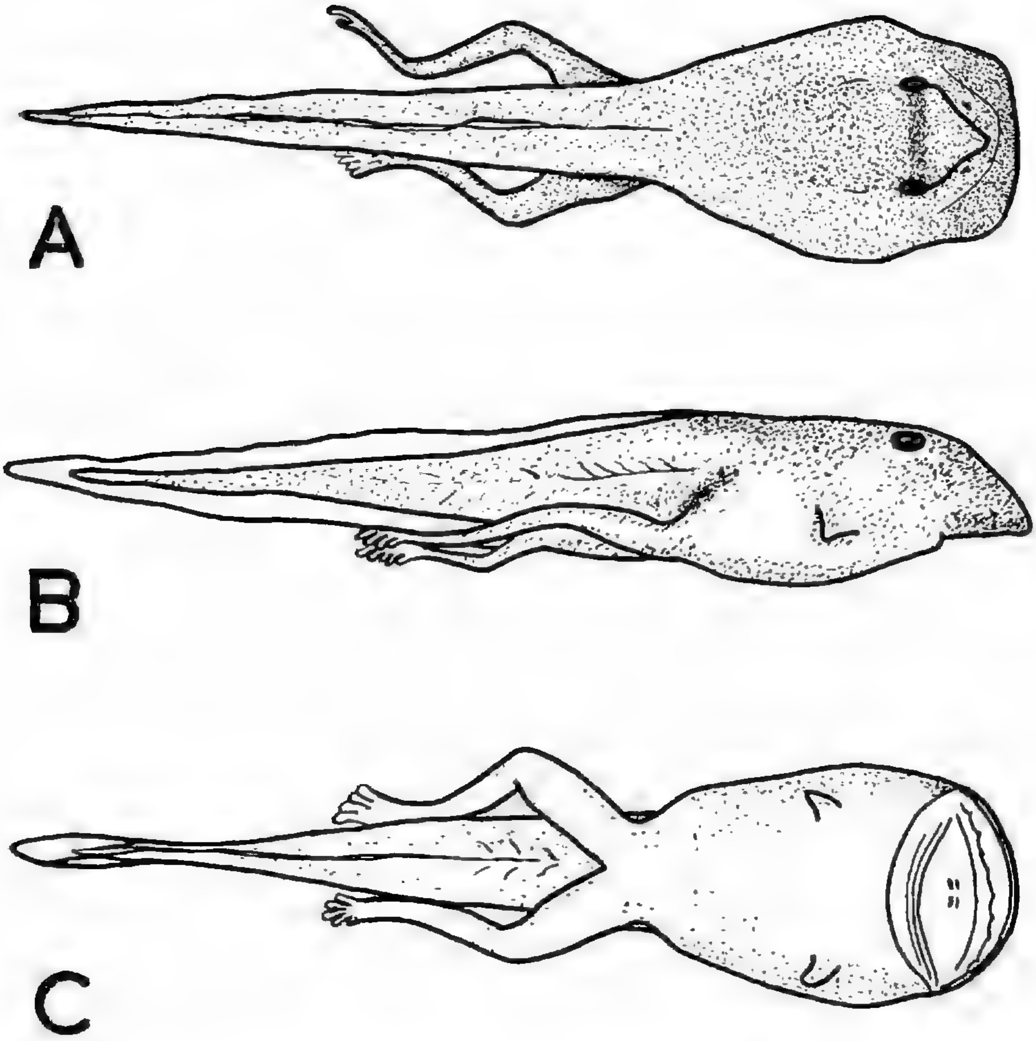

Fig. 4. Tadpole of *Hyla angularis*. B.M. 1961.1243. A = dorsal surface; B = lateral; C = ventral.

flat stones in a stream on Mt. Pipening at 6,500 ft. on 9.5.60. Figures of one of these specimens are depicted in Fig. 4.

The tadpoles are structurally adapted to an environment where they are subjected to fast-flowing water. The body is flattened dorso-ventrally, and the large ventral, suctorial mouth enables the tadpole to obtain a purchase on the smooth undersurface of flat stones. The labial teeth and horny beak are highly specialised, and are believed to function in such a way that the tadpole is able to feed whilst yet maintaining its hold. The mouth is depicted in Fig. 5 and the following is a description of the mouthparts:

The first and second rows of upper labial teeth are complete rows. Those of the second row are far longer than the first, and each individual tooth is of bicuspid form with tips projecting posteriorly and downwards. The horny beak is reduced to two pairs of short rows of fused teeth, situated on either side of the midline. There are three complete rows of lower labials. The relative lengths of the teeth of the different rows is as follows (U.L. = upper labial; L.L. = lower labial): U.L.2 > L.L.1 > U.L.1 = L.L.3.

The tadpoles of this species were always found attached to stones in the manner described, and presumably feed upon the algae which inevitably coated the stones. The following explanation is the writer's opinion of their likely mode of action:

The horny beak of the tadpoles of most species of frogs inhabiting static or slowly moving water consists of two semi-lunar plates of fused teeth which are far larger in size than any of the rows of labials.

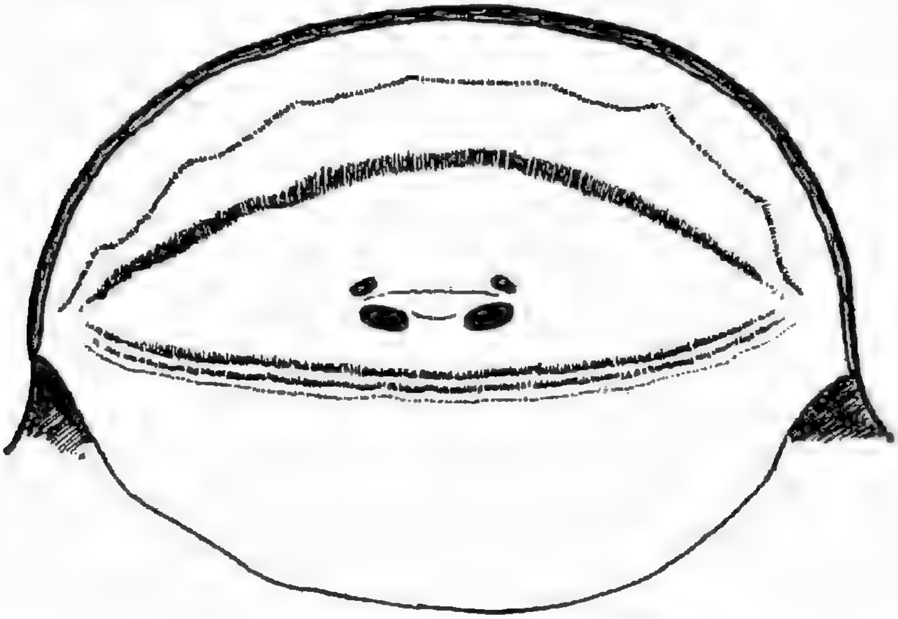

Fig. 5. Mouthparts of *Hyla angularis* tadpole.

In the tadpoles of *H. angularis* it is suggested that the second row of upper labials is responsible for the rôle normally undertaken by the horny beak. The latter, being situated more deeply within the mouth at the border of the pharyngeal region is structurally unsuited for rasping off a film of algae. Were the horny beak to play this rôle in *H. angularis* it would need to project far further forwards and, even then, only the medial portion would be functional. The more superficial site and greater mobility of the second row of upper labials presumably enable this row to rasp large portions of food from the stone without the tadpole losing purchase. The first row of upper labials may loosen the food medium, whilst the lower rows could act as a trap. The horny beak probably plays no part at all in feeding, but could effectively seal the opening to the oesophagus when the need to do so arose.

Smith (1927) figured the mouthparts of the tadpole of *H. everetti* and it is apparent that the tadpole of *H. angularis* bears no relationship with it.

Notes: The native names of *H. angularis* are "*Karga*" and "*Kuglam-balka*". The specific name of *angularis* refers to the characteristic angular form of the canthus rostralis.

Hyla becki Loveridge

Hyla becki Loveridge, 1945, *Proc. biol. Soc. Wash.*, 58, p. 55.

Material: 33 ♂♂, 13 ♀♀ — Austral. Mus. R.17627-17634; B.M. 1961. 1176-1203; S.A.M. R.4142-4149.

Description: The present series agrees with the description of the type series in but a few respects. The males have a nuptial pad on the inner surface of the first finger (Fig. 3).

Body Length: 26·2-35·6 mm. ♂♂ (mean: 29·6 mm.); 32·0-37·1 mm. ♀♀ (mean: 34·6 mm.).

Colour in Life: Dorsal and lateral surfaces of body, limbs and head posterior to transocular region dark green with lighter patches; anterior portion of head pale green. Ventral surface of body lime, limbs similar, lightly stippled with grey.

Locality: Three specimens were taken in moss-forest on the Wahgi-Sepik Divide near Nondugl at 6,000 ft. on 26.3.60, and the remainder on the nearby Mt. Podamp at 7,500 ft. on 1.4.60.

Remarks: Loveridge's holotype, a 38 mm. male, is larger than any of the present series which, being taken at the height of the breeding season, would presumably include specimens of the maximum size attained. The females are larger than the males and several are gravid containing unpigmented ova approxmately 2·5 mm. in diameter.

Direct comparison of the present series with the types will be necessary before it can be established whether there are any further differences not apparent from the original description.

Distribution: *Hyla becki* is only known from the type locality of Mt. Wilhelm where it was collected at 7,500-10,000 ft.

Notes: Two frogs (B.M. 1961.1204, 1205) with body lengths of 31·1 mm. and 27·4 mm. were found to be the hosts of leeches measuring 23·5 mm. and 23·8 mm. in length respectively. The leeches were situated subcutaneously on the dorsal surface of the body from above the anus to the posterior portion of the head. A third frog (B.M. 1961.1193) was infested by a 9·0 mm. leech which lay beneath the skin of the ventral surface of the humerus and pectoral region.

Nematodes were recovered from the stomach and ileum of one frog and the ileum of another, whilst the bladders of 45 per cent. of the series were infested with trematodes. The total number of trematodes recovered was 69.

The natives refer to this species as either "*Ken-dangma*" or "*Boo-ganda*".

Hyla becki was so named as an acknowledgment to the collections made in New Guinea by Sgt. W. M. Beck.

Hyla darlingtoni Loveridge

Hyla darlingtoni Loveridge, 1945, *Proc. biol. Soc. Wash.*, 58, p. 53.

Material: 21 adult ♂♂, 10 adult ♀♀, 1 juvenile, 1 tadpole. Austral. Mus. R.16839-16844; B.M. 1961.1126-1149, 1150 (tadpole); K.T.C. F.5.021, 024.

Description: Head as broad as long, length of subacuminate snout approximately twice the horizontal diameter of eye; pupil horizontal or circular in life; diameter of tympanum exceeds three-quarters that of eye; vomerine teeth situated in two series directly between choanae and separated by a distance equal to the length of one of them: outer finger three-quarters webbed, connected to disc by narrow fringe; heel of adpressed hind limb extends to anterior border of eye; skin of body smooth above, granular beneath. Male possesses a raised nuptial pad (Fig. 3) which is pigmented (17 specimens) or unpigmented (3).

Body Length: 34·4-43·7 mm. ♂ ♂; 42·0-47·1 mm. ♀ ♀; 29·0 mm. juvenile.

Colour in Life: Ground colour of dorsal and lateral surfaces of body and limbs orange brown (24), dull sepia (4) or grey (3); narrow, pale mid-vertebral stripe extends from tip of snout to sacrum in first-mentioned form, but continues to vent in others; head and skin covering transverse processes of vertebrae dark brown (20) or black (11). Behind knee and at groin of adults are large irregular black patches variegated with brilliant orange. In the juvenile the patches are brown variegated with yellow and a similar mark occurs at base of forearm. In adults the latter is replaced by a few pink spots.

Throat lightly pigmented with brown (23) or dull yellow (8); thorax, abdomen and limbs immaculate cream (27) or pale pink (4).

The colour in preservative is similar to the description of the type specimens (Loveridge, 1948).

Locality: All but one of the series were collected at Nondugl (5,700 ft.) on 24th-25th March, 1960. The exception was taken at Mintima, near Kundiawa in the Wahgi Valley, and approximately 20 miles south-east of Nondugl, at 6,000 ft. on 1.6.60.

Remarks: Three plates are included in the description of *Nyctimystes flavomaculata* (Forcart, 1953), a species which is clearly conspecific with *H. darlingtoni*.

Habitat: *Hyla darlingtoni* is an arboreal species and by far the most abundant frog found in the Wahgi Valley. It was recorded upon the leaves of coffee trees (*Caffea typica*) and giant tree ferns (*Cyathea contaminans*), and in the moist spaces at the base of leaves of Mauritius Hemp, banana and *Pandanus* sp.

Habits: A total of 132 food items were recovered from the stomachs of 53 specimens collected, but not retained, during the period 22.1.60-28.3.60. The nature of these food items has been tabulated elsewhere (Tyler, in press).

The call consists of a series of 20 to 30 separate notes over a total duration of from three to seven seconds. It starts on a high note and ends on a low one. The duration of each individual note is brief at the commencement of the call, but noticeably extended at the end.

Calling became most intense towards the end of March and it was noticed that there were two separate choruses or periods of activity. The first and most vociferous occurred from 9.00 p.m. to midnight and the second from 1.00 a.m. to 3.00 a.m. At the height of a chorus, individuals would occasionally emit a laborious squeak, quickly repeated two or three times, but the function of this sound could not be determined.

Development: The number of ripe ova dissected from gravid specimens collected in February, 1960, was found to exceed 400. Diameter of ovum 1·5 mm.; upper pole black, lower pole pale cream.

Tadpoles were collected in April from shallow ponds and blocked drainage ditches in native gardens on the Wahgi Plains, at altitudes of 5,000-5,500 ft. Insufficient numbers were obtained to warrant the description of anything but the dentition, which showed very little variation between individuals.

Larval Mouthparts:

Row I Upper labials—complete row.
Row II Upper labials—wide median gap.
Horny beak—undivided; deep; strongly serrate.
Row I Lower labials—complete row.
Row II Lower labials—complete row.
Row III Lower labials—narrow median gap.

The maximum length (body + tail) of the tadpoles examined was 58 mm. Eruption of hindlimbs occurred after a reduction to a maximum total length of approximately 53 mm.

The feeding habits of tadpoles were observed on several occasions. They were seen foraging amongst organic debris on the floor of the ponds and buried themselves in this material when disturbed. Intestinal contents were found to consist of decomposing plant material and silt.

Distribution: Only recorded from Mt. Wilhelm, where the type series was taken at 5,000-7,000 ft., Mt. Hagen and intermediate localities in the Wahgi Valley.

Notes: The only record of predation upon adult *H. darlingtoni* is the observation made by the writer on 15.3.60, when a Colubrid snake, *Ahaetulla calligaster calligaster* (Gunther) was found on a frond of *Cyathea contaminans* ingesting a 45 mm. frog.

The introduction of small fish (*Gambusia* sp.—live-bearing tooth carps of the family Doeciliidae) into ponds in the Wahgi Valley in 1946 in an attempt to eradicate mosquito larvae, has probably reduced the endemic population of *H. darlingtoni*. Mr. Shaw Mayer of the Hallstrom Livestock and Fauna Station informed the writer that spawn and large numbers of tadpoles, which were probably *H. darlingtoni*, were seen prior to the introduction at Nondugl (? in 1952).

A frog collected at Mintima on 1.6.60 was found to be the host of an ectoparasitic leech.

The native names of *darlingtoni* are "*Warr-sip*" in the vicinity of Nondugl, and "*Nar-goon-gar*" by natives living in the Chimbu region.

The specific name honours the collector, Capt. P. J. Darlington.

Hyla iris Tyler

Hyla iris Tyler, 1962, *Rec. S. Aust. Mus.*, 14 (2), p. 253.

Hyla iris is a pygmy species recently described from a series of 26 specimens collected on the Wahgi-Sepik Divide near Nondugl. Data in the present paper are restricted to ecological and biological observations excluded from the description of the type series.

Habitat: This species was found in low vegetation beside streams in moss-forest. A single specimen (B.M. 1961.1226) was collected at the summit of a pass at 9,500 ft., at least 1,500 ft. above the source of the nearest stream.

Development: Spawning was found to occur in April. The ova are pale green in colour, and measure approximately 2·5 mm. in diameter when freshly laid. There are two vitelline membranes and the diameter of the outer is approximately 4 mm. The eggs are laid in either hemispherical masses of clear albumen on the upper surface of leaves of trees overhanging water, or in ovoid-shaped masses around the stems of ferns or sturdy grasses at the edge of streams. In 26 clumps of eggs which were examined during the period 15-19.4.60

the number of ova per clump was as follows: Range =4-37; mean = 14. The largest hemispherical clump was almost 50 mm. in diameter, whilst the largest ovoid clump had a length of 75 mm. and breadth of 50 mm.

The first cleavage plain was visible after 24 hours, and it was noticed that several of the embryos rotated within the vitelline membranes during this period. Rotation was on no definite axis, and continued for up to three hours.

Within three days the embryos were clearly differentiated into head, body and tail. At this stage the head, tail and dorsal surface of the body had assumed a pale brown colour, but the ventral surface remained green.

Fig. 6. Tadpole of *Hyla iris* at time of emergence from spawn. Distance between mouth and vent = 3·5 mm.; vent-tip of tail = 6·5 mm.

Hatching occurred at approximately fourteen days, by which stage the tadpoles had grown to a length of 10 mm. (head + body = 3·5 mm., tail = 6·5 mm.); the outer vitelline membranes were cloudy white, and their diameter had increased to 12 mm. At the time of hatching the tadpoles possessed internal gills and strong muscular tails (Fig. 7). Their dorsal colouration had darkened to black and the ventral surface to a paler green.

The hatching tadpoles wriggled their way to the surface of the spawn mass and either dropped into the streams or were washed there by rain.

A culture of tadpoles was reared on filamentous algae for a further four weeks, and observations were unfortunately terminated before the eruption of the hindlimbs. One tadpole was preserved as B.M. 1961.1227 and a description of this specimen is as follows:

Mouth prominent, raised to form manubrium; papillae on lateral and anterior borders, but absent from posterior border which is associated with marginal upper labial teeth. Upper labials consisting of two rows, of which the second is interrupted by wide median gap; lower labials in three rows; second and third complete, first with narrow gap.

Notes: The native name for *H. iris* is "*Kenda-koo-bagandu*".

Green ova have previously been recorded for *Megalixalus laevis* of Cameroon, and *Agalychnis moreletti* of El Salvador, Central America.

Hyla micromembrana new species

Holotype: S.A.M. R.4150; ♀ collected at an elevation of 7,500 ft. on Mt. Podamp, Wahgi-Sepik Divide, near Nondugl on April 1st, 1960.

Diagnosis: A moderately sized species closely allied to *Hyla pratti*, possessing only basal webbing between the fingers and fully webbed toes. The specific name refers to the condition of the finger webbing.

Description of Holotype: Vomerine teeth in two oblique series between the oval choanae, separated from each other by one-quarter and from the choanae by two-thirds of the length of one of them; tongue two-thirds as wide as mouth opening, almost circular, its posterior border emarginate; snout large, rounded when viewed from above, almost blunt in profile; nares lateral, their distance from end of snout almost equal to that from eyes. Canthus rostralis prominent, strongly rounded; loreal region oblique and concave. Eye large, prominent, its diameter slightly greater than its distance from naris, pupil horizontal; interorbital distance less than width of upper eyelid, which is slightly greater than internarial distance. Tympanum distinct, annulus clearly visible, almost one-third diameter of eye, separated from eye by distance greater than its own diameter. Second, third and fourth fingers webbed at base, first free. Fingers in decreasing order of length: $3 > 4 > 2 > 1$. Disc of first finger smaller than tympanum, second, third and fourth slightly greater. Second, third and fourth toes webbed to penultimate phalanx, continuing to disc as fringe; first half-webbed, fourth two-thirds webbed. Toes in decreasing order of length $4 > 5 = 3 > 2 > 1$, discs approximately equal to tympanum; a small oval outer but no inner metatarsal tubercle.

Body not elongate, in post-axillary region a little narrower than greatest width of head; when hindlimb is adpressed, heel extends beyond tip of snout; when limbs are laid along the sides, knee and elbows meet; when hindlimbs are bent at right-angles to body the heels overlap considerably. Skin of upper parts smooth with few scattered warts, particularly on upper eyelids. Strong fold of skin extends from posterior corner of eye to between the angle of the jaw and the forelimb, hiding upper border of tympanum; ventral surfaces granular, particularly upon the thighs. Skin of head not co-ossified with skull. Female gravid.

Dimensions: Head and body 51·5 mm.; head length 15 mm.; head breadth 17 mm.; femur 29 mm.; tibia 34 mm.

Colour in Alcohol: Dorsal surface a uniform very dark slate, ventral surface grey variegated with dark violet, particularly on the throat.

Colour in Life: Dorsal surface dark chocolate, flecked with green on laterals and upon discs of digits. Ventral surface violet flecked with slate blue, grey and brown.

Variation: Paratypes—Five adult ♀♀—Austral. Mus. R.17991-17992; B.M. 1962.154-156.

Two of the paratypes were collected at Bilikep, 6,300 ft. on the Wahgi-Sepik Divide on 26.3.60, and the remainder with the holotype on 1.4.60.

Body Length: 45·0-51·5 mm.

The paratypes conform closely to the description of the holotype. The pupil of one specimen was vertical in life, but there is no palpebral venation. The distance between eye and naris is approximately one and one-quarter to one and one-half of the internarial distance; the distance between eye and naris is equal to (1 specimen), or very slightly greater than, the distance between tip of snout and naris (4). TL/S-V = 0·58-0·66 (mean = 0·604).

The dorsal surface of the skin is pustulose in all specimens and large tubercles are present on the upper eyelids.

Comparison with Other Species: The reduced webbing between the fingers and the proportions of the head will serve to distinguish *H. micromembrana* from *H. mintima*, and all of the species compared with *mintima* in the account of that species except *H. pratti* and *H. wollastoni* Boulenger. The tympanum of *pratti* is nearly half the diameter of the eye, whereas in *micromembrana* it is less than one-third. The toes of *pratti* are only three-quarters webbed as opposed to fully webbed, whilst the foot lacks an outer metatarsal tubercle.

Hyla mintima new species

Holotype: S.A.M. R.4151; ♂ collected at Mintima (lat. 5°57'S., long. 144°54'E.), Chimbu Region, at 6,000 ft., on June 1st, 1960.

Diagnosis: A moderately sized species closely related to *Hyla montana* Peters and Doria, with a small tympanum, reduced webbing between the fingers and extensively webbed toes. The specific name is that of the type locality.

Description of Holotype: Vomerine teeth in two oblique series between the rounded choanae, separated from each other and the choanae by a distance approximately two-thirds the length of one of them; tongue one-half as wide as mouth opening, almost circular, its posterior border not emarginate; snout large, rounded when viewed from above, strongly convex in profile, the upper jaw extending considerably beyond lower; nares lateral, their distance from end of snout slightly less than that from eye. Canthus rostralis prominent, slightly concave; loreal region oblique. Eye large, prominent, its diameter slightly greater than its distance from naris, pupil horizontal; interorbital distance almost equal to width of upper eyelid, which is relatively wide and slightly greater than internarial distance. Tympanum indistinct, annulus hardly visible, almost one-third the diameter of eye, separated from eye by distance greater than its own diameter.

Second finger webbed at base, third and fourth less than one-third webbed, first free. Fingers in decreasing order of length 3 > 4 > 2 > 1. Disc of first finger equal to tympanum, second, third and fourth considerably larger. Second, third and fifth toes webbed to disc, first and fourth to penultimate phalanx and continuing to disc as fringe. Toes in decreasing order of length 4 > 5 = 3 > 2 > 1, disc of second covering tympanic area; a distinct oval inner, but no outer metatarsal tubercle. A row of small tubercles on tarsus, a disinct fold on outer edge of fifth toe; a distinct crenulated fold on outer edge of forearm continuing as ridge along fourth finger.

Body not elongate, in post-axillary region a little narrower than greatest width of head; when hindlimb is adpressed, heel reaches naris; when limbs are laid along the sides, knee and elbow overlap considerably; when hindlimbs are bent at right-angles to body, heels overlap slightly. Skin of upper parts of head, body and limbs granular; strong fold of skin extends from posterior corner of eye to above insertion of forelimbs, hiding upper margin of tympanum. Abdomen and thighs coarsely granular, throat and thorax slightly so. Skin of head not co-ossified with skull. Male with nuptial pads (Fig. 3) and vocal sac.

Dimensions: Head and body 55·6 mm.; head length 21·5 mm.; head width 22·2 mm.; tibia 29 mm.

Colour in Alcohol: Dorsal surface deep plumbeous; grey beneath darkening posteriorly.

Colour in Life: Dorsal surface a very dark green. Side of head similar, with a dusky gold patch in the shape of an isosceles triangle beneath eye. Sides of body dark green spotted with gold on dorso-laterals and white on ventrolaterals. Throat and thorax pale slate grey spotted with white; abdomen and ventral surface of limbs deep violet stippled with white and cream.

Variation: Paratypes—Four adult ♂♂—Austral. Mus. R.17993-17994; B.M. 1962.157-158.

The paratypes were collected at the type locality on 1.6.60.

Body Length: 52·0-53·0 mm. TL/S-V = 0·55-0·61 (mean = 0·576).

The horizontal diameter of the eye is always less than the interorbital diameter, whilst distance between eye and naris is one and one-half to one and three-quarters of the internarial distance. The distance from eye to naris is greater than (approximately one and one-quarter) that between naris and the medial tip of the snout.

Colouration of the paratypes in alcohol and in life is similar to that of the holotype.

Comparison with Other Species: There are few New Guinea *Hyla* which possess the combination of the following characters: a tympanum which is less than half of the eye diameter; outer fingers with webbing which is either basal or extends for no more than one-third of the length of the digit, and vomerine teeth. Species fulfilling these requirements are *H. albolabris* Wandolleck, *H. angiana, H. arfakiana, H. montana, H. pratti* and *H. wollastoni*. *Hyla mintima* can be distinguished from most of these species by the extent of the webbing between the fingers and toes. *Hyla albolabris* has narrowly webbed toes, whilst they are fully webbed in *mintima*; the fingers of *wollastoni* have a very narrow basal webbing as compared to up to one-third webbing in *mintima*. The remaining four species all occur in the Central Highlands. *Hyla angiana* has one-third webbing of the fingers, but the head is far more depressed, with the interorbital breadth clearly greater than an upper eyelid and the colouration bears not the slightest resemblance to *mintima*; *H. arfakiana* has the first toe nearly free and only two-thirds webbing between the remainder, whilst *pratti* has only basal webbing between the second, third and fourth fingers.

The webbing of the hands and feet of *mintima* is almost identical to *montana*, to which it is apparently most closely allied. The latter has a broad head and larger tympanum. The interorbital space is greater than the width of an upper eyelid, whilst it is narrower in *mintima*. The disc of the first finger of *montana* is smaller than the tympanum, whilst the disk of *mintima* covers the tympanum. The colour patterns of the two species are quite distinct.

Hyla montana Peters and Doria

Hyla (*Litoria*) *montana* Peters and Doria, 1878, *Ann. Mus. Stor. nat. Genova*, 13, p. 423.

Material: Four adult ♂♂, two adult ♀♀. Austral. Mus. R.17989-17990; B.M. 1962.150-153.

Description: The vomerine teeth of the present series differ from the diagnosis of van Kampen (1923) in that they are situated in oblique instead of transverse rows. In four specimens they are directly between the choanae and between the posterior borders of the choanae in the fifth. The dermal folds on the back of the forearm occur as single rows of tubercles instead of a continuous ridge, and there is no inner metatarsal tubercle. TL/S-V = 0·55-0·60 (mean = 0·573).

Body length = 45·0-57·0 mm. ♂♂; 72·0-75·1 mm. ♀♀. Male with a nuptial pad on the first finger (Fig. 3).

The colour in life is a sandy brown on the dorsal surface, with pale green patches before and beneath the eyes and upon the scapulae. The ventral surface is pale grey suffused with pink. Van Kampen states colour in life to be "yellowish green". Despite this discrepancy there is such slight variation between the morphology of the present series and the elaborate description of the types that their identity as *H. montana* is made without reservation.

Locality: Collected upon the Wahgi-Sepik Divide within ten miles of Nondugl during the period 26.3.60-9.6.60. Altitude range: 6,400-8,700 ft.

Distribution: Hyla montana, as its specific name implies, is a montane species. The type locality is the Arfak Mountains in Dutch New Guinea, and other records include Humboldt Bay north of the type locality (van Kampen, 1914), and Toromanbanau in the Bismarck Mountains of the Australian Trusteeship Territory, by Loveridge (1948). There are no previous records of its occurrence in the Central Highlands.

Notes: One of the females (B.M. 1962.153) is gravid. The ova are unpigmented and approximately 2·5 mm. in diameter.

The native vernacular name of this species is "*Pee-un-day*".

DEVELOPMENT

Information on the development of *Nyctimystes* spp. is very limited. Zweifel (1958) examined gravid females of twelve species and reported that the ova often exceeded 2 mm. in diameter and in one species exceeded 3 mm. With the exception of *N. ruepelli* (Boettger) the eggs were unpigmented. Parker (1936) described the tadpoles of *N. montana* Parker and *N. semipalmata* and suggested that the dorso-lateral flattening of the bodies and the suctorial mouths which were common to these species might characterise other members of the genus.

Numerous clumps of spawn referable to the genera *Nyctimystes* and *Hyla* were found by the writer in February and March at elevations of 6,000-7,000 ft., but few could be associated with particular species. The clumps were situated either between stones at the waterline where they lay in water less than one inch deep or adhering to the undersurface of flat stones submerged in torrents. Water temperatures in these situations fluctuated between 13° C. and 17° C. The ova were unpigmented with diameters of 2·5-4·0 mm. The albumen surrounding them was gelatinous and so firm that it could be cut with a knife. Diameters of the outer vitelline membranes of individual eggs was 4·0-9·0 mm., and the number of eggs per clump averaged approximately 200. It was considered that fertilisation of spawn laid beneath stones could not have occurred at the site of the final deposition. Many of the clumps at the waterline were infested with dipterous larvae which devoured the ova. A note on these observations has been published elsewhere (Tyler, 1962b).

All tadpoles found in the mountain torrents were similar to those Parker described. Although the tadpoles of all *Nyctimystes* may prove to share those characteristics, the fact that *H. angularis* tadpoles are similarly adapted to montane conditions indicates that the genera cannot be distinguished by their gross morphological form.

In referring *Nyctimystes loveridgei* Neil to *Hyla*, Zweifel comments that the ova are "typical of *Hyla*, being small, with a dark animal hemisphere". Although the ova of *H. darlingtoni* fit this description, those of *H. iris* are green and *H. angiana, H. angularis, H. becki, H. micromembrana* and *H. montana* are unpigmented. Thus the eggs of *H. darlingtoni* may be typical of the majority of species in this widely distributed genus, but they are apparently atypical when compared with other highland species in both appearance and site of deposition. The selection of static or slowly moving water for the deposition of spawn by *H. darlingtoni* has prevented this species from establishing itself at higher altitudes, but the remaining *Hyla* of the Central Highlands appear to be as well adapted to montane conditions as are *Nyctimystes.*

The arboreal spawning habits of *H. iris* are by no means unique. Arboreal spawning has not previously been reported from the Papuan region and the closest parallel is probably exhibited by Neotropical frogs. Noble (1927) states that all *Phyllomedusa* spp. deposit spawn on leaves of foliage above pools and, referring to the field notes of Mr. C. M. Breder, Jr., reported similar sites for a *Centronella* species in Panama believed to be *C. parabambae.* Dunn (1924) reported that *H. uranochroa* from the same region laid eggs on leaves above streams.

THE STATUS OF THE GENUS *NYCTIMYSTES* WITH NOTES ON THE APPEARANCE OR ABSENCE OF GENERIC CHARACTERISTICS IN LIFE

Stejneger (1916) erected the genus *Nyctimystes* for New Guinea Hylidae which had been referred to the South American genus *Nyctimantis* by Boulenger (1897, 1914) on the grounds that he considered the faunae of these regions could not be closely related. Noble (1931) suppressed *Nyctimystes* and referred the species back to *Nyctimantis.* This decision was reversed by Parker (1936), a move subsequently supported by Zweifel (1958). It is of interest to note that several of the genera sharing either the palpebral venation or the vertical pupil which, when together in New Guinea Hylids are diagnostic of *Nyctimystes,* are in fact South American. Although not disputing the opinion of Parker that *Nyctimystes* represents a homogeneous group of true generic status, there are occasional discrepancies between the appearance of living frogs and the generic definition of Zweifel (*loc. cit.*) which was based on preserved specimens. For example, the pupil of live *N. narinosa* is a horizontal slit, and is not vertical in any of the series of that species discussed in this paper.

Although tropical American frogs of the genus *Phyllomedusa,* with which *Nyctimystes* has been compared, and which includes species possessing the salient characters of the latter, may be distinguished by the form of hands and feet; habits are similar. *Nyctimystes* has very sensitive digits which are well suited for grasping narrow branches, but the first finger is not opposable as in the former genus.

The palpebral venations of living *Nyctimystes* are more distinct than in preserved specimens, and have a metallic appearance in several species.

Mature males in the present collection and the type series of *N. gularis* possess a nuptial pad which extends further proximally, than in the *Hyla* spp. examined. This may prove to be a further characteristic for distinguishing members of the two genera. The proximal border of the nuptial pad of *Nyctimystes* covers the phalango-metacarpal joint, and occasionally the distal end of the phalanx. In *Hyla* it terminates on the proximal head of the metacarpal.

DISTRIBUTION

Of the eleven members of the Hylidae which occur in the Central Highlands, no less than six must currently be regarded as endemic to this area. That such a proportion of the species should be regarded as endemic is not so surprising when allowance is made for the fact that much of the vast area of land which separates the Central Highlands from the northern and southern coastal belts is

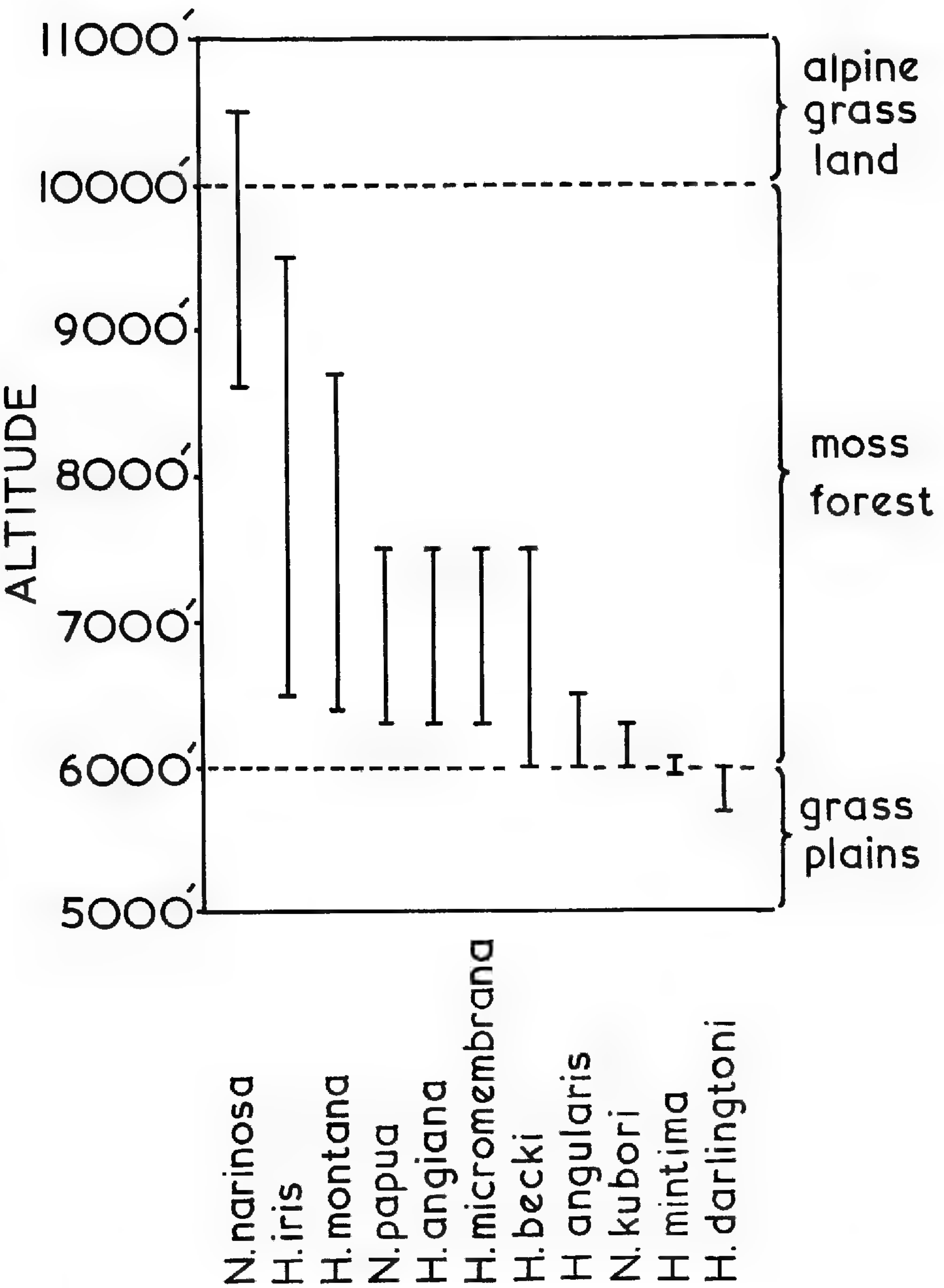

Fig. 7. Altitudinal distribution of the Hylidae of the Central Highlands. (Based on the writer's observations on the Wahgi-Sepik Divide.)

virtually unexplored and the herpetofauna therefore completely unknown. Locality records indicate that the non-endemic species, *Nyctimystes papua*, *Hyla angiana*, *H. arfakiana*, *H. montana* and *H. pratti*, select a montane habitat and have not been collected at altitudes lower than 5,000 ft.

Distribution may be partly associated with climatic conditions. For example, specimens of the distinctive *N. humeralis* (Boulenger) were collected by the writer near the source of the Jimmi River, in tropical forest at approximately 2,000 ft., yet were not found on the Wahgi-Sepik Divide ten miles to the south, which is subjected to far lower temperatures. The herpetofauna of the tropical regions surrounding the highlands will probably show greater affinities to coastal forms than to the montane.

In Fig. 8 the range of altitudes at which *Nyctimystes* and *Hyla* spp. were observed in the vicinity of Nondugl are compared.

CHECK LIST OF CENTRAL HIGHLANDS HYLIDAE

Nyctimystes kubori Zweifel
Nyctimystes narinosa Zweifel
Nyctimystes papua (Boulenger)
Hyla angiana Boulenger
Hyla angularis Loveridge
Hyla arfakiana Peters and Doria
Hyla becki Loveridge
Hyla darlingtoni Loveridge
Hyla iris Tyler
Hyla micromembrana new species
Hyla mintima new species
Hyla montana Peters and Doria
Hyla pratti Boulenger

Four specimens of *H. pratti* in the British Museum collection (B.M. 1953.1.7.49-52) were collected in 1951 at Tomba, near Mt. Hagen, by Mr. F. M. Shaw Mayer. Loveridge (1948) regarded *pratti* to be a sub-species of *H. montana* which is apparently sympatric, but there is now little doubt that they are members of a group of closely allied species, so the writer prefers to recognise their distinct specific status.

Nyctimystes flavomaculata Forcart is excluded from the above list as it has been referred to the synonymy of *H. darlingtoni* and *N. humeralis* (Boulenger) on the grounds that the specimens from the Kubor Mountains determined as this species by Zweifel (1958), are now regarded to be of a distinct and probably undescribed species (Zweifel, *in litt.*).

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ROCK ENGRAVINGS OF PANARAMITEE STATION, NORTH-EASTERN SOUTH AUSTRALIA

BY C. P. MOUNTFORD AND R. EDWARDS

Summary

This paper records the rock engravings on Panaramitee station in northeastern South Australia. The engravings are figured and their designs and antiquity discussed. Rock engravings, the designs of which are made up of a series of abrasions or peck-marks, are widespread throughout Australia, having been recorded, among others, by Basedow (1914, pp. 195-210) from South Australia; Wilkins (1928, p. 80) from Northern Queensland; Mountford (1960, pp. 145-147; 1929, pp. 337-66) from Central and South Australia; Davidson (1936, pp. 30-66) from Delamere in the Northern Territory; Lindsay Black (1943, pp. 9-76) from Western New South Wales, and Hall, McGowan and Guleksen (1951, pp. 375-80) from Eucolo on the Nullabor Plain. North-eastern South Australia is particularly rich in examples of this art. Basedow (1914, pp. 195-210) described two sites and Mountford (1929, pp. *337*-66) fifteen from that area. During 1926 one of us (C.P.M.) recorded rock engravings on Panaramitee station. The authors of this paper have recently undertaken a comprehensive survey of the rock engravings of this area. Two factors were responsible for this choice; the unstinted help and hospitality of the Wade family of Panaramitee station and the fact that there appeared to be more rock engravings within the boundaries of this station than elsewhere in South Australia. The results of that survey form the subject of this paper.

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[Read 12 April 1962]

SUMMARY

This paper records the rock engravings on Panaramitee station in north-eastern South Australia. The engravings are figured and their designs and antiquity discussed.

Rock engravings, the designs of which are made up of a series of abrasions or peck-marks, are widespread throughout Australia, having been recorded, among others, by Basedow (1914, pp. 195-210) from South Australia; Wilkins (1928, p. 80) from Northern Queensland; Mountford (1960, pp. 145-147; 1929, pp. 337-66) from Central and South Australia; Davidson (1936, pp. 30-66) from Delamere in the Northern Territory; Lindsay Black (1943, pp. 9-76) from Western New South Wales, and Hall, McGowan and Guleksen (1951, pp. 375-80) from Eucolo on the Nullabor Plain.

North-eastern South Australia is particularly rich in examples of this art. Basedow (1914, pp. 195-210) described two sites and Mountford (1929, pp. 337-66) fifteen from that area. During 1926 one of us (C.P.M.) recorded rock engravings on Panaramitee station. The authors of this paper have recently undertaken a comprehensive survey of the rock engravings of this area. Two factors were responsible for this choice: the unstinted help and hospitality of the Wade family of Panaramitee station and the fact that there appeared to be more rock engravings within the boundaries of this station than elsewhere in South Australia. The results of that survey form the subject of this paper.

LOCALITY

Panaramitee station, 206 miles to the north-east of Adelaide, has an area of 120 square miles (Map, Fig. 1). The many creeks which rise in the short ranges and rolling hills of the property flow through open valleys to a wide plain (Plate 1D) which, in turn, is drained by the Yunta Creek.

Although the average annual rainfall is about eight inches a year, the country, during the period of this survey, had suffered from a series of droughts. Five successive years of extremely dry conditions had considerably reduced the natural herbage of saltbush (*Atriplex vesicarium*) and bluebush (*Kochia sedifolia*). Nevertheless, the fact that we saw numbers of kangaroos, emus, lizards, goannas, snakes and other game whilst engaged on this survey showed that, prior to the advent of Europeans, the aborigines would have had an adequate supply of food, even during drought seasons.

WATER SUPPLY

The only permanent spring on Panaramitee station is known locally as Salt Creek (Map, Fig. 1). The water of this spring is now salty, although, according to the old European residents, the water was fresh fifty years ago. If this is correct, Salt Creek would have been a good water supply when the aborigines inhabited the country.

Nevertheless we found that all the engravings on Panaramitee station are adjacent to some form of water supply, usually rockholes of varying sizes, some large enough to hold water for several months (Plate 1C). At the completion of this survey we were fortunate to witness the breaking of the drought conditions when a series of thunderstorms brought heavy rains which transformed the country causing the creeks to run swiftly and the numerous rockholes to fill. Similar conditions must have provided a period of plenty and consequent leisure for the aborigines.

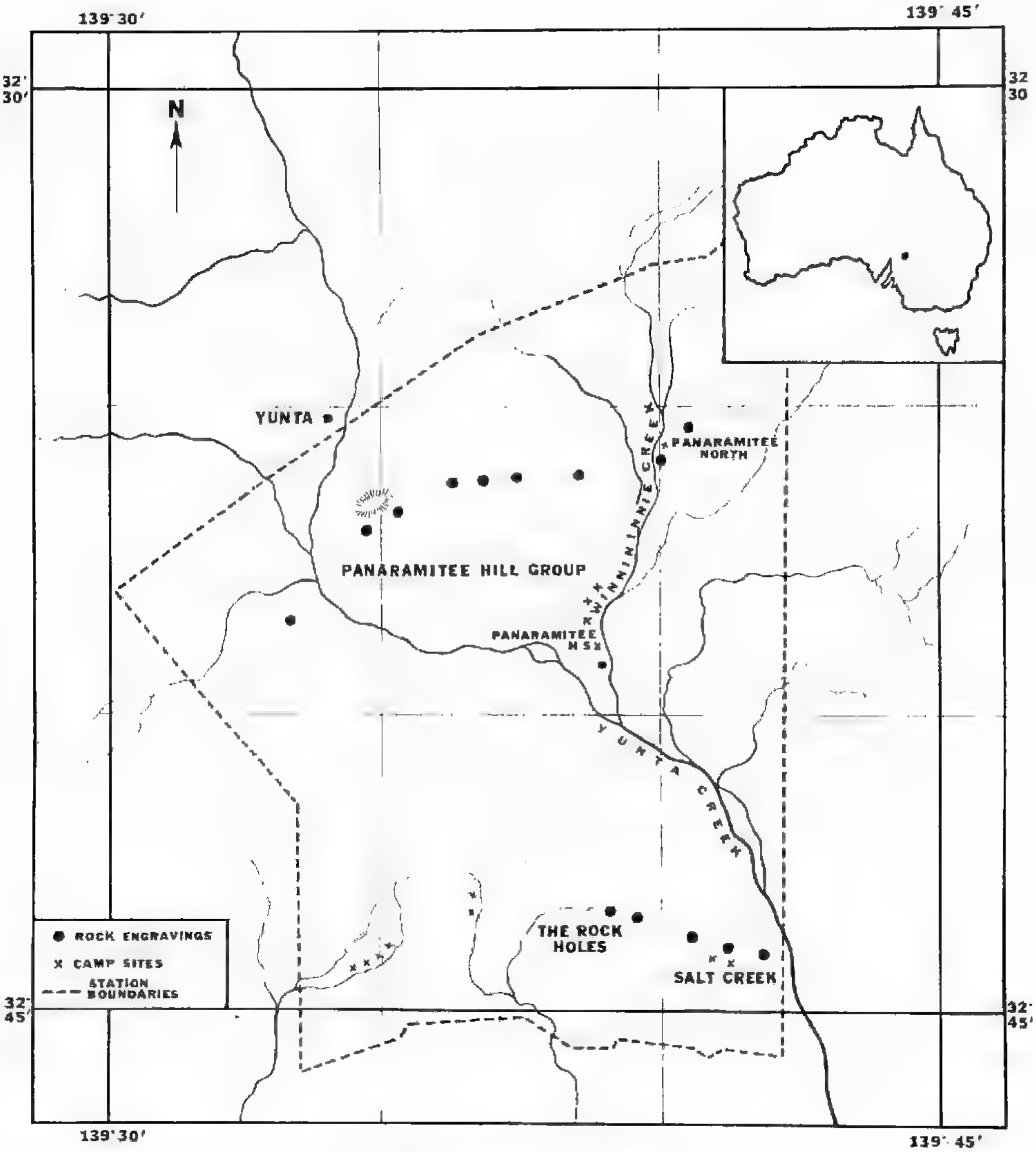

Fig. 1. Panaramitee Station.

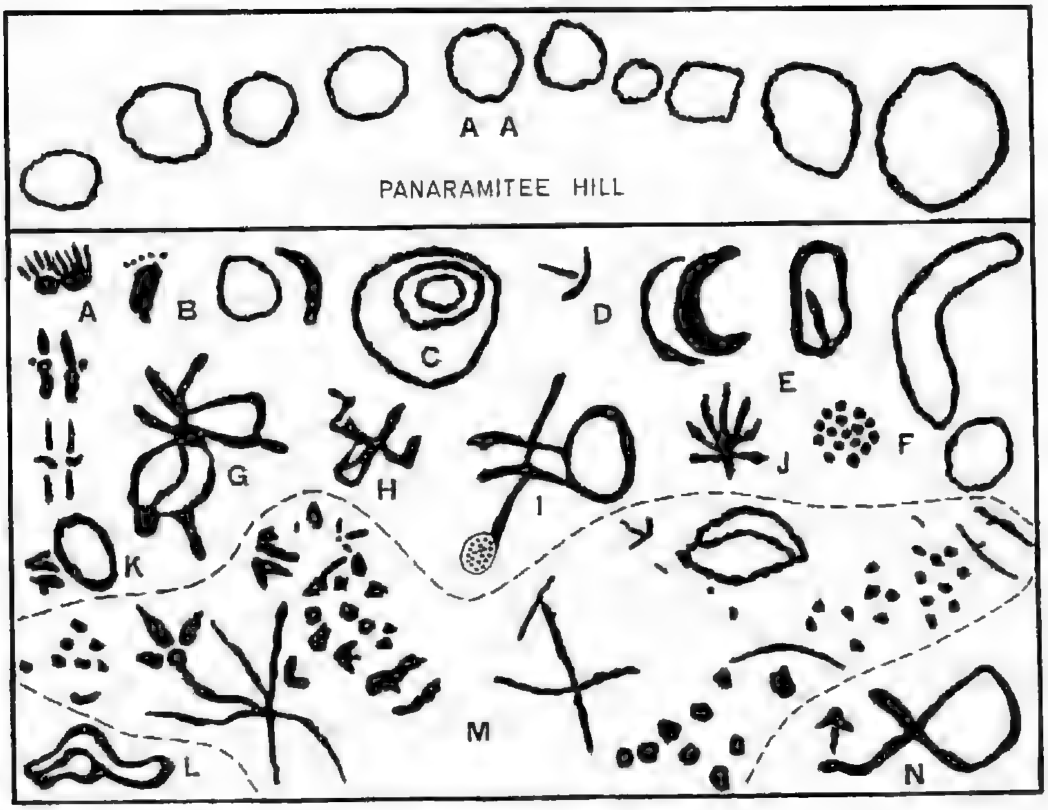

Fig. 2. Panaramitee North.

DESCRIPTION

For the purposes of this paper the engravings on Panaramitee station are divided into four groups, i.e. Panaramitee north, Salt Creek, the Rockholes and the Panaramitee Hill group (Map, Fig. 1). Mountford (1929, pp. 344-52) described and localized Salt Creek and Panaramitee north in 1928. Mountford's Salt Creek group extends for over two miles along a valley which commences at Salt Creek and terminates at a group of rockholes to the west (Map, Fig. 1). This group, divided by a brief area devoid of engravings, has now been separated into two sections, Salt Creek and the Rockholes.

PANARAMITEE NORTH

Mountford (1929, pp. 349-52) recorded designs from Panaramitee north (Map, Fig. 1) on the Winnininnie Creek. During 1929 Mountford (1929, pp. 245-48) discovered and later described a remarkable rock engraving of the head of the sea-going crocodile (*Crocodilus porosus*). Hale and Tindale (1929, p. 30) also published a small note on the same subject. A further examination by the authors has revealed another unusual engraving of what appears to be a salt-water fish.[1]

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[1] This and other unusual engravings in the area have now been published (Mountford and Edwards, 1962, Article, 174).

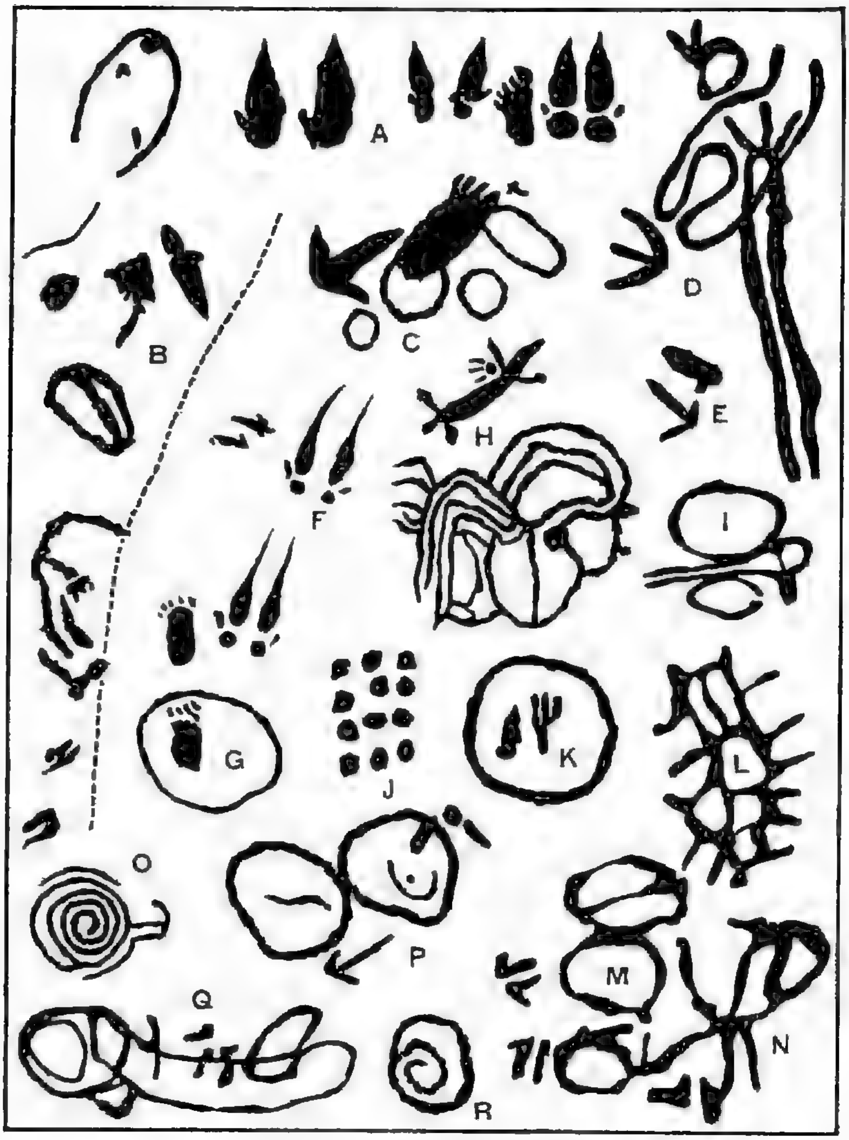

Fig. 3. Panaramitee North.

There are several large outcropping rocks at Panaramitee north (Map, Fig. 1), which the aboriginal artists (who have shown preference for the large, smooth surfaces) have covered with engravings. These rock surfaces continue into the bed of the creek where they are also engraved with some well-finished examples of aboriginal craftsmanship (Fig. 3F, G).

At Panaramitee north there is a large series of unidentifiable designs such as Figs. 2G, H, I, L, N; 3D, H, L, M, and Q. There are many circles (Figs. 2B, F, I, K; 3C, G, K and P), as well as several concentric circles (Fig. 2C), barred circles (Fig. 3B and M) and spirals (Fig. 3R and O). There are also numerous engravings of animal, bird and reptile tracks (Figs. 2A; 3A, E, F, and Plate 2A).

Several engravings found to continue below ground level are illustrated in Fig. 3B, the broken line indicating the land surface. Hale and Tindale (1925, pp. 53-54) also recorded whole or partially buried designs in the Northern Flinders Ranges.

SALT CREEK

This locality (Map, Fig. 1) has an open plain on its eastern margin while on its western side the ground rises gradually from Salt Creek until it forms a series of rolling hills.

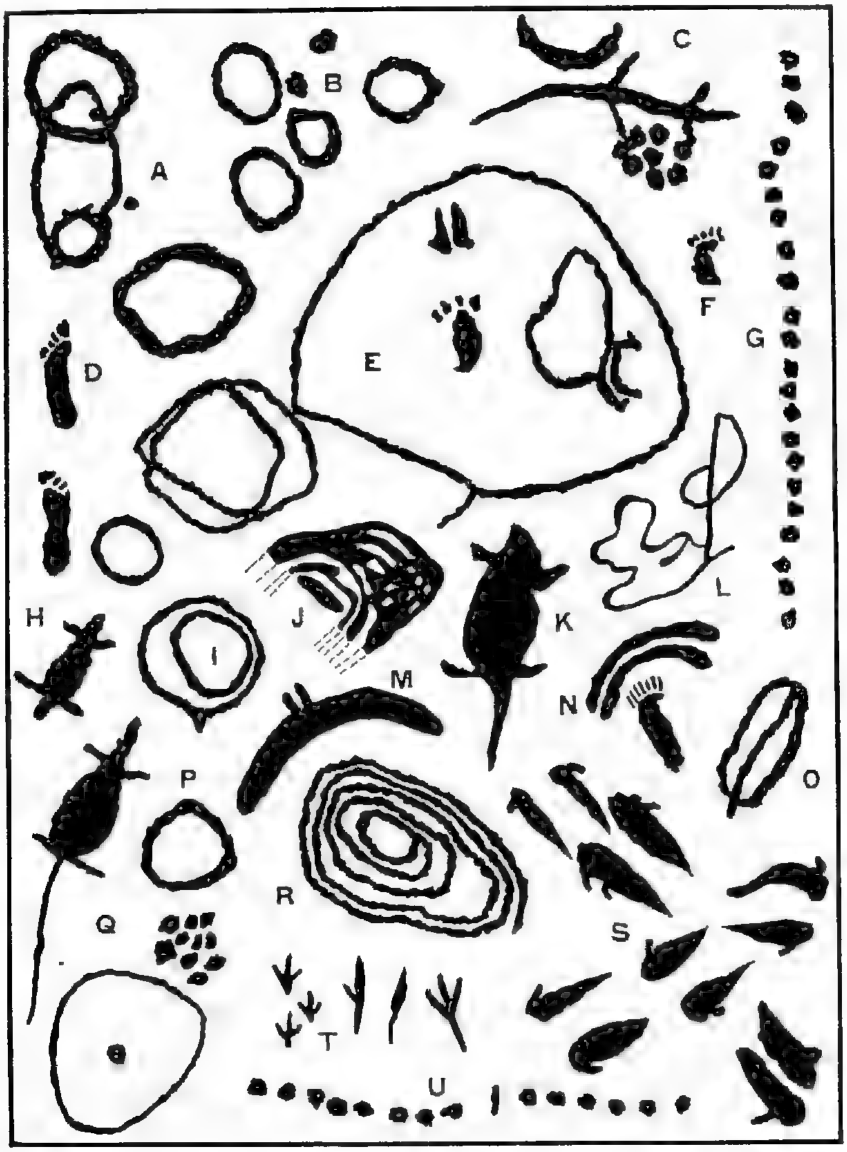

Fig. 4. Salt Creek.

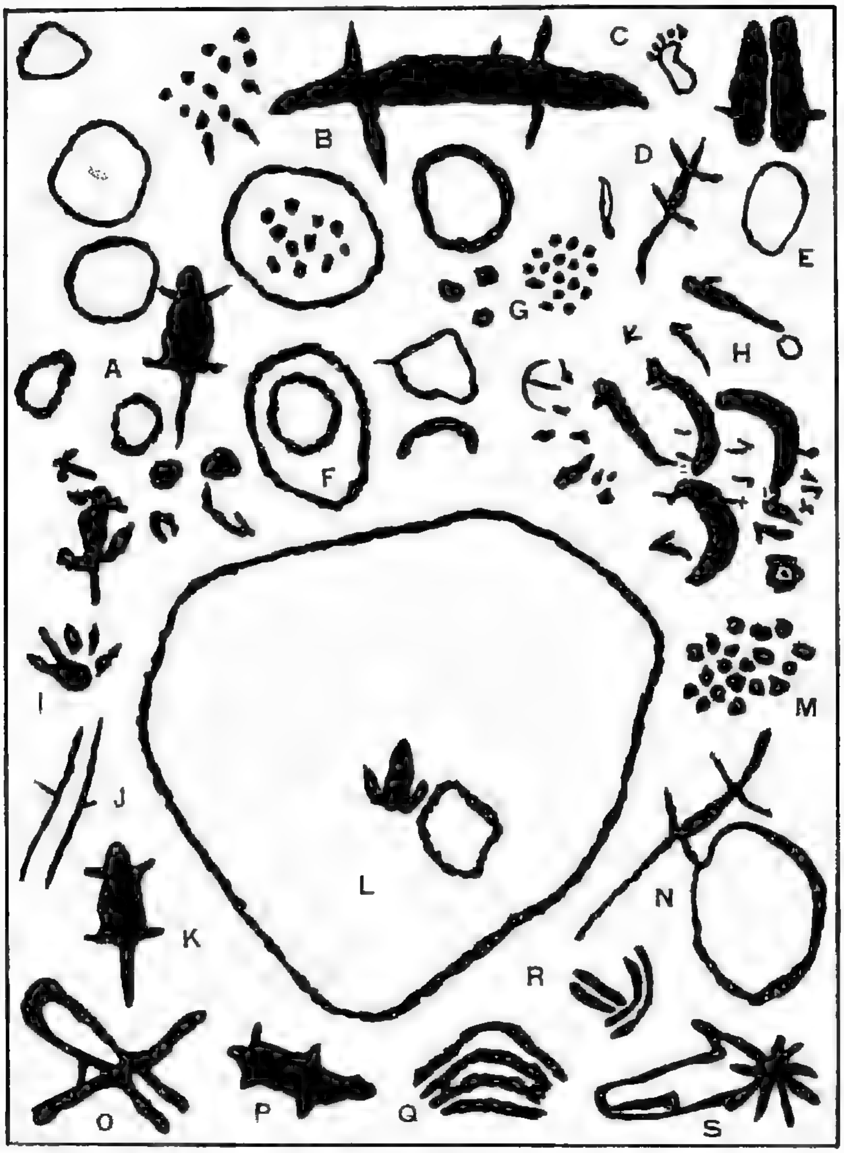

Fig. 5. Salt Creek.

A large outcropping rock extends westward from the bed of Salt Creek providing smooth, flat areas of stone on which the aboriginal artists have engraved many designs (Plate 1A).

Salt Creek is more extensive in area and richer in designs than Panaramitee north. The greatest number of engravings we saw depicted the tracks of the creatures. These were so numerous and similar in design that we have only recorded a few examples. Fig. 4T, shows a series of unidentified bird tracks; Fig. 4S, a particularly well-preserved group of kangaroo tracks; Fig. 5E, a pair of large kangaroo tracks associated with a circle; Fig. 5J, a pair of elongated kangaroo tracks; Fig. 6G, kangaroo tracks adjacent to a lizard design; Fig. 6H, a pair of bird tracks and a circle, and Fig. 6P a heterogeneous series of tracks.

Many of the lizard designs, all of which are fully intagliated resemble the living reptiles. It is likely that Figs. 5N and 6N are goannas (*Varanus gouldii*) and Fig. 4C a goanna adjacent to its nest of eggs. Although Figs. 4H, 5B and P resemble stump-tail lizards (*Trachysaurus rugosus*), it is not possible to identify the other engravings of lizards such as Figs. 4K, Q; 5A, D, K; 6B, G, Q, and 7N. On the other hand, Fig. 6M bears more than a passing resemblance to the jew-lizard (*Amphibolurus barbatus*). There is also an unusual engraving of an emu (Fig. 7B, Plate 2D), whose head and neck have disappeared due to erosion. These are indicated by dotted lines.

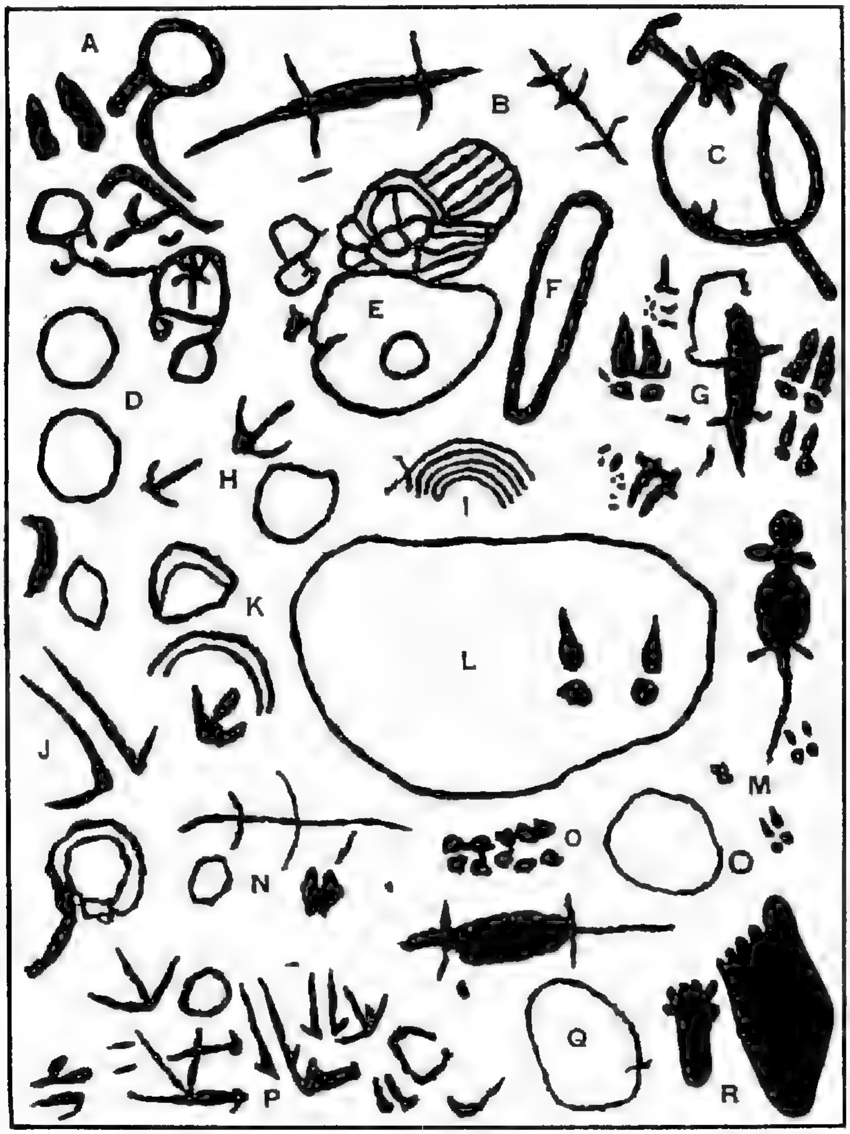

Fig. 6. Salt Creek.

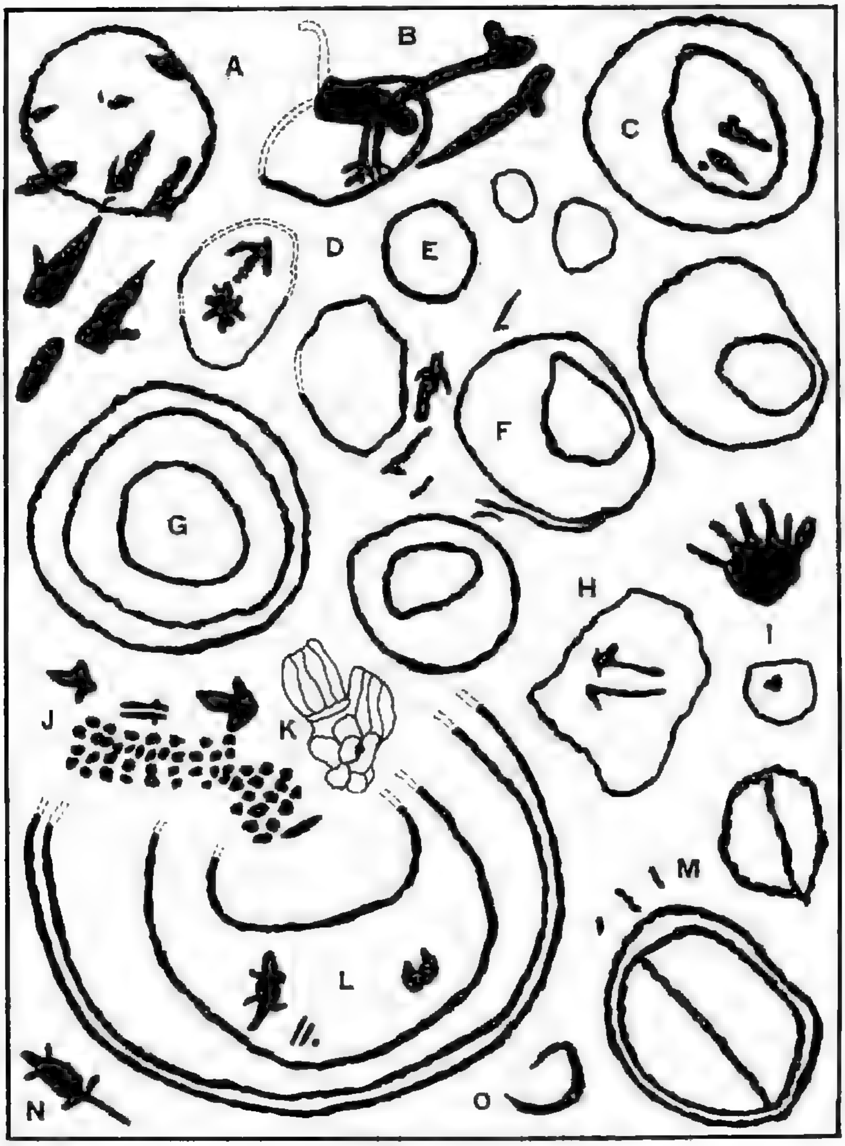

Fig. 7. Salt Creek.

The simple circle, one of the more common designs at Salt Creek[2] is shown on Figs. 4P; 6D and 7E although sometimes the circle is adjacent to other designs as in Figs. 4H; 5A, N; 6M and N. The circle is also associated with tracks (Figs. 5E and 6H), while multiple circles form the more complex designs of Figs. 4A, B and 5A, the largest circle recorded being four feet in diameter. Many simple and concentric circles enclose other designs such as Figs. 5B; 6L; 7C, D and H. The concentric circle is common (Figs. 4I; 5F and 7G), whereas the barred circle (Fig. 4O) and the spiral design (Fig. 4R) are uncommon.

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[2] The circle is a common design in South Australia; Campbell (1925, pp. 123-127) records a group of engravings at the Burra, South Australia, which is composed almost entirely of these designs.

Only six examples of human foot-prints are recorded from Salt Creek (Figs. 4D, E, F, N; 5C and 6R). There are a number of small intagliated circles in this locality, usually about one inch in diameter. Some of these are arranged in systematic groups (Figs. 4C, Q; 5G and M); some in long lines (Fig. 4G and U), while others form irregular patterns (Figs. 6O and 7J).

At Salt Creek the crescent designs vary widely both in size and form. On Fig. 4M there is a single crescent with two small appendages, while 4N is a double crescent associated with a human foot. There is a wide difference between the irregularity of Fig. 5H and the orderly groups of crescents on Figs. 5R, Q and 6I. Unidentifiable designs are figured on Figs. 4J, L; 5O, S, and 6A, C and E.

Fig. 8. The Rockholes.

THE ROCKHOLES

The Rockhole group of engravings (Map, Fig. 1), so named because they are adjacent to natural rockholes, is the largest, in both area and in abundance of engravings, of any of the groups on Panaramitee station. The outcrops of rock on which the engravings are situated are scattered over a distance of one and a half miles along the floor of an open valley.

There are many unusual designs among the maze of rock engravings in the Rockhole group; the snake with eggs (Fig. 8D); an engraving of emu tracks (Fig. 12E) which probably represent an emu with chicks; a line of kangaroo tracks (Fig. 9E), which depict a kangaroo first sitting on its heels, then sitting with its forepaws on the ground, then sitting up again, then again with its forepaws on the ground, then hopping away; each set of prints is approximately

Fig. 9. The Rockholes.

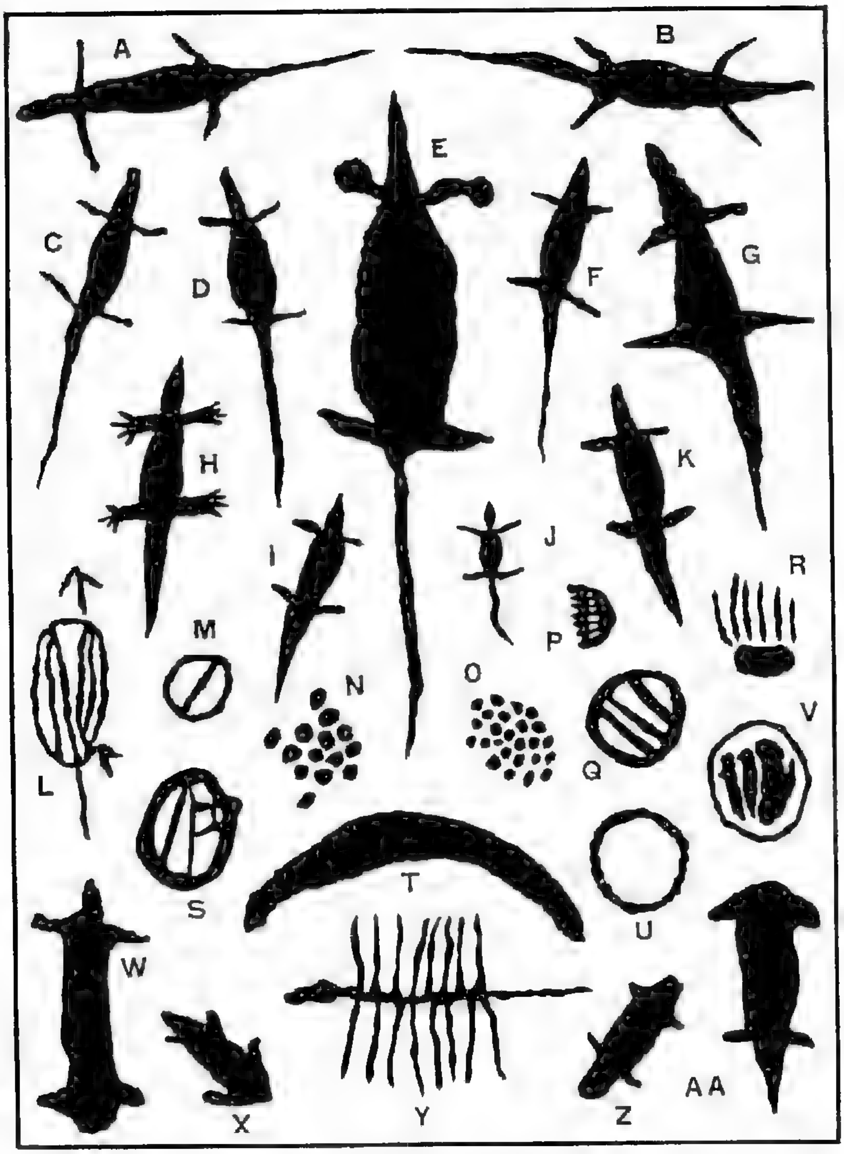

Fig. 10. The Rockholes.

twenty inches apart. There is a line of human footprints (Fig. 12A), probably those of an adult and child; another line of footprints of an adult (Fig. 12G), and a number of individual engravings of footprints, which are grouped together for purposes of illustration (Fig. 9A). There is also a series of decorative but unidentifiable designs (Figs. 8A, B, J, K, P, R; 10Y; 11C, D, L and N).

Lizard designs are also common at the Rockholes, but although Fig. 10W, X, Z and AA probably represent the stump-tail lizard (*Trachysaurus rugosus*), many of the other lizard designs on Fig. 10 cannot be identified. The largest engraving of a lizard (Fig. 10E) was three feet in length.

As at Salt Creek the circle is common among the designs at the Rockholes, i.e., simple circles (Fig. 10U); simple circles enclosing other designs (Figs. 8C;

10V; 11F, K, M, O and S); concentric circles (Fig. 11T); concentric circles enclosing tracks (Fig. 11P, Q), and barred circles (Figs. 8C; 9P, Q, R; 10L, M and Q). Three interesting designs with radiating lines are shown in Figs. 8I; 9H and 11G. There are also a number of disc-like engravings, similar to those at Salt Creek (Figs. 8G, S; 9J, O; 10N, O and 11I), as well as some groups of crescentic engravings probably representing boomerangs (Figs. 8F, H, Q; 9D, M; 10T; 11J, F, and 12C).

PANARAMITEE HILL GROUP

This group commences on rising ground about two miles west of the Winnininnie Creek (Map, Fig. 1). A recent washaway has uncovered several large flat outcrops of rock on which we found the engraved designs shown on Fig. 13H.

Further westward a valley leads towards Panaramitee Hill, the highest point on the station (Map, Fig. 1). Scattered among these hills are numerous rock outcrops, some of which contain small rockholes. Adjacent to these rockholes are a number of engravings (Fig. 13 excluding H), the most outstanding being a line of circle designs (Fig. 2AA).

Near a small watercourse at the base of Panaramitee Hill there are also some indistinct rock engravings, while two miles south-west a further series is situated on rock outcrops on a hillside (Map, Fig. 1). Among this group are engraved human footprints (Fig. 12M, N, Q and R), and a pair of carvings of the forepaws of a kangaroo as well as a large emu track (Fig. 12.O).

DISCUSSION

The engravings recorded in this paper are more or less typical of those found in South Australia where, except for the incomplete engraving of an emu at Salt Creek (Fig. 7B), and possibly a small bird at Wabricoola (Mountford, 1929, Fig. 152), there are no engravings of the creatures on side elevation, all the other examples, such as the reptiles, being in plan. In contrast to this, the engravings recorded from Koonawara and elsewhere in western New South Wales by Pulleine (1926, pp. 180-182); Dow (1938, pp. 101-120); Black (1943, pp. 9-76) and Mountford (1962, pp. 245-48), depict human figures, kangaroos and other creatures in side elevation. At present there is no evidence to explain this wide variation of motifs less than two hundred miles apart.

ANTIQUITY

A number of writers, Basedow (1914, pp. 198-203); Campbell (1925, pp. 123-127); Hale and Tindale (1925, p. 55); Mountford (1929, pp. 341-342); and Cooper (1941, p. 1), have suggested that the rock engravings of South Australia are of considerable antiquity. This hypothesis is supported by Mountford (1960, p. 145), who states that the aborigines attribute a mythical origin to these engravings. The fact, too, of the engraving of the head of a sea-going crocodile at Panaramitee north (Mountford, 1929, pp. 243-247) 1,000 miles south of the locality where the crocodile now lives, suggest that this engraving is of considerable antiquity. Engravings recently discovered of a sea-going turtle and fish still further support this hypothesis of antiquity (Mountford and Edwards, 1962, Article 174).

Further indications of antiquity are suggested by heavy patination and the condition of many of the engravings. Although on Panaramitee station many of the engravings on the flat smooth surfaces are in an excellent state of preservation, there are numerous examples which are badly eroded and some where the rock surface has so disintegrated that only small portions of the engravings remain (Plate 2C). Basedow (1914, pp. 195-210) recorded similar conditions in other parts of South Australia.

TECHNIQUES

The engravings have been produced, in both outline and full intaglios, by a series of abrasions or peck-marks (Plate 1B). Because this rock art is no longer a part of the living culture, we have no first-hand information about the methods employed to produce these rock engravings, nor did a close search in the vicinty

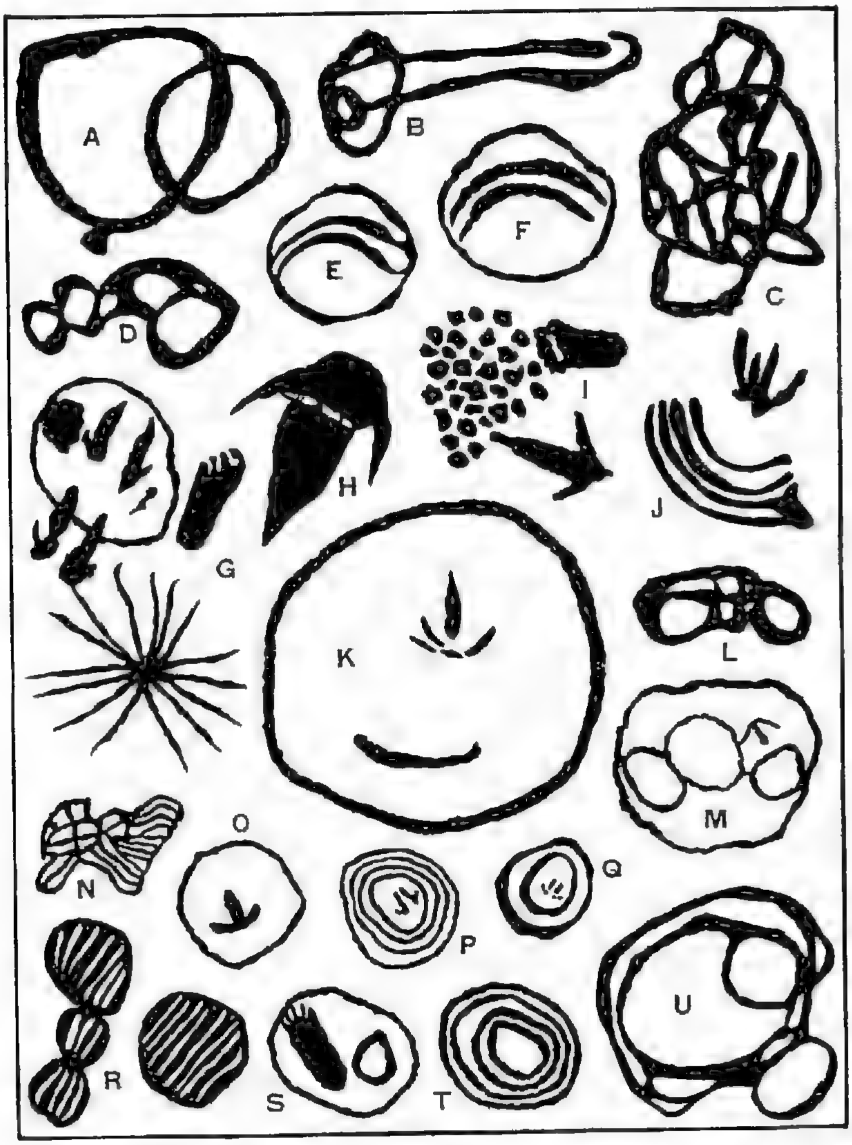

Fig. 11. The Rockholes.

of the groups of engravings on Panaramitee station disclose any tools that could have been used for this purpose. As it is possible, however, to cut identical markings by striking the surface with a sharp-edged boulder of hard stone held in the hand, it appears likely that those who made the ancient rock markings used similar tools. Examination of a number of incomplete engravings indicate that the aboriginal artist first outlined the design with light surface pecking before he removed the inner surface with repeated blows (Plate 2B).

STRAIGHT-LINE MARKINGS

We found several small groups of straight-line markings or incisions among the pecked engravings on Panaramitee station. This particular type of engraving

Fig. 12. The Rockholes and Panaramitee Hill.

has been recorded by a number of investigators; Basedow (1914, pp. 195-210) described a group at Mallett, in South Australia; Tindale and Mountford (1926, pp. 156-159) at Morowie; Mountford (1929, pp. 337-60; 1960, pp. 145-147) at Winnininnie Springs, Yunta Springs, Wabricoola, Oulnina and Ewaninga; Davidson (1936, pp. 59-60) at Delamere, Northern Territory; and Cooper (1941, pp. 1-3) at Marree, South Australia. Basedow when describing the straight-line markings at Mallett, stated they were the result of the sharpening of the implement used to produce the nearby engravings. Mountford, who was not in agreement with Basedow's opinion, stated (1935, p. 212) that although it is possible to produce these markings with a sharp stone implement, such as a stone axe, this operation would dull rather than sharpen the edge of the tool.

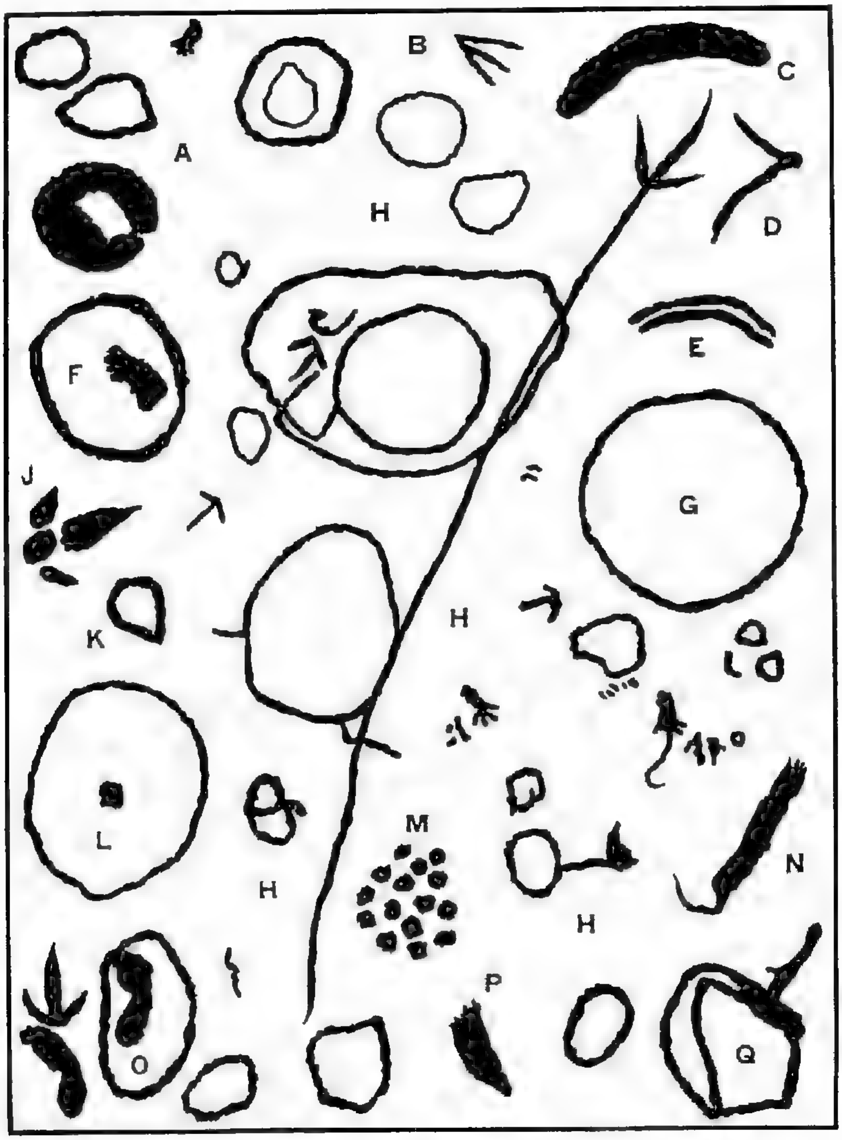

Fig. 13. Panaramitee Hill.

METHOD OF RECORDING

The figures accompanying this paper were prepared by first carefully outlining the engravings with chalk, then tracing them on transparent paper. These tracings, when filled in with Indian ink, were then reduced photographically to a size suitable for reproduction. With the exception of Fig. 9E which is reduced eighteen and Fig. 2AA seventeen times; the remainder having been reduced approximately twelve times.

ACKNOWLEDGMENTS

The authors wish to acknowledge the full co-operation and interest of the Wade family without whose assistance this survey would not have been possible. Mr. Igor Zorich and Mr. George Holman assisted with field work; the Surveyor-General, Mr. H. A. Bailey, and Mr. W. R. Marchant of the S.A. Lands Department gave advice in the preparation of the map of Panaramitee station; and Mr. K. T. Borrow helped with the photographs. Acknowledgment is also made to the S.A. Museum for the use of their facilities.

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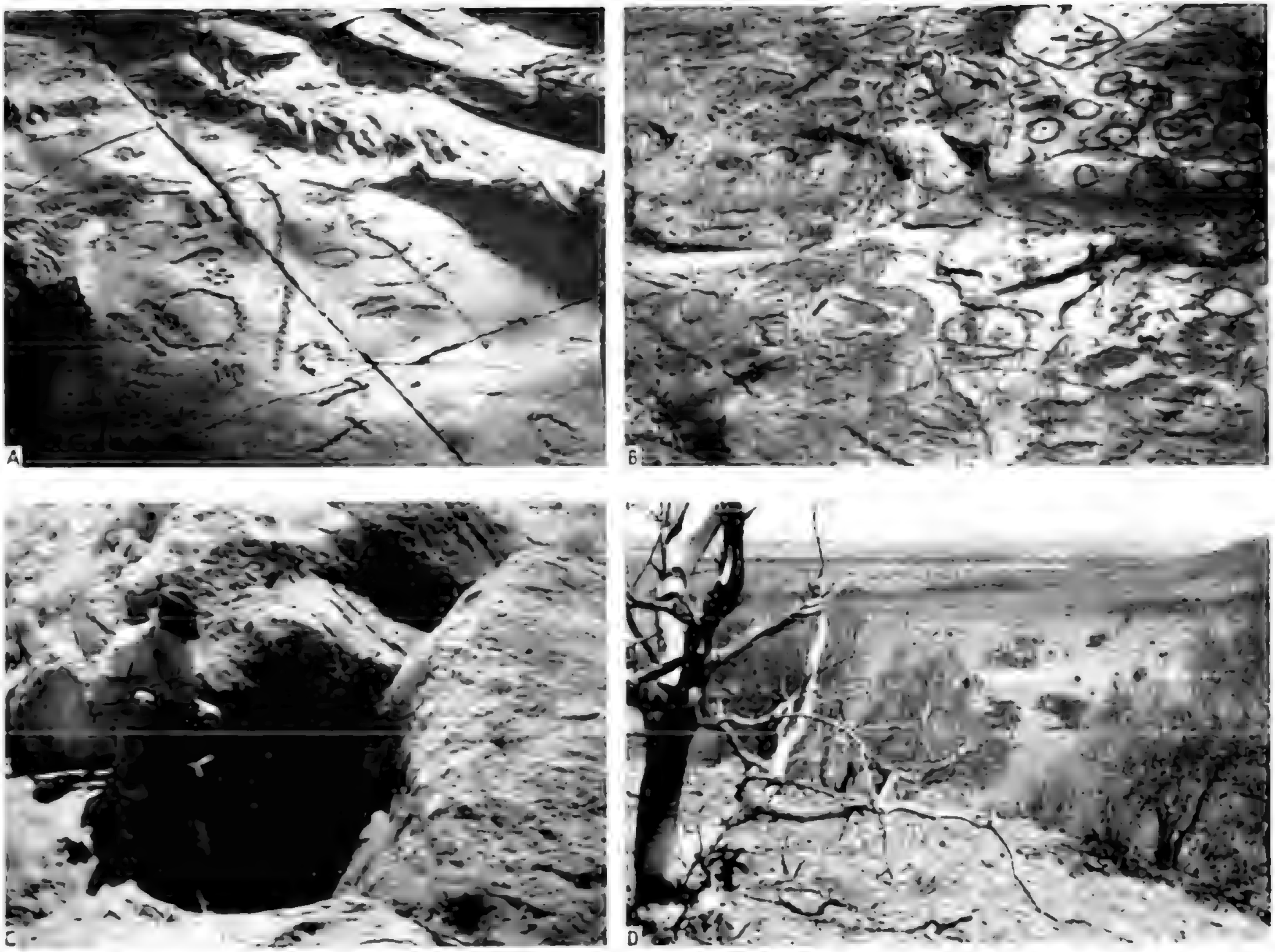
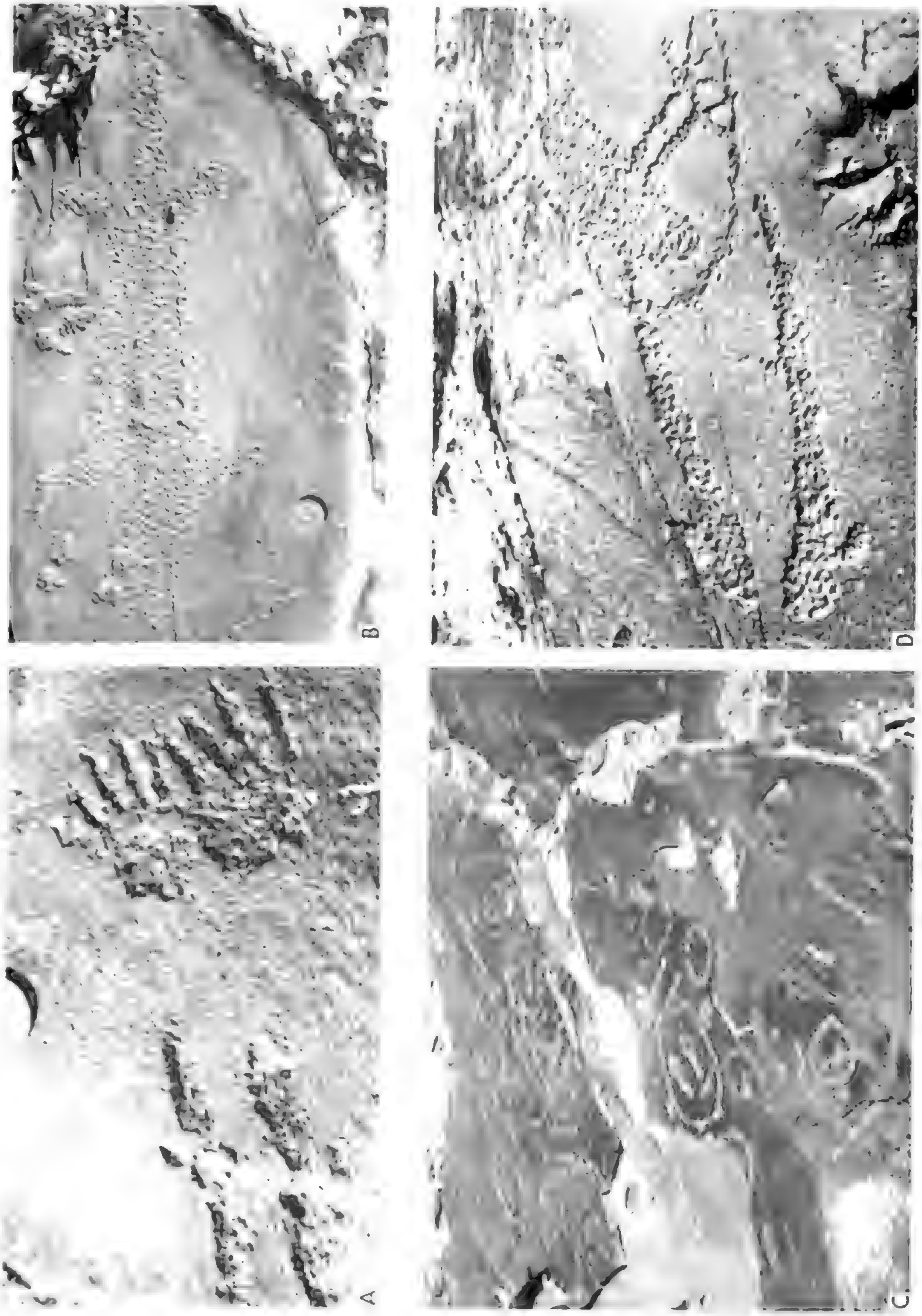


Rock Engravings, Panaramitee, South Australia. A. Engraved Rock Surface, Salt Creek. B. Extensively Engraved Surface, Rockhole Group. C. Rockhole Adjacent to Engravings. D. Topography, Panaramitee Station.



A. Feet and Paw Marks of Kangaroo, Panaramitee north. B. Lightly Pecked Lizard Design, Salt Creek. C. Engraved Pavement Showing Effects of Extensive Erosion. D. Paired Kangaroo Tracks and Incomplete Emu.

TWO NEW SPECIES OF ACARINA FROM BAT GUANO FROM AUSTRALIAN CAVES

BY H. WOMERSLEY

Summary

In the present paper two new species of Acarina found associated with the guano of bat caves in the Eastern States of Australia and South Australia are described. The first, *Coproglyphus dewae* sp. nov. (fam. Tyroglyphidae, subfam. Carpoglyphinae) is entirely of coprophilous habit in all stages. The other, *Neotrombidium gracilare* sp. nov. (fam. Leeuwenhoekiidae) has only been found in the guano as adults, and is probably only coprophilous in that stage. The larvae when known may on analogy with the larval species *N. (Monunguis) streblidum* (Wharton), be found parasitic on Streblidae or other ectoparasites of bats. The known species of *Neotrombidium*, whether known as adults or larvae, are discussed and their possible hosts considered.

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by H. Womersley*

[Read 12 April 1962]

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In the present paper two new species of Acarina found associated with the guano of bat caves in the Eastern States of Australia and South Australia are described. The first, *Coproglyphus dewae* sp. nov. (fam. Tyroglyphidae, subfam. Carpoglyphinae) is entirely of coprophilous habit in all stages. The other, *Neotrombidium gracilare* sp. nov. (fam. Leeuwenhoekiidae) has only been found in the guano as adults, and is probably only coprophilous in that stage. The larvae when known may on analogy with the larval species *N.* (*Monunguis*) *streblidum* (Wharton), be found parasitic on Streblidae or other ectoparasites of bats.

The known species of *Neotrombidium*, whether known as adults or larvae, are discussed and their possible hosts considered.

Suborder SARCOPTIFORMES Reuter, 1909.

Family TYROGLYPHIDAE Donnadieu, 1868.

Subfamily CARPOGLYPHINAE Ouds., 1923.

Genus COPROGLYPHUS E. and F. Türk, 1956.

Türk, E. and F., 1956. Syst. u. Ökol der Tyroglyphiden Mitteleuropäischer Acarina, Bd. 1, Teil 1, pp. 44, 45 and 181.

Type *C. stammeri* E. and F. Türk.

This genus, placed by E. and F. Türk in the subfamily Carpoglyphinae, was erected for a new species found in bat guano from Erlangen in Germany.

Whereas Vitzthum, 1941, lists only the genera *Carpoglyphus* Robin, 1869, and *Ferminia* Oudemans, 1928, in the subfamily and Zachvatkin, 1941, includes *Hyadesia* Megn., 1889, and *Hericia* Can., 1888, along with *Carpoglyphus*, the Türks include *Hericia*, *Cohieria* Ouds., 1938, besides the type genus and their new genus *Coproglyphus*. Of the genera mentioned *Hyadesia* is now included in a separate subfamily, the Hyadesinae, while *Cohieria* Ouds., 1938, is a synonym of *Ferminia*[1] Ouds., 1928.

The four genera are keyed as follows (after E. and F. Türk):

1. Propodosoma in all stages with lens-like organs.
Carpoglyphus Robin 1869
No such organs present 2

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* South Australian Museum.

[1] The genus *Ferminia* was erected by A. C. Oudemans, 1928 (8), for *Glyciphagus fuscus* Ouds., 1902. In 1939 (9) he re-named the genus *Gohieria* citing *Ferminia* as being used earlier by Barbour, 1926, for a honey-eater (Proc. New England Zool. Club, 9, p. 74) on information received from Dr. W. Meise of Dresden. Actually, according to Neave's Nomen. Zoologicus, 5, 1950, the name used by Barbour was *Ferminaria* not *Ferminia*, hence the latter and not *Cohieria* is the valid generic name for *Glyciphagus fuscus* Ouds., 1902.

Trans. Roy. Soc. S. Aust. (1963), Vol. 86.

2. Dorsal setae simple 3
Dorsal setae more or less clavate or spathulate and ciliate. *Coproglyphus* E. and F. Türk 1956

3. Legs with strong spines. In tree sap ... ... *Hercia* Canest 1888
Legs with simple or feathered setae ... ... *Ferminia* Ouds. 1928

The genus *Coproglyphus* is defined by the Türks as follows: "Epimera I in both sexes joined. In the male epimera III joined with epimera IV. All other epimera free ending. Female genital orifice between coxae II and III; in male, genital orifice between coxae III and IV.

Type *Coproglyphus stammeri* n. sp."

Coproglyphus dewae sp. nov.

Fig. 1 A-H.

Description.—Holotype female (Fig. 1 A-D): Shape broadly oval but squarish posteriorly. Dirty white in colour. Surface of dorsum strongly wrinkled with irregular lines. Length of idiosoma 322,[2] width 226. Legs I (excluding coxae) 182 long, II 187, III 211, IV 240.

Dorsum.—(Fig. 1A): With a lightly defined propodosomal shield, suture between propodosoma and hysterosoma ill-defined, pseudostigmatic organs on margins of propodosoma lateral of the shield well sclerotised and with a curved tapering and ciliated pseudostigmal seta posteriorly to 15 long, at the anterior end of the pseudostigmal organ with a minute seta (? Grandjean's organ). With 14 pairs of dorsal setae of varying lengths as follows: vertical internal (vi) 55, vertical exterior (ve) 41, inner propodosomal (ip) 58, outer propodosomal (ep) 58, first dorsal (d1) 44, second dorsal (d2) 17, third dorsal (d3) 15, fourth dorsal (d4) 15, inner humeral (hi) 58, outer humeral (he) 64, first lateral (l1) 29, second lateral (l2) 15, third lateral (l3) 15, posterior (p) 17, all these setae are blunt, ciliated and rod-like and tend to show a longitudinal splitting in the longer ones (Fig. 1C).

Venter.—(Fig. 1B): Epimera I united medially to form a short sternum touching the genitalia anteriorly, epimera III and IV joined. Coxae I, III and IV with a single simple seta, that on IV about three times as long as those on I and III. Genital orifice between coxae II and III, with a distinctly sclerotised boomerang-shaped plate anteriorly, with two pairs of short setae and the usual two pairs of small discs or suckers, length of orifice 90. Anal orifice 73 long, reaching tip of opisthosoma, with four pairs of short paranal setae. Midway between genital and anal orifices with one pair of short setae and posteriorly on each side of the anus a long simple seta (pa) to 260 in length. Posteriorly a short bursa copulatrix. The legs are fairly stout and subequal in length, tarsi all with a single claw on a long caruncle and reaching past the pulvilli; there appears to be no solenidia on tarsi I and II, but the tibiae of these legs carry a long recurved subapical seta.

Allotype Male.—(Fig. E-H): General facies as in female. Length of idiosoma 264, width 163. Legs I 152 long, II 154, III 172, IV 182.

Dorsum.—As in female but setae relatively shorter, vi 32, ve 26, ip 26, ep 26, d1 17, d2 6, d3 6, d4 9, hi 29, he 35, l1 15, l2 9, l3 9, p 9 and pa 131.

Venter.—(Fig. 1E): With the epimera as in the female. Genital orifice between coxae III and IV, with one pair of setae and the anterior sclerotised

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[2] All measurements in micra (μ).

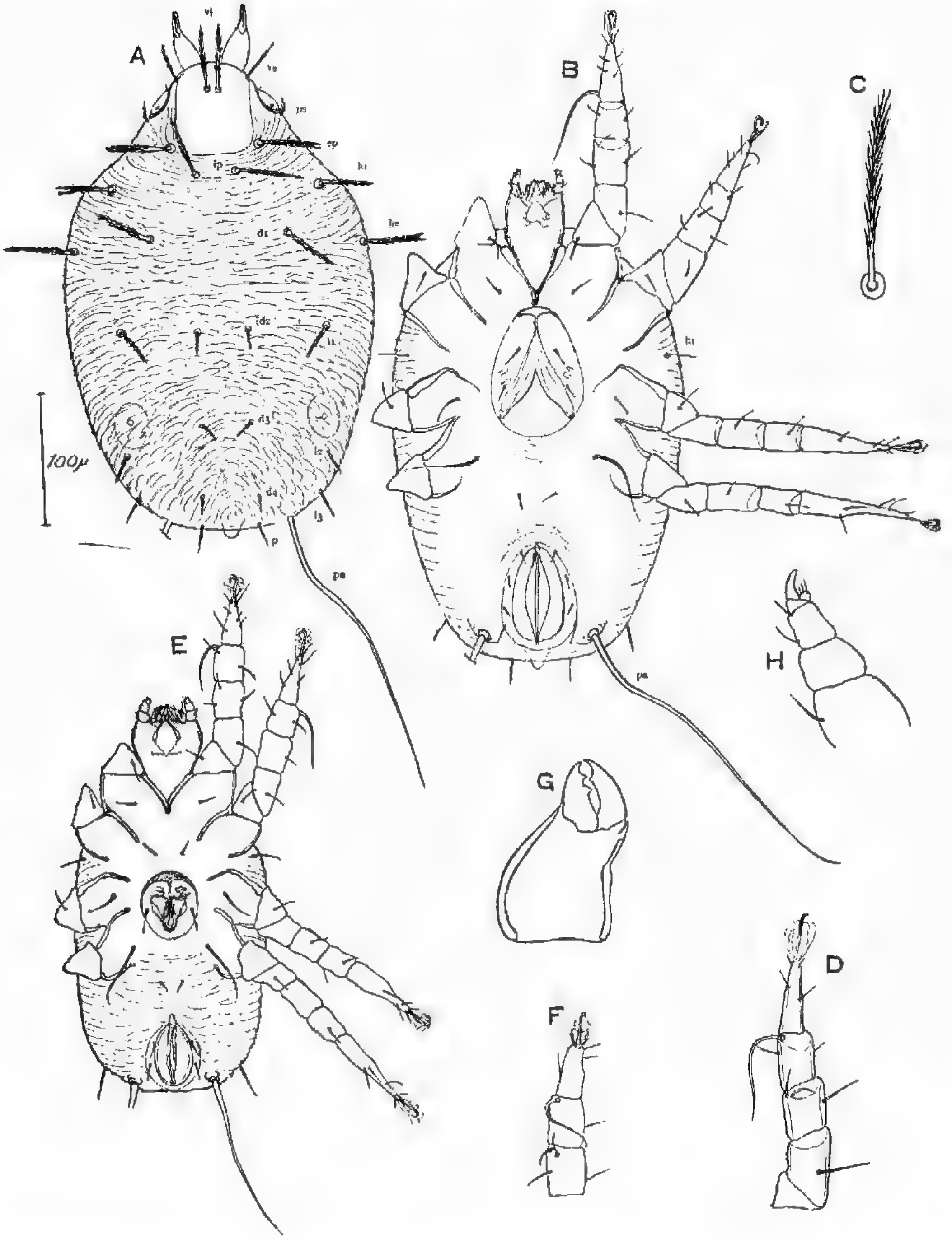

Fig. I. *Coproglyphus dewae* sp. nov. A, dorsal view of female; B, ventral view of female; C, dorsal setae; D, leg I of female; E, ventral view of male; F, genu, tibia and tarsus of leg IV of male; G, mandible; H, palp.

boomerang-shaped plate as in the female. Coxal setae as in the female. There are only two pairs of anal setae, and a single pair of short setae between genital and anal orifices.

Locality and Habitat.—Numerous specimens from bat guano from Fig Tree Cave, Wombeyan, New South Wales, 21st Aug., 1960, collected by Miss Barbara Dew, to whom the species is dedicated. Also from Railway Tunnel, North Sydney, N.S.W. (coll. B.D. 12/8/60), Basin Cave, Wombeyan, N.S.W., 21/8/60 (B.D.), and from Naracoorte, South Australia, Oct., 1961 (P. Aitken).

Location of Types.—In the South Australian Museum.

Comparison with the Genotype.—This new species has the same habitat as the genotype *Coproglyphus stammeri* E. and F. Türk. It differs in that the Türks' figures show the dorsal setae of *stammeri* to be of almost uniform length and slightly more clavate, whereas in *deweae* there are marked differences in the setae lengths, those of the d series except d1 being very much shorter. In *stammeri* the pseudostigmal setae are described as simple and not ciliated.

Suborder TROMBIDIFORMES Reuter 1909.

Family LEEUWENHOEKIIDAE Womersley 1948.

Leonardi, G., 1902. Acari sudamericani—Zool. Anz., 25, p. 18.

Type *Trombidium furcigerum* Leon., loc. cit., 17.

Neotrombidium gracilare sp. nov.

Fig. 2 A-N.

Description.—An elongate oval species with the hysterosoma narrower than the propodosoma and with a slight constriction between (Fig. 2A). Dorsum thickly furnished with trident-like setae (Fig. 2C, D) the tines of which are barbed and the middle tine the longest, all tines of equal thickness and apically pointed. Crista on an indistinct shield (Fig. 2B) with a transversely oval posterior sensillary area carrying long, fine, distally shortly barbed or ciliated setae; anteriorly the crista ends in a narrow elongated nasus with two simple but barbed setae (homologous with the anterior median scutal setae of larval Leeuwenhoekiidae). Eyes two on each side, sessile on ocular shields, in front of the middle of the crista, posterior eyes the smaller. Mandibles (Fig. 2E) very long and narrow, fixed digit slender, and non-serrated. Palpi with single claw on tibia, and a tibial comb of about 10-12 strong simple curved spine-like setae, on the inner face with a single spine-like seta scarcely stronger than the comb setae; tarsi slightly over-reaching tip of tibial claw. Legs long and slender, not exceeding body length, furnished with simple barbed setae, tarsi I 4 to 5 times as long as high, with small paired claws, claws of other legs somewhat larger, coxae in two groups widely separate and with tapering barbed setae (Fig. 2I and J), coxae of leg I with the outer anterior angle produced and cone-like (Fig. 2I). Genitalia with two pairs of elongate oval discs (Fig. 2K).

Holotype Female.—Length of idiosoma (mounted) 1580, width across propodosoma 720. Crista 245 long, sensillae 86, sensillary area 29 long by 48 wide, anterior setae 70. Mandibles 246 long. Palpal claw 35. Dorsal setae anteriorly 43, posteriorly 52 long; ventral setae 30 long. Genital opening 192 long. Anal opening 82 long. Legs I 979 long, II 706, III 787, IV 1018; tarsus I 254 long by 72 high.

Allotype Male.—Length of idiosoma 1162, width across propodosoma 504. Legs I 926 long, II 821, III 917, IV 1200: tarsus I 312 long by 62 high.

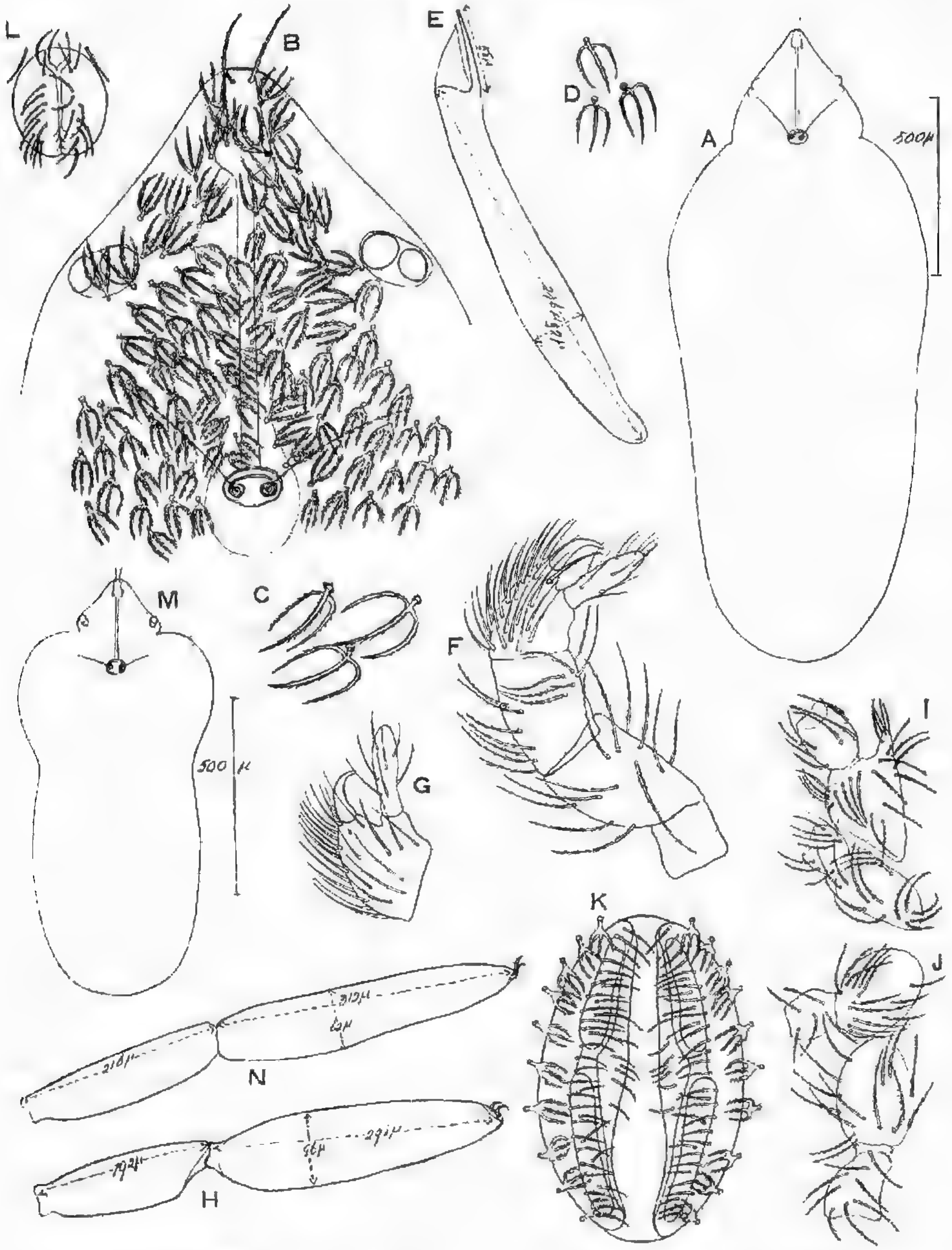

Fig. 2. *Neotrombidium gracilare* sp. nov. A-L female: A, body outline; B, anterior of propodosoma showing crista and eyes; C, medial dorsal setae; D, ventral setae; E, mandible; F, palp from inside; G, palpal tibia and tarsus from outside; H, tibia and tarsus of leg I (holotype); I, coxae I and II; J, coxae III and IV; K, genital orifice; L, anal orifice; M-N, male: M, outline of body; N, tibia and tarsus of leg I of allotype.

Other Specimens.—Six other females showed some variation in size, being generally rather larger than the type. The length of the legs and proportions of the front tarsi were also variable, as follows: Legs I 987-1181 (mean 1092), II 598-797 (742), III 720-893 (828), IV 979-1152 (1074); ratio tarsal length to height 3·5-4·4 (4·1). The larva is unknown.

Locality and Habitat.—The holotype female from bat guano from Fig Tree Cave, Wombeyan, New South Wales, Aug. 21st, 1961 (coll. Miss B. Dew). A smaller specimen, probably a nymph, from similar habitat from Murder Cave, Cliefden, N.S.W., Apr. 2nd, 1960 (B.D.). A further eight specimens, of which one was a male (the allotype), have been received from bat guano from Punchbowl Cave, N.S.W., collected by Messrs. D. Purchase and F. Slaker, June 7th, 1958.

Location of Types.—South Australian Museum.

Remarks on the Genus Neotrombidium

Southcott in his review of the genus (11) lists five species known from the adult, viz. *N. furcigerum* Leon. 1902, from Argentina, *N. opthalmicum* (Berl. 1888) from Paraguay, *N. barringunense* Hirst 1928, from Australia, *N. tricuspidum* Borland 1956, from North Carolina, and *N. neptunium* Southcott 1961, from Queensland. Of these, only two, *barringunense* and *tricuspidum*, are included in a list of five species known from the larvae. The other larval species are *N. strcblidum* (Wharton, 1938) (=*Monunguis* Wharton, 1938) from Mexico, a new species undescribed recorded by Borland, 1956, from N. America, and *N. tenuipes* Womersley (=*Cockingsia* Womersley, 1954) from Malaya. Since Southcott's paper two other adult species have been described by André (1) from Angola, viz. *N. elongatum* and *N. armatum*. Thus with the new species *N. gracilare* described herein eight species of adults are now known and these can be keyed as follows:

Key to the known adult species of *Neotrombidium* Leon.

1. Median tine of dorsal setae more or less clavate 2
   Median tine of dorsal setae pointed like the lateral tines 4

2. Median tine of dorsal setae 2 to 3 times as long as the laterals and with scale-like surface. Tarsi I ca. 3 times as long as high, 105μ by 55μ. Dorsal setae to 25μ long (median tine) *N. elongatum* André, 1957 (Angola)
   Median tine of dorsal setae only slightly longer than the laterals and with denticulate surface 3

3. Tarsi I 3 times as long as high, 210μ by 70μ. Dorsal setae to 35μ long. Palpal tibia with comb of four strong curved spines *N. armatum* André, 1957. (Angola)
   Tarsi I twice as long as high. Dorsal setae to 50μ long. Palpal tibia with comb of four strong curved spines. Tarsi I slightly more than twice as long as high, 200μ by 90μ. *N. neptunium* n. nov. Southcott, 1961. (=*tridentifer* Southcott, 1957, non. Ewing, 1909.) (Queensland, Australia.)

4. Tines of dorsal setae not serrate, setae to 15μ long. Tarsi I 150μ long by 70μ high *N. opthalmicum* (Berl., 1888). (Paraguay.)
   Tines of dorsal setae serrated 5

5. Dorsal setae to 70μ long, median tine not much longer than laterals. Tarsi I ca. 3 times as long as high, 200μ by 70μ. *N. furcigerum* Leon., 1901.
Genotype (Argentina).

Dorsal setae much shorter 6

6. Coxae I with a pronounced extension of the outer anterior angle. Dorsal setae to 43μ long. Tarsi I ca. 4 times as long as high, 240μ-318μ (mean 279μ) by 57μ-82μ (68·4μ). Palpal tibia without accessory claw, with comb of 10-12 strong simple curved spines *N. gracilare* sp. nov.
(New South Wales and South Australia in bat guano.)

Coxae I normal 7

7. Dorsal setae to 35μ long. Tarsi I three times as long as high 216μ by 72μ. Palpal tibia with 3 comb spines near base of claw.
N. barringunense Hirst, 1928.
(Queensland, Australia.)

Dorsal setae shorter, to 26μ. Tarsi I about twice as long as high, 170μ by 83μ. Palpal tibia with only one strong accessory spine near base.
N. tricuspidum Borland, 1956.
(North America)

The biotope for most of these adult species is under loose bark or in leaf debris, except for *gracilare* which was found in bat guano in caves in Eastern Australia, inhabited by the common bat, *Miniopteris schreibersii blepotis* Temminck. No reference to the habitat of the two South American species, *N. furcigerum* and *N. opthalmicum*, are given; but these also may possibly be from under bark.

The hosts of the known larval species with the exception of *N. streblidum* (Wharton) which is parasitic on Streblid flies, and *N. barringunense* Hirst, still unknown, are timber infesting beetles of the families Cerambycidae and Cleridae. The following table summarises knowledge of the habitat of all eight species.

TABLE 1.

Species	Adult	Larva	Adult biotope	Host of larva
furcigerum	+		?	?
opthalmicum	+		?	?
barringunense	+	+	under bark	?
tenuipes	—	+	—	Coleoptera, Cerambycidae.
tricuspidum	+	+	under bark	Coleoptera, Cerambycidae.
neptunium	+	—	under bark, & leaf litter.	?
sp. undescribed	—	+	—	Coleoptera, Cleridae.
elongatum	+	-	under bark	?
armatum	+		in leaf debris	?
streblidum	-	+	—	Diptera, Streblidae.
gracilare	+	—	in bat guano	?

In 1954, Southcott (10) suggested the synonymy of the genus *Monunguis* Wharton, erected for a species *streblida* Wharton found parasitic on bat flies, *Pterellipsis araneae* Coq. and *Trichobius dugesii* Townsend (Diptera, Streblidae) from a cave at Yucatan, Mexico, with *Neotrombidium*. Borland, 1956 (4), was somewhat doubtful of this synonymy but upon examination of a cotype expressed the opinion "that while recognition of the synonymy may be expedient at the present time, as more data became available the two genera may be validly separated". From a close study of Wharton's figures and descriptions there are a number of features which might separate it from *Neotrombidium* but regretfully Borland did not refigure or redescribe the species. Until such times as this can be done, there is some doubt as to the synonymy.

Cockingsia Womersley, 1954, for *tenuipes* Womersley from Malaya was also synonymised in 1957 (11) by Southcott and this is certainly valid and the adult when known will undoubtedly be a typical *Neotrombidium*.

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A NEW SPECIES OF FORCELLINIA (ACARINA, TYROGLYPHIDAE) FROM BEE HIVES IN WESTERN AUSTRALIA

BY H. WOMERSLEY

Summary

A new species *Forcellinia galleriella* sp. nov. from bee hives in Western Australia is described. The hives were heavily infested with larvae and pupae of the wax moth, *Galleriella melonella,* upon which the mites were apparently feeding.

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by H. Womersley[*]

[Read 12 April 1962]

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Family TYROGLYPHIDAE LATREILLE 1796.

Subfamily Tyroglyphinae Ouds. 1932.

Genus Forcellinia Ouds. 1924.

Oudemans, A. C., 1924 Analytical Key for the Classification of Families and Genera of Diacrotricha Ouds., 1906 (Acari) — Ent. Ber. VI, No. 135, pp. 226-235.

Type *Tyroglyphus wasmanni* Moniez, 1892.

Only three species of this genus are known. The genotype, *F. wasmanni* (Moniez), is known from both male and female as well as the deutonymph. It has been abundantly recorded, Michael (1), Zachvatkin (4), and E. and F. Türk (3), from the nests of many species of ants in Europe. *F. fuliginosa* E. and F. Türk, 1956, is only known from the male and deutonymph from the nest of an ant, *Lasius faliginosus*. A third species, *F. rufae* n. sp., was described by E. and F. Türk, 1956, from the nests of *Formica rufa* from the deutonymph only.

The new species here described occurred in numbers in a bee hive strongly infested with the wax moth, *Galleriella melonella*, at Perth, Western Australia, forwarded by Mr. G. D. Rimes.

Only the adults were found, no deutonymphs being observed.

Forcellinia galleriella sp. nov.

Description: *Female holotype*.—Fig. A-D. Length of idiosoma 440[1], width 290. Shape, oval. Colour, a dirty white.

Dorsum: With a quadrate propodosomal shield. With 12 pairs of long setae excluding the pseudostigmal (ps), all strongly and shortly ciliated; setae d1, d2, d3, and l1 slightly clavate, the rest blunt and tapering; vi 57, ve 48, ps 24, sci 62, sce 72, d1 48, d2 58, d3 72, d4 72, p 192, l1 67, l2 53, l3 144, h 106. Palpi two segmented. Chelicerae as figured, with two or three teeth on each digit.

Venter: Genital opening between coxae III and IV. Epimera of leg I joined medially to form a short sternum, epimera of other legs free; only coxae I and III with a short fine seta. Anal opening 86 long as figured.

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[*] South Australian Museum.

[1] All measurements in micra (μ).

Trans. Roy. Soc. S. Aust. (1963), Vol. 86.

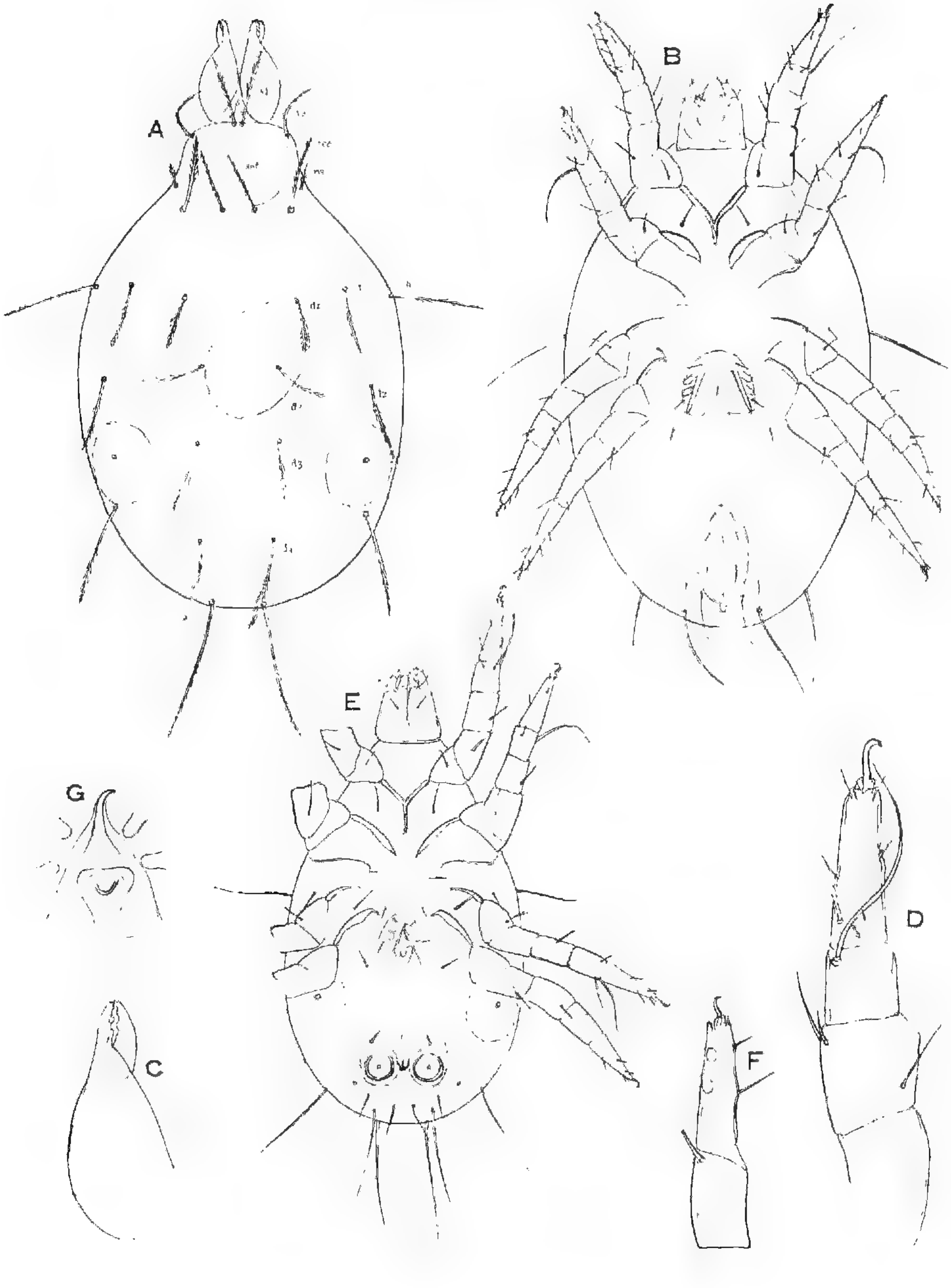

Fig. 1. *Forcellinia galleriella* sp. nov. A-D female: A, dorsal view; B, ventral view; C, mandible; D, leg I dorsal; E-G male: E, ventral view; F, tibia and tarsus of leg IV; G, genitalia showing penis.

Legs: Short and fairly stout, length (excluding coxae), I 216, II 211, III 216, IV 240; tarsi I 58, tibia 29, genu 48, tibia with a long subapical seta reaching to tip of claw; tarsi with short caruncle and long claw, and the sensory setae as figured.

Male allotype: Fig. E-G.—Idiosoma 365 long, width 235. Dorsal setae, vi 48, ve 34, ps 24, sci 48, sce 72, d1 24, d2 43, d3 48, d4 58, p 163, l1 53, l2 48, l3 77, h. 72. Epimera as in female. Genital opening between coxae IV. Anal suckers as figured. Tarsal discs on leg IV in the distal half 14 apart, tarsus 48 long.

Legs: I 206, II 197, III 206, IV 211 long.

Remarks: *F. galleriella* sp. nov. differs from the other two known adult species in the dimensions of the dorsal setae and can readily be separated by the following key.

Key to the Known Adults of the Genus *Forcellinia*.

1. All dorsal setae, including the posterior pair and the humerals, short and of subequal length . . . . *F. fuliginosa* E. and F. Türk.
   Dorsal setae mainly longer and of varying lengths 2
2. Internal vertical setae (vi) much finer and shorter than the propodosomal setae (sci and sce); d1 much shorter than d2-d4, but equally strong; d2-d4 as long as p. . . . . . *F. wasmanni* (Moniez)
   vi subequal in length and structure to sci or sce; d1-d4 less than half length of p. . . . . *F. galleriella* sp. n.

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THE SMARIDIDAE (ACARINA) OF NORTH AND CENTRAL AMERICA AND SOME OTHER COUNTRIES

BY R. V. SOUTHCOTT

Summary

The Smarididae of North and Central America are reviewed and redescribed from various collections, and some Smarididae from other countries are referred to, where they throw further light on the American forms. The following species are described or redescribed for the adult (and in some cases the nymph); Smaris zeteki, sp. nov., S. lanceolata, sp. nov., S. grandjeani (Oudemans, 1941 1, f.p., S. grandjeani subsp. christensoni, subsp. nov., S. boneti, sp. nov., Calorema, gen. nov., C. azteka, sp. nov., Fessonia serrata, sp. nov., F. australiensis Southcott, 1946 (including North American, Asian and further Australian material), *F.* lappacea, sp. nov., *F.* scobina, sp. nov., F. lacrimosa, sp. nov., Hirstiosoma bolivari, sp. nov., Trichosmaris gen. nov., T. dispar, sp. nov., T. dispar subsp. dentella, subsp. nov., *T.* jacoti (Southcott, 1946), comb. nov., Clavismaris, gen. nov., C. conifera, sp. nov., C. cybaea, sp. nov. An attempt is made to evaluate the systematics of smaridid mites previously described from North and Central America. The genus Leuchsia Oudemans, December 1941, is shown to be a synonym of Smaris (Latreille) Womersley and Southcott, July, 1941. The structure of the smaridid dorsal idiosomal seta (scobala) is examined and a terminology proposed for its various parts. Comment is made upon mounting media used in the study of the Smarididae. It is recommended the use of media containing polyvinyl alcohol be abandoned.

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by R. V. Southcott

[Read 10 May 1962]

SUMMARY

The Smarididae of North and Central America are reviewed and redescribed from various collections, and some Smarididae from other countries are referred to, where they throw further light on the American forms.

The following species are described or redescribed for the adult (and in some cases the nymph): *Smaris zeteki*, sp. nov., *S. lanceolata*, sp. nov., *S. grandjeani* (Oudemans, 1941), f.p., *S. grandjeani* subsp. *christensoni*, subsp. nov., *S. boneti*, sp. nov., *Calorema*, gen. nov., *C. azteka*, sp. nov., *Fessonia serrata*, sp. nov., *F. australiensis* Southcott, 1946 (including North American, Asian and further Australian material), *F. lappacea*, sp. nov., *F. scobina*, sp. nov., *F. lacrimosa*, sp. nov., *Hirstiosoma bolivari*, sp. nov., *Trichosmaris* gen. nov., *T. dispar*, sp. nov., *T. dispar* subsp. *dentella*, subsp. nov., *T. jacoti* (Southcott, 1946), comb. nov., *Clavismaris*, gen. nov., *C. conifera*, sp. nov., *C. cybaea*, sp. nov.

An attempt is made to evaluate the systematics of smaridid mites previously described from North and Central America. The genus *Leuchsia* Oudemans, December, 1941, is shown to be a synonym of *Smaris* (Latreille) Womersley and Southcott, July, 1941.

The structure of the smaridid dorsal idiosomal seta (scobala) is examined and a terminology proposed for its various parts.

Comment is made upon mounting media used in the study of the Smarididae. It is recommended the use of media containing polyvinyl alcohol be abandoned.

1. INTRODUCTION

Few previous studies have been made of the smaridid mite fauna of North and Central America. Up to the present time the only smaridids recognizable as such recorded for this area are:

(1) *Smaris longilinealis* Ewing, 1909. Ewing's account is insufficient for the generic placing of this mite with any certainty. The possibility that this species is a synonym of *Trichosmaris dispar*, sp. nov., of the present paper is discussed later.

(2) *Smaris longilinealis* Ewing, 1910. This mite is also not generically placeable from the information given by Ewing. It is very unlikely that this species is conspecific with *Smaris longilinealis* Ewing, 1909, and it is probably not congeneric with it. This subject is discussed further in the text.

(3) *Hirstiosoma jacoti* Southcott, 1946, proposed as a new name for *Smaris sericea* Jacot, 1938, non *Trombidium sericeum* Say, 1821. The lectotype is selected in the present paper and the species renamed *Trichosmaris jacoti*, comb. nov. The species is possibly a synonym of *Trichosmaris dispar*, sp. nov. This is discussed further in the text.

Trans. Roy. Soc. S. Aust. (1963), Vol. 86.

(4) *Smaris* sp. Jacot, 1938, p. 125. This species is distinct from the preceding, as Jacot realized. It was placed by Womersley and Southcott (1941, pp. 63, 78) in *Hirstiosoma*, but with the erection of further genera in the Hirstiosomatinae its generic placing is now uncertain. The possibility that this species is conspecific with *Clavismaris cybaea*, sp. nov., is discussed later.

(5) *Leuchsia grandjeani* Oudemans, 1941. This species was referred to earlier by the writer (1961a, p. 434) as belonging probably to *Smaris*. In the present paper the species is redescribed from specimens forwarded from America, and *Leuchsia* is placed confidently as a junior synonym of *Smaris*.

(6) *Smaris mamillatus* Baker and Wharton, 1952. This species was correctly placed generically by these authors; the good figure given is sufficient for generic identification. Possibly the species figured is the female of *Smaris lanceolata*, sp. nov., described from the male in the present paper. The specific name *mamillatus* (of Say, 1821) is not usable, being now allotted to a species of *Labidostomma* (see Southcott, 1961a, p. 573) (see also the remarks under *S. lanceolata*, and in Section IV).

The primary object of the present paper is a systematic study of the smaridid mites of North and Central America. It has been found desirable, however, to extend the study to a small amount of additional material from other countries. The study originated from a request from the United States National Museum, Washington, for a systematic revision of their mounted collection of Smarididae. The collection sent for study consisted of 75 slides, and was received in 1948. It contained specimens originating as early as 1905, and included material collected in the United States by E. A. McGregor, H. E. Ewing and others. The major part of the collection was, however, made up of mites received from the Plant Quarantine Service of the United States, which had been intercepted at stations on the United States-Mexico border or at shipping ports in the United States. Much of it had originated in Mexico, and other material came from various countries of Central America. In addition there was a small number of slides of specimens (*Fessonia australiensis* Southcott, 1946) from Hawaii, taken on plants originating in China, one specimen taken at Boston from India (same species), and one specimen taken at New York on onions coming from Europe (*Clavismaris cybaea*, sp. nov.). In view of the long life history of these mites, and the lack of information on whether any fumigation was done to the containers from which these mites originated, between ship voyages, there is no certainty that these mites did actually originate in the same country as that from which the plants came; such material should be treated with caution as far as attributing localities to species is concerned. Thus it is thought likely, on distributional grounds, that the smaridid mite taken upon the onions from Europe originated in North America. Despite these reservations the material received from these sources is of interest, and repays study. This group of 75 slides has been allotted identification numbers ACA 1642-1716.*

A further slide of a smaridid mite was received from the United States National Museum, following a request from the author for information about the type specimen of *Smaris longilinealis* Ewing. That specimen was labelled

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*The author has used these numbers and prefixes to identify mites in his own collection: ACA 1, ACA 2, . . . for mites of the superfamily Erythraeoidea; ACB 1, ACB 2, etc., for mites of the family Trombidiidae (s.l.); ACC 1, ACC 2, etc., for mites of other groups. This system has also been extended to provide identification numbers of mites of the same groups referred to him for identification, even though the mites are not retained in his own collection. Frequently such mites are referred for identification in slide mounts without identification numbers, or may be received unmounted, then usually without such numbers.

"Cotype", and has U.S.N.M. Serial Number of 20231 (ACA 1752 of the author). It is not the holotype, and cannot be designated a lectotype as it did not come from the topotype area; it has in fact little nomenclatorial significance (see later).

The author has also had available for study a collection of 10 slides from the collection of the South Australian Museum, mostly of material collected in Mexico by F. Bonet, and mounted by Mr. H. Womersley or the author. These slides have identification numbers ACA 1717-1723, 1731A, 1731B and ACA 1731C, D.

A few slides in these two collections are not in a state which permits identification, mainly from over-treatment by potashing or from inadequate clearing in polyvinyl alcohol media.

In addition, in 1958 Mr. W. F. Rapp, Jr., entomologist, Department of Health, State of Nebraska, United States of America, submitted seven slides of smaridid mites collected in Nebraska and Texas. These have been allotted identification numbers ACA 1724-1730.

The present study has resulted in the description of three new genera and thirteen new species or subspecies, and extends the known range of the two previously described and recognizable species—*Smaris grandjeani* (Oudemans, 1941) and *Fessonia australiensis* Southcott, 1946—considerably. The latter species was originally described from the Northern Territory of Australia; in the present paper it is recorded from the Asian mainland and Mexico, as well as from Queensland, Australia.

For the descriptive terms used in the present paper, as well as the definitions of the previously described genera of the Smarididae, the author's monograph on the Erythraeoidea (1961*a*) should be consulted.

II. A NOTE ON THE STRUCTURE OF THE SMARIDID DORSAL IDIOSOMAL SETA AND ITS TERMINOLOGY

The smaridid dorsal idiosomal seta is typically a complex structure, though variable between species, and as its form will be used as an important determinant in systematics it has been found necessary to refer to its parts with somewhat more precision than has previously been customary. Certain new terms will be introduced here, additional to those used for setae by the author (1961*a*).

The seta (scobala) consists of a pedicle (*pedicellus*) and an expanded part, the *scobillum* (see Fig. 1). The pedicle has a bulbous proximal end which articulates in a socket in a chitinized epidermal structure, the *amphora*. The amphora has a cavity for the nerve supply, which responds to pressure changes resulting from movement of the seta, e.g. from touch, transmitted to the bulb of the pedicle. Usually the bulb of the pedicle is surrounded by a flat chitinized ring, the projecting part of the amphora, the *annulus* or seta base. This in smaridids (and other mites) is often set in a *seta fossa* in the skin. In certain smaridids with large setae the amphora may take the form of an enlarged chitinized papilla rising above the surface of the skin; this is, for example, the case in *Trichosmaris dispar* gen. nov., sp. nov., where the annulus becomes an invaginated cone set within the papilla (see Fig. 31K, L).

The scobillum has an external or dorsal (in the case of the dorsal setae) surface, the *tectum setae* or *tectum scobilli*, provided with a number of pro-

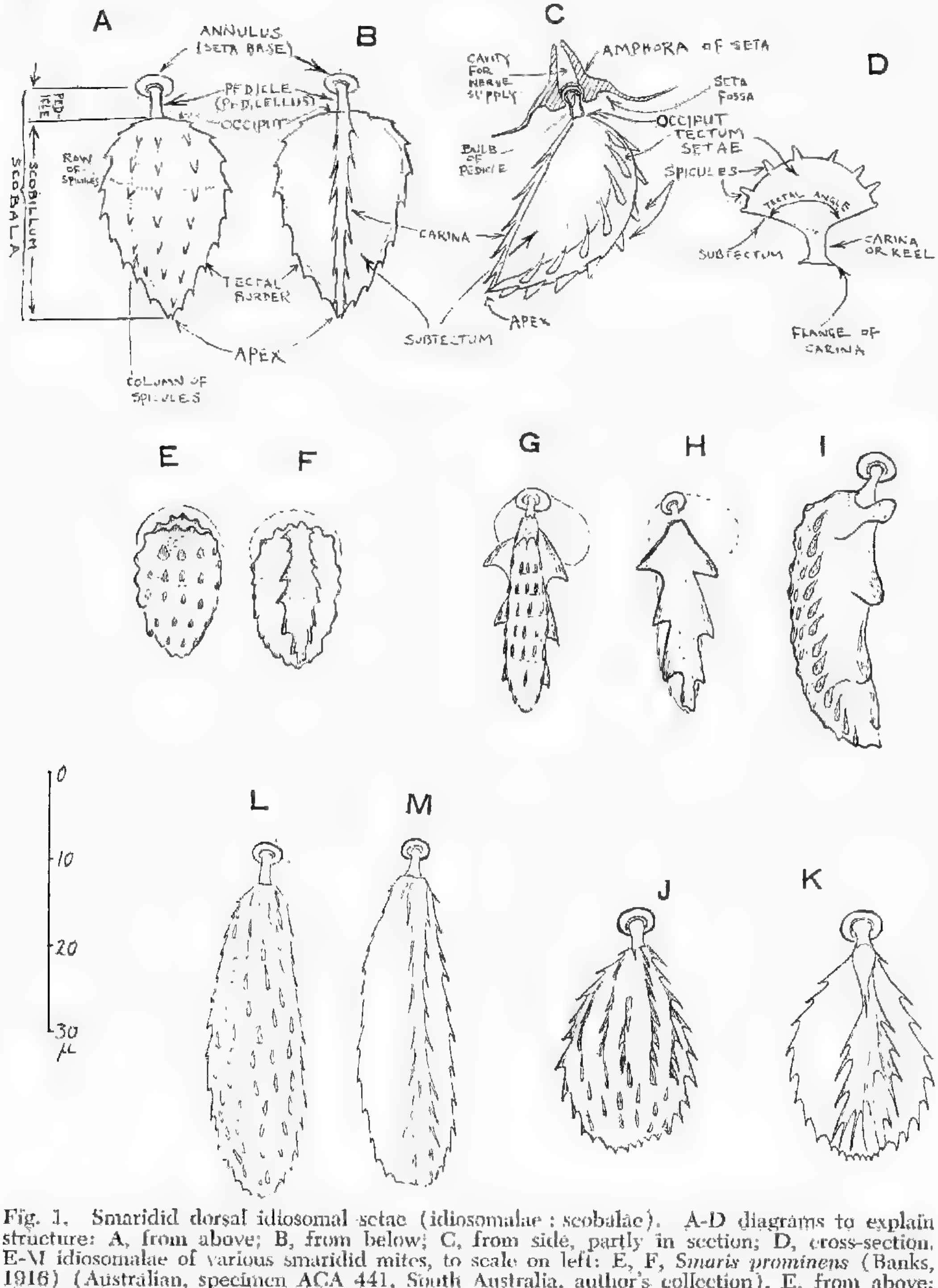

Fig. 1. Smaridid dorsal idiosomal setae (idiosomalae : scobalae). A-D diagrams to explain structure: A, from above; B, from below; C, from side, partly in section; D, cross-section. E-M idiosomalae of various smaridid mites, to scale on left: E, F, *Smaris prominens* (Banks, 1916) (Australian, specimen ACA 441, South Australia, author's collection), E, from above; F, from below. G-I, *Smaris cooperi* Southcott, 1961 (Australian, holotype specimen, Kangaroo Island, South Australia), G, from above; H, from below; I, another seta in side view. J, K, *Fessonia australiensis* Southcott, 1946 (Australia, holotype specimen), J, from above; K, from below. L, M, *Fessonia lacrimosa*, sp. nov. (Mexico, holotype specimen), L, from above; M, from below. (Figs. E-I, to scale shown.)

jections, the spicules or modified ciliations. The tectum is most frequently convex, but may be concave or canoe-like, prismatic or irregular. Laterally it is bounded by the tectal borders, which run from the *occiput* or proximal part of the scobillum to the *apex* or distal point. On the internal or ventral surface of the scobillum is a *keel* or *carina*, which may be narrow, or at times partly swollen, and may be expanded into a distinct flange on each side. The carina is usually provided with ciliations or spicules, which may become large and prominent (see e.g. Fig. 1G-I). The area between the tectal margins and the carina is the *subtectum*. The two planes of the subtectum meet, on production, to form the *tectal angle* (Fig. 1D). The tectal spicules may be arranged in *columns* or *rows*, in some species the arrangement being regular, and in others more or less irregular, and in some cases the arrangement is partly regular and partly irregular (see Fig. 1).

Most of the preceding is a systematizing of terms already in existence, or an extension of them. The scobillum does not appear to have had a formal name applied to it previously, but was referred to by Grandjean (1935, p. 6) as the "couche externe" of the seta, which surrounds in his concept a colourless "axe de chitine", which includes the pedicle (pedicellus).

III. SYSTEMATIC PART

Subfamily SMARIDINAE Southcott (expanded)

(Synonymy as in Southcott, 1961*a*, p. 438)

Genus SMARIS Latreille

Restricted by Womersley and Southcott (1941)

For synonymy see Southcott 1961*a*, p. 438, and in addition, *Smaris* Southcott, 1961*b*, p. 133.

For definition and a discussion on the type species see Southcott (1961*a*).

Key to the Species and Subspecies of Adults of the Genus *Smaris* in North and Central America.

1. Dorsal idiosomal setae of the middle of the posterior dorsal idiosomal shield elongate, three or four times as long as the other dorsal idiosomalae — *S. zetcki*, sp. nov.
   Dorsal idiosomal setae of a more uniform character — 2

2(1). Dorsal idiosomal setae lanceolate, the tectum almost nude, with a few faint rows of spicules on the tectum setae and outlining the tectal borders — *S. lanceolata*, sp. nov.
   Dorsal idiosomal setae otherwise — 3

3(2). Dorsal idiosomal setae to 16μ long, pointed at apex, the tectum setae provided with rows of short, sharp spicules — *S. grandjeani* (Oudemans, 1941), f.p.
   Dorsal idiosomal setae similar, to 22μ long — *S. grandjeani* subsp. *christensoni* subsp. nov.
   Dorsal idiosomal setae to 30μ long, blunted and rounded at apex, with rounded tectal spicules — *S. boneti*, sp. nov.

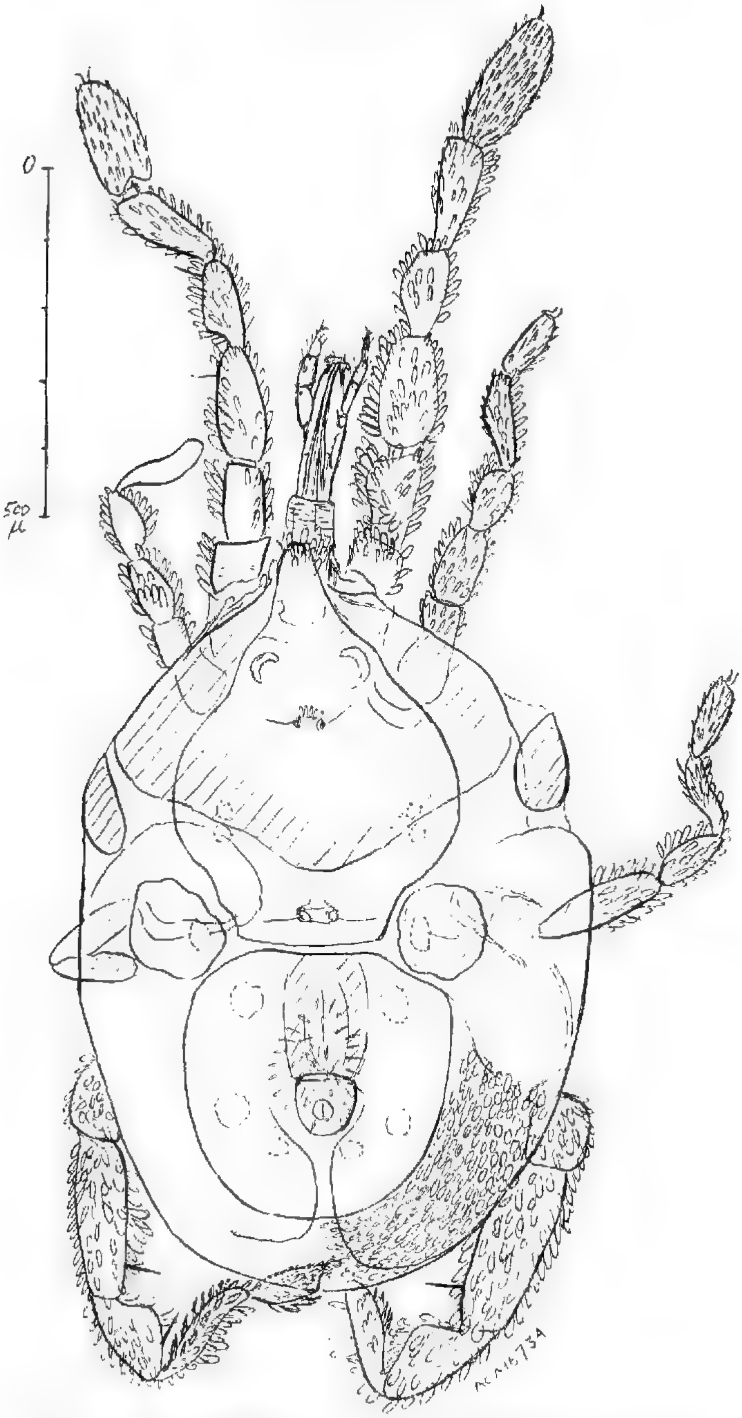

Fig. 2. *Smaris zeteki*, sp. nov. Adult female (holotype). View of mount of entire animal, somewhat compressed, shown mainly as from the dorsal aspect, but also to some extent in transparency, to show some ventral structure of idiosoma; setae mostly omitted, ventral structures shaded; broken lines outline asetose areas of dorsal shields.

Smaris zeteki sp. nov.

Figs. 2-4

Description of Adult Female (from Holotype ACA 1673A).

Colour in life not recorded. Animal of normal smaridid shape, fairly robust, with a short nasus, and with heavily sclerotized plates. Idiosoma 1045μ long to tip of nasus, by about 650μ wide where widest.

Anterior dorsal scutum present, 575μ long by 382μ wide, enclosing the sensillary areas and eyes, and extending forward to cover the nasus; this scutum is roughly pyriform, but with the edge somewhat irregular, and with ocular projections. it is flattened posteriorly where its edge almost abuts the anterior edge of the posterior dorsal scutum.

Eyes 2 + 2, each lateral pair conjoined upon a sessile sclerotized tuberosity. Anterior eye the larger, cornea 34μ across, and directed anterolaterally; posterior eye smaller, with cornea 24μ across, and directed posterolaterally. Each lateral eye tuberosity placed fairly close to the anterolateral border of the scutum which projects there to form the "ocular projection" of the scutum. Anterior sensillary boss wide, carrying the two anterior sensillae plus a number of large scobalae, as figured. Posterior sensillary boss as figured. Anterior and posterior sensillae filiform, ciliated, the ciliations longer terminally. There is some indication of a narrow pathway between the scobalae of the anterior dorsal scutum, outlining a "crista" between the anterior and posterior sensillae. Each scobala (ordinary seta) of the anterior dorsal scutum originates in the base or side of a deep pit in the scutum, these pits thus giving the anterior dorsal scutum a cribriform appearance. Upon the anterior dorsal scutum are two pairs of laterally placed asetose areas, set close together, as figured (see Fig. 2); the anterior of each pair about 20μ across and equivalent in space to about that occupied by one scobala, the posterior about 30μ across and equivalent in space to 4-5 scobalae.

The standard data (see Southcott, 1961*a*) for the two specimens studied are.

	ASens	PSens	SBa	SBp	ISD	DS
Holotype ACA 1673A	90	ca. 90.	55	26	250	12-56
Paratype ACA 1673B	94	98	62	29	236	12-54

Posterior dorsal scutum large, oval but with flattened margins giving it a somewhat square appearance, 400μ long by 380μ wide. The anterior margin of the posterior dorsal scutum comes close to the posterior margin of the anterior dorsal scutum. Posterior scutum with 6 asetose areas of moderate size (up to 30μ across), as figured (Fig. 2). The setae of the posterior scutum are in its peripheral part similar to the adjoining dorsal idiosomal scobalae, being pyriform to lanceolate in outline (rather like the segment of an orange), pointed apically but flattened below, and with 4-5 columns of spicules in 6-8 rows; setae 18-22μ long by 6-10μ wide. In the centre of the posterior dorsal scutum the scobalae are considerably elongated, being lanceolate and clavate and in general are 50-56μ long by 2·5-5μ wide.

Two smaller mid-dorsal shields are present, irregularly oval, 135μ long by 108μ wide, and occupy the angles formed by the separating margins of the anterior and posterior dorsal scuta on each side. These mid-dorsal shields have,

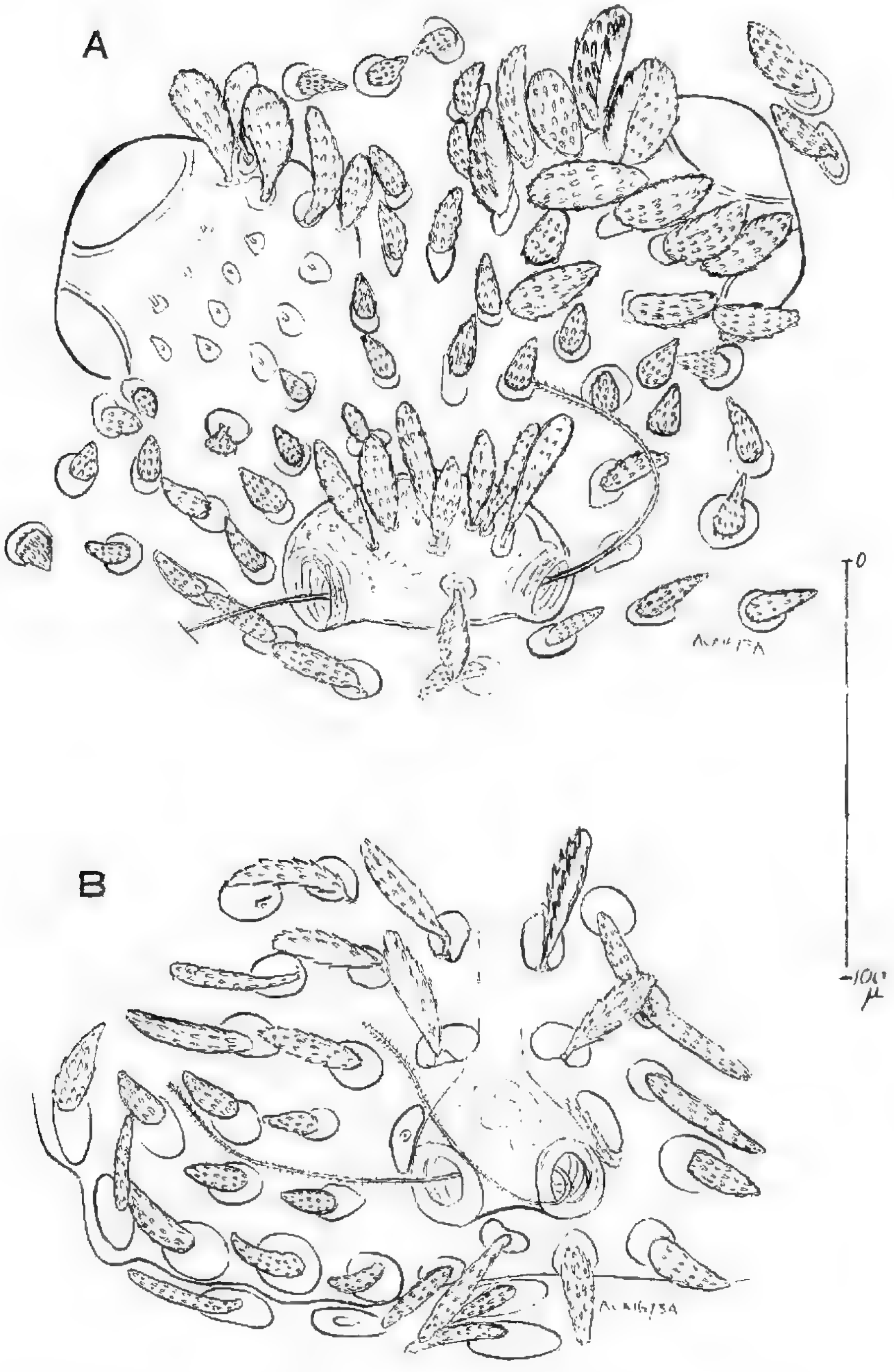

Fig. 3. *Smaris zeteki,* sp. nov. Adult female (holotype). A, anterior sensillary area and eyes; B, posterior sensillary area and surrounding structures (both to scale shown).

particularly on their lateral sides, an irregular undulating edge, each wave going around a seta-socket. These shields carry normal dorsal idiosomal scobalae, but each shield has a small asetose area about 50μ long by about 20μ wide, in its medial part.

The remainder of the dorsum of the idiosoma carries a large number of setae, each seta being set individually in a small sclerotized plate, which may be irregularly oval, reniform or ovoid, and measure roughly 16-26μ long by 12-14μ wide. These are thickly set upon the flexible skin of the idiosoma, and particularly posterolaterally upon the idiosoma are so heavily packed together that they tend to overlap each other, in the mounted specimen. Each seta plate has a thickened margin and a central depression in which the seta takes origin.

Ventral surface of idiosoma: The anterior part of the venter is covered by the normal anterior ventral plate of *Smaris*, enclosing coxae I and II of each side; this plate is heavily sclerotized. At its posterolateral margins are the two large oval anteroventral accessory plates, placed nearly at the lateral edge of the animal in dorsal view; these measure about 130μ long by 50-60μ wide. On each side the coxa III and IV are fused and set in a large posterolateral ventral plate, which extends anteriorly about 80μ in front of the anterior edge of coxa III, this anterior projection lying behind the anteroventral accessory plate and the lateral part of the anteroventral plate.

External genitalia set in a large genital plate as figured. Anus set in the posterior part of the anal plate, which is ovoid, with flattened anterior and lateral margins, 94μ long by 80μ across. The anterior edge of the anal plate approximates the posterior edge of the genital plate. The genital and anal plates are set in the midline between the paired posterolateral ventral plates of the idiosoma.

Legs somewhat irregular when seen in lateral view; heavily sclerotized. Leg lengths (trochanter to tips of tarsal claws): I 810μ, II 590μ, III 580μ, IV 620μ. Tarsus I 170μ long by 79μ high, tibia I 175μ long by 62μ high, genu I 148μ long, tarsus II 101μ long by 34μ high (a little oblique), tibia II 130μ long, tarsus IV 120μ long by 45μ high, tibia IV 185μ long, genu IV 168μ long (tarsal lengths exclude claws and pedicle). Tarsi with conical spiculate setae (scobalae) interspersed among the sensalae (solenoidalae). Tarsal claws ciliated obliquely along their sides in the proximal two-thirds. The scobalae of the tarsi and the dorsum of tibiae conical, pointed, with regular pointed spicules, rather like a pine cone. Other leg scobalae in general similar to usual idiosomal scobalae. The legs carry also various specialized sensalae (sensory setae). Specialized scobalae are also present in the form of pointed and ciliated tactalae upon the ventral distal parts (one per segment) of the telofemora and genua.

Gnathosoma as figured. Palpal scobalae simple or lightly ciliated.

Locality. This species is known from two specimens only, with identification numbers ACA 1673A (Holotype ♂) and ACA 1673B (Paratype ♀), Barro Colo[rado] Island, Canal Zone, Oct.-Nov., 1941, J. Zetek, slide labelled also Z-4915. Lot 42-8741. Holotype in collection of United States National Museum; paratype in South Australian Museum, ex U.S.N.M.

Remarks. (1) *Smaris zeteki* is quite a distinct species; the author knows of no other *Smaris* which has a similar elongation of a group of dorsal idiosomal scobalae. The species is dedicated to its original collector.

(2) The Holotype and Paratype specimens were on receipt mounted and heavily overstained with some pink dye. They have now been remounted and destained as far as possible without undue damage. They remain still fairly heavily stained, but are in a state fit for description of all features of taxonomic significance. The lack of clarity of the ventral plates in the mounts with dorsum-uppermost is due to this residual overstaining.

(3) It is of interest to note that the external genitalia and anus are each surrounded by a large sclerotized plate, within which the lips of the vulva and anus articulate. A somewhat similar feature was figured by Berlese (1894) (A.M.S. 71, 4, Fig. 2) for S. *squamata* Berlese, 1883, and which Grandjean (1947, p. 53) doubted (see also the comment by Southcott (1961*a*, p. 440)).

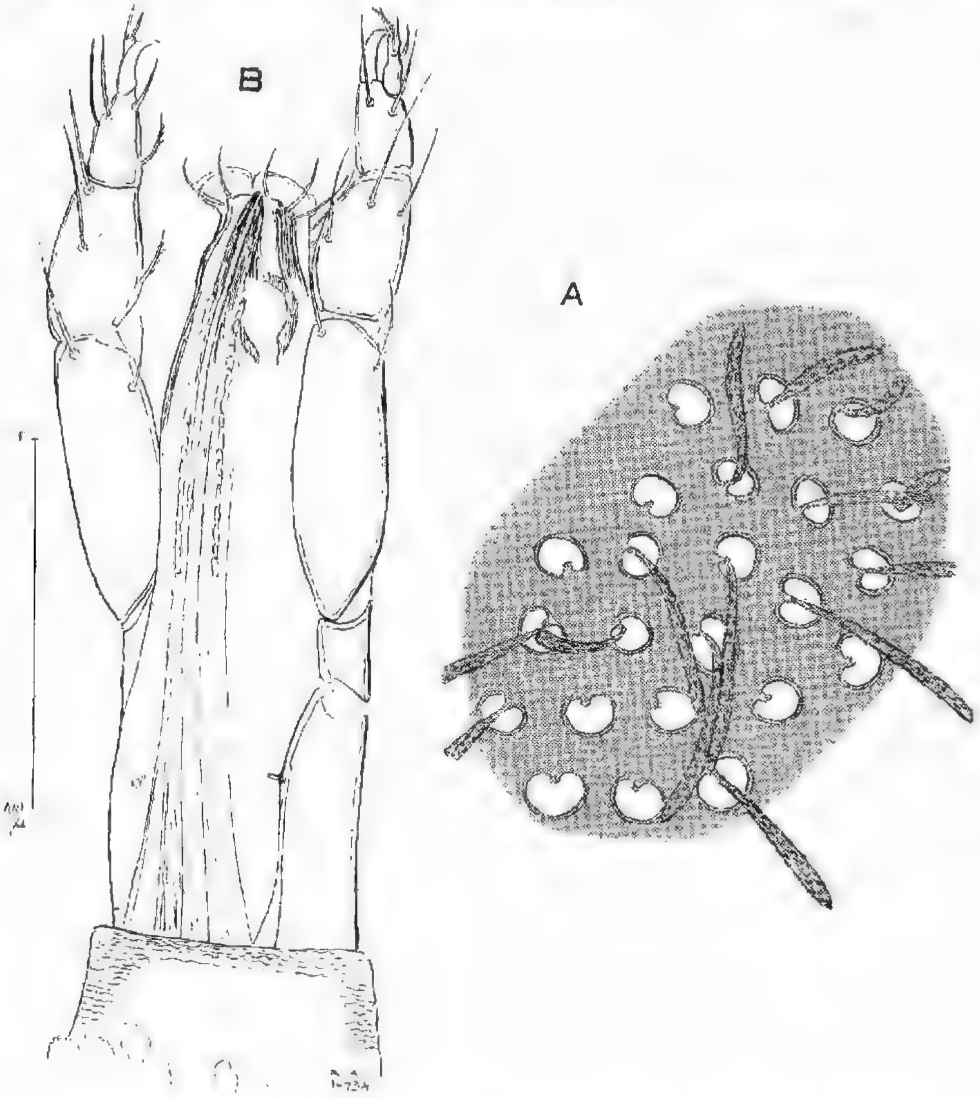

Fig. 4. *Smaris zeteki*, sp. nov. Adult female (holotype). A, central part of posterior dorsal scutum to show setae and seta-pits; B, mouthparts, dorsal aspect (to same scale).

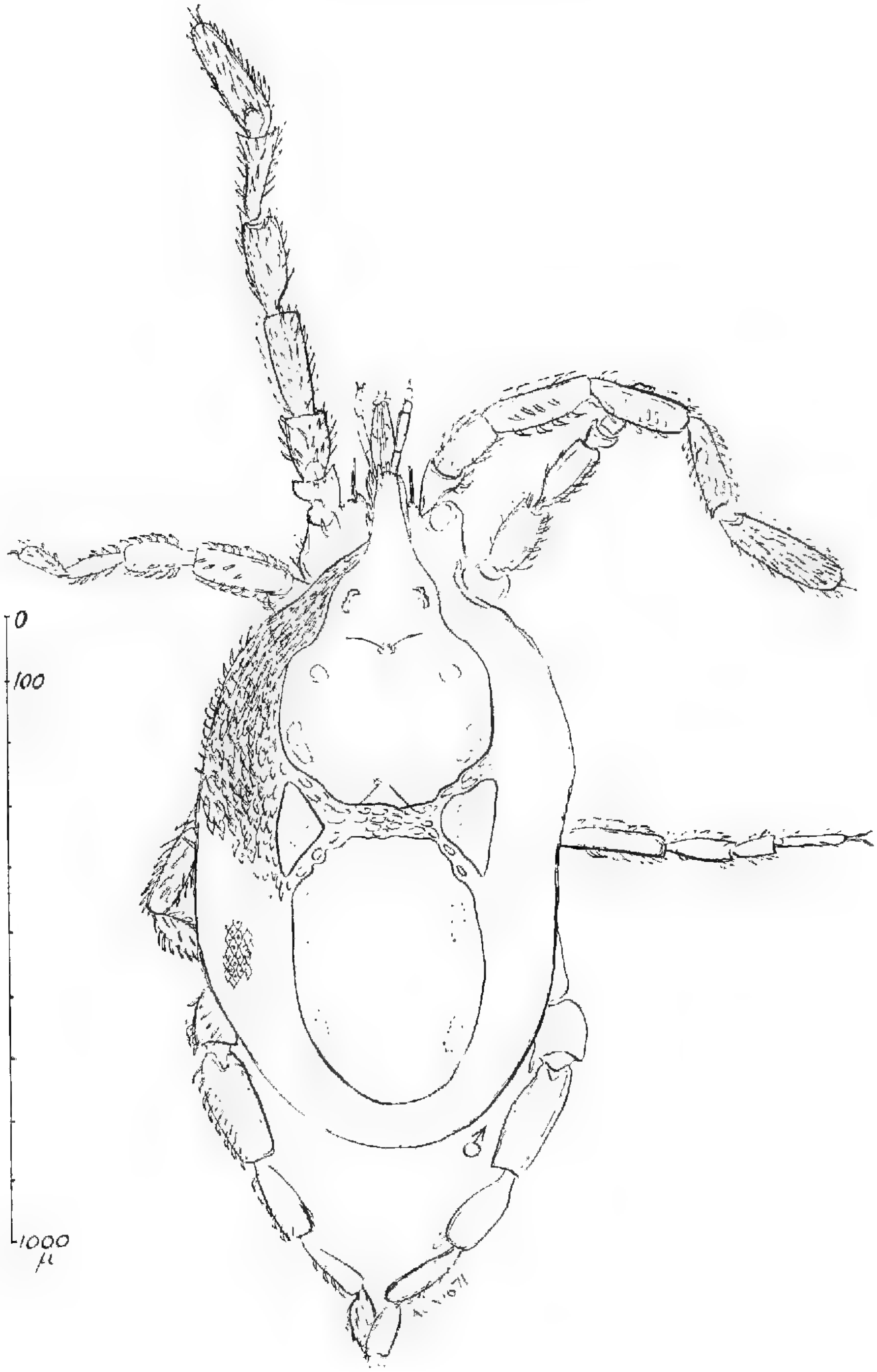

Fig. 5. *Smaris lanceolata,* sp. nov. Adult male (holotype), dorsal aspect, setae mostly omitted.

Smaris lanceolata sp. nov.

Figs. 5-7

?*Smaris mamillatus* Baker and Wharton, 1952, p. 242, Fig. 179.

Description of Adult Male (from Holotype ACA 1671).

Colour in life not recorded. Animal of normal smaridid shape, somewhat slender, with a narrow nasus of moderate length. Idiosomal plates lightly sclerotized. Idiosoma 1020μ long to tip of nasus, 540μ wide where widest.

Anterior dorsal scutum present, 510μ long by 304μ wide, enclosing the sensillary areas and eyes. The scutum is irregularly pyriform, but with well-marked ocular projections on the lateral margins, and the posterior margin is flattened.

Eyes 2 + 2, each lateral pair forming a conjoined indented tubercle, moderately sclerotized. Anterior eye the larger, placed somewhat medially to the posterior eye, and directed anterolaterally, with cornea 30μ across; posterior cornea directed laterally, and 24μ across. Each lateral pair of eyes is fairly close to the edge of the scutum, where there is a large ocular projection (see Fig. 5).

Anterior sensillary boss lightly sclerotized, and in addition to the two anterior sensillae it carries about 5 scobalae (in Paratype ACA 1719; uncertain in Holotype). The anterior sensillae ciliated, slightly clavate, as figured (Fig. 6A). The posterior sensillary boss as figured (Fig. 6B); the posterior sensillae of uniform thickness, ciliated.

The anterior dorsal scutum has no indication of any crista. It has four asetose areas, as figured (Fig. 5) for muscular insertions.

The standard data of the Holotype specimen are:

ASens	PSens	SBa	SBp	ISD	DS
36	41	30	19	208	20-22

Posterior dorsal scutum fairly large, an elongate oval, but flattened anteriorly and anterolaterally, 415μ long by 270μ wide. The anterior margin comes close to the posterior margin of the anterior dorsal scutum, the separation 40μ. Its scobalae are of uniform character, similar to those of the remainder of the dorsum of the idiosoma. There are 4 punctate areas practically or entirely devoid of setae on the anterior dorsal scutum, placed as figured (Fig. 5).

Two mid-dorsal shields are present, set in the angles between the anterior and posterior median dorsal shields; they are roughly triangular, 160μ long by 85μ wide, and are devoid of scobalae. In addition, they each have a central longitudinal punctate part as figured (Fig. 5).

Apart from the dorsal scuta the dorsum of the idiosoma is thickly beset with scobalae. These setae are in general lanceolate, sharply angled near their base, and almost devoid of ciliations. The leaf-like tectum setae is outlined by a thickened tectal border, and carries upon its surface three rows of projections or spicules, as figured (Figs. 6 A, B, 7 A-D). The spicules are weak and adnate, and appear as weak segmented columns rather than as outstanding serrations. Along the ventral surface of the scobala the keel forms a protuberance near the occiput of the scobillum, the keel then expands fanwise distally. The scobalae of the dorsal shields are set in small fossae, and each of these scobalae arises mostly toward the edge of the fossa. On the remainder of the dorsum of the idiosoma each scobala is set individually in a small oval or diamond-shaped shield, as figured (Figs. 6 B, 7 A-D). Each individual seta-shield has a central excavation in which the seta takes origin; the shields appear like small canoes or coracles, and are thickly packed together.

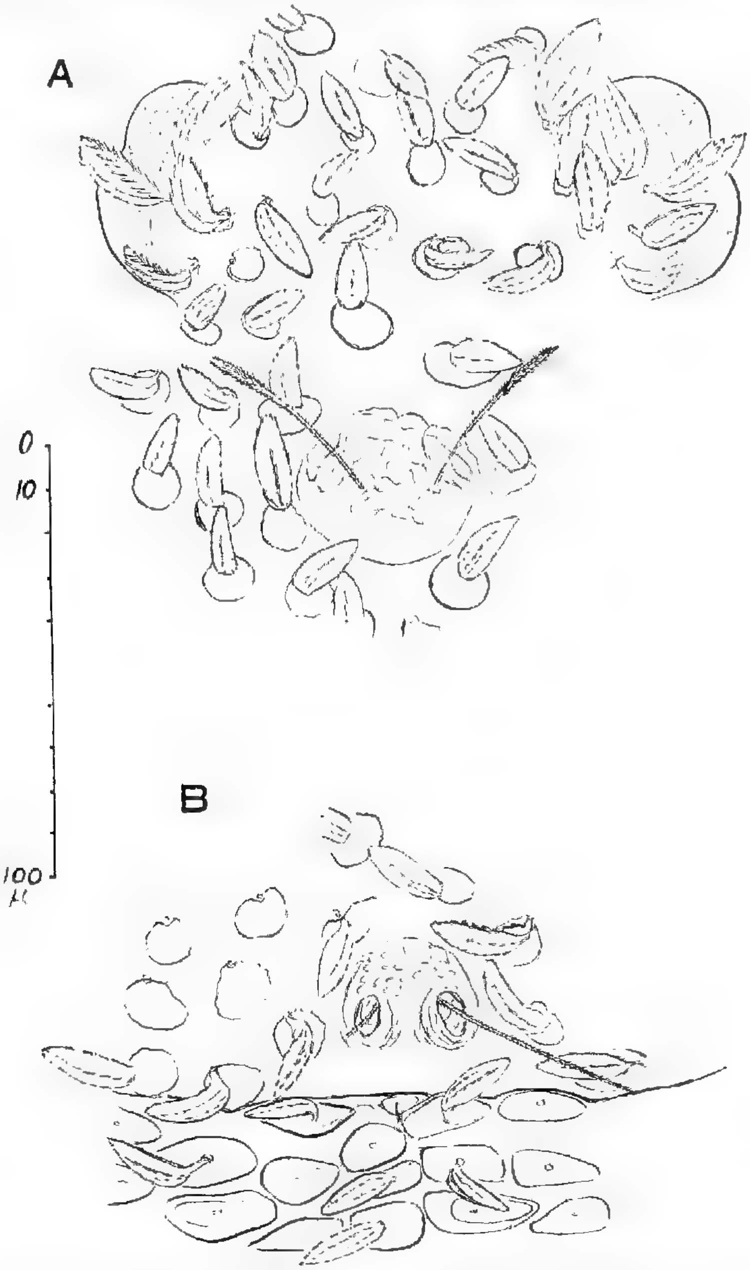

Fig. 6. *Smaris lanceolata*, sp. nov. Adult male (holotype). A, anterior sensillary area and eyes; B, posterior sensillary area and adjacent structures.

Scobalae of somewhat different character are found dorsally on the nasus at the tip and inferiorly to it; these setae are expanded and more rugose; the tectum setae carries up to 5 rows of finger-like projections arranged in regular columns and rows extending to the apex of the seta; the setae are thus large, fan-like, chitinized, 30μ long by 9μ wide.

Venter: the normal large anteroventral scutum is present, enclosing the the anterior coxae; there are no large anteroventral accessory plates. Each coxa III and IV of each side is fused as usual into a large posterolateral ventral coxal plate, lightly sclerotized, and with an anterior flange projecting well forward from coxa III.

External genitalia lightly sclerotized, the male labia majora being 167μ long by 72μ across with the lips in apposition. Flanking the external genitalia posterolaterally are two triangular adgenital plates, 210μ long by 67μ across, as figured (Fig. 7 E).

The anal plate is large, 126μ long by 146μ across, the anus set in the anterior part of it as figured, with spindle-shaped burr-like bushy setae ("analae") alongside. There are 4 posterior ventral plates as shown around the opisthosoma ventrally (Fig. 7 E).

The ventral scobalae are in general similar in character and size to those of the dorsum of the idiosoma. Those not arising from the larger ventral plates are set individually on small seta-plates as figured (Fig. 7 E), between the other plates.

Legs normal; leg lengths, including trochanter to tip of tarsal claws, I 870μ, II 530μ, III 540μ, IV 720μ. Tarsus I 190μ long by 55μ high, tibia I 200μ long, genu I 180μ long, tarsus II 88μ long by 43μ high, tibia II 115μ long, tarsus IV 97μ long by 41μ high, tibia IV 163μ long, genu IV 157μ long (tarsi measured exclusive of claws and pedicle). Tarsal claws lightly obliquely ciliated, except terminally. Tarsi with many scobalae, heavily ciliated with stiff pointed ciliations hence burr-like, pointed apically, angled basally, more rugose than the body setae but of somewhat similar character; setae of typically smaridid character. Various sensalae present among the scobalae of the legs, especially distally.

Gnathosoma as figured (see Fig. 7 F; also 5, 7 E); palpal scobalae lightly ciliated.

Locality. The following three specimens have been examined: ACA 1671, adult male (Holotype), under dead orange bark, La Campana, Panama, Sept. 28, 1938, J. Zetek, Number 4288. Lot 38-17223, U.S.N.M. In United States National Museum.

ACA 1672, one specimen, adult ? ♀, Paratype. On *Lycaste* sp., Canal Zone, at B'ville [= Brownsville, Texas, United State of America], April 29, 1946, Williamson-Allen, collectors. Brownsville 60882, Lot 46-5491. To be deposited in South Australian Museum ex United States National Museum.

ACA 1719, one specimen, Paratype. Miramar, Manzanilla, Mexico, January 16, 1943, F. Bonet, No. 692. This specimen is in poor condition, and its identification is a little dubious. In South Australian Museum collection.

Remarks. As indicated in the introduction of this paper, Baker and Wharton (1952, Fig. 179, p. 242) figured an adult female smaridid mite which they identified as *Smaris mamillatus* (Say). That specific name has, however, now been given to a species of *Labidostomma*.*

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* Note added in proof: Atyeo and Crossley (1961) give reasons for proposing that *Labidostoma* is the correct spelling of the name *Labidostomma* Kramer, 1879.

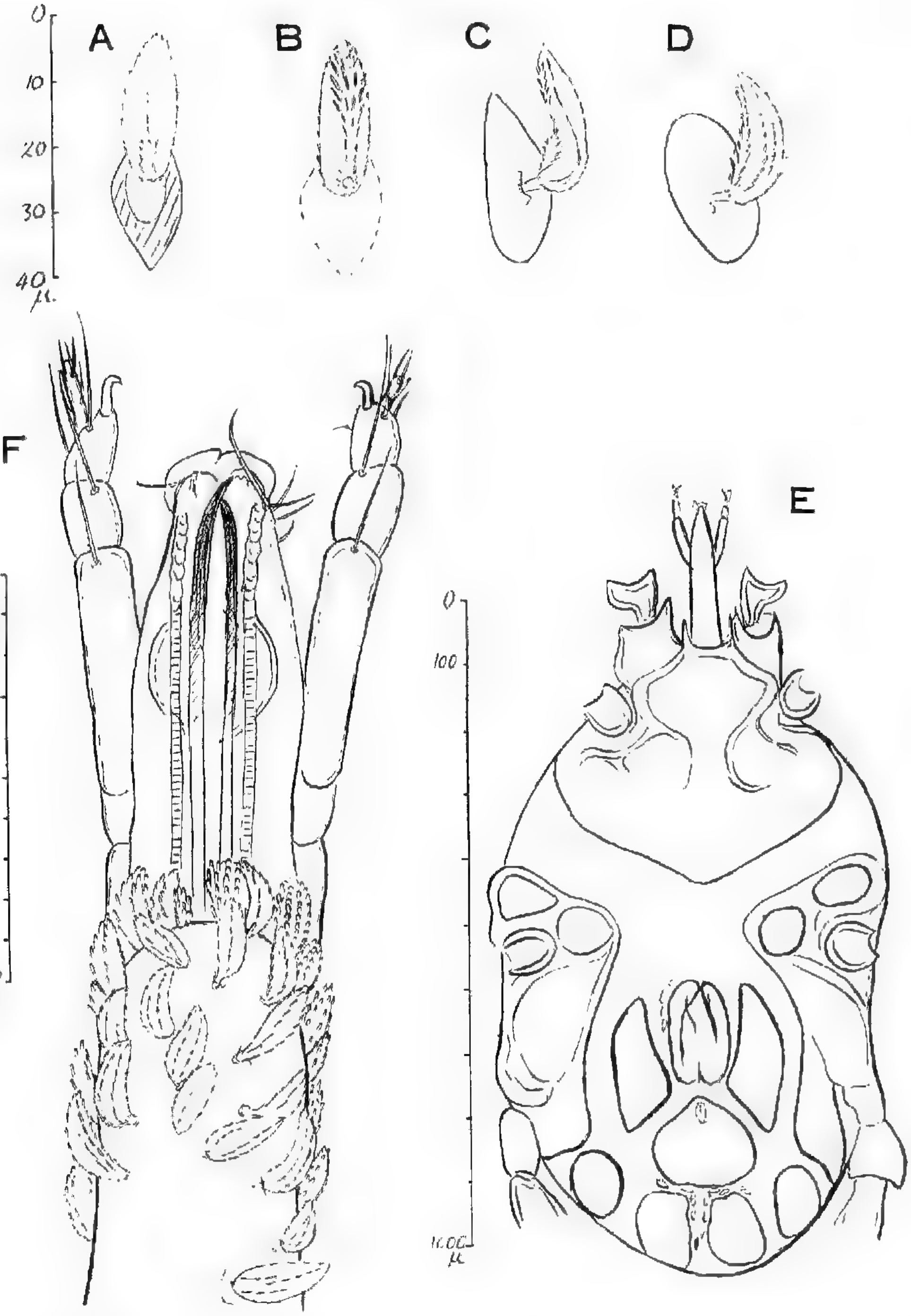

Fig. 7. *Smaris lanceolata*, sp. nov. Adult male (holotype). A-D, dorsal idiosomal setae, to scale on left. A, seta and seta plate, from left of middle of dorsum; B, same seta from below; C, D, setae from near posterior pole of idiosoma, seen in side view; E, ventral surface of idiosoma, to show shields, setae omitted; F, gnathosoma and tip of nasus from above.

The general appearance of Baker and Wharton's specimen is in agreement with *Smaris lanceolata.* The mid-dorsal shields lack setae, and the disposition of the asetose areas on the anterior dorsal and mid-dorsal shields is in agreement with the male *S. lanceolata.* The central setae of the posterior dorsal scutum are not lengthened. In the anterior half of the posterior dorsal scutum Baker and Wharton figure two small laterally placed asetose areas, and in the posterior half they show a curved row of four asetose areas. That arrangement appears to agree with the specimen ACA 1672 referred to above. As, however, specimen ACA 1672 is not ideal for description, it is thought best to leave the description of the female and the selection of an allotype specimen to the future. (It is not possible to identify Baker and Wharton's specimen with more precision as no detail of a dorsal scobala is given, etc. No locality data were given.)

Smaris grandjeani (Oudemans) f.p.

Figs. 8 and 9

Leuchsia grandjeani Oudemans, 1941, p. 182.

Smaris grandjeani Southcott, 1961*a*, p. 434.

Redescription of Adult (from ACA 1674, Male)

Colour in life not recorded. Animal of normal smaridid shape, with a slender nasus of moderate length, and with the idiosoma provided with a number of sclerotized plates. Idiosoma 850μ long to tip of nasus, by 565μ wide where widest (the animal is somewhat compressed in the slide mount).

Anterior dorsal scutum as figured (Figs. 8, 9A), 460μ long by 280μ wide, enclosing the eyes and sensillary areas, and extending to the nasus. It is pyriform, widest posteriorly, and with its edge cut into undulations which accommodate adjacent seta-plates.

Eyes 2 + 2, normal, each lateral pair arising from a normal sclerotized ocular boss. Anterior eye the larger, cornea 28μ across, the eye directed anterolaterally; posterior eye with cornea 24μ across, directed posterolaterally. The ocular boss carries about 7 normal dorsal idiosomalae (scobalae). Each pair of eyes placed close to border of scutum, and there is a slight ocular projection upon the scutum's anterolateral border. Anterior sensillary boss present, only moderately sclerotized, carrying the 2 anterior sensillae plus 3 scobalae. Anterior sensillae slender, with minute ciliations throughout the proximal 2/3, the ciliations thereafter longer to form a slight enlargement at the end. Posterior sensillary boss fairly small, lightly sclerotized, and without scobalae (posterior sensillae missing in specimen ACA 1674).

The standard data of specimen ACA 1674 are:

ASens	PSens	SBa	SBp	ISD	DS
46	—	26	18	192	12-16

The scobalae of the anterior dorsal scutum originate individually from the side of a circular or irregular pit, thus giving the anterior scutum a cribriform appearance.

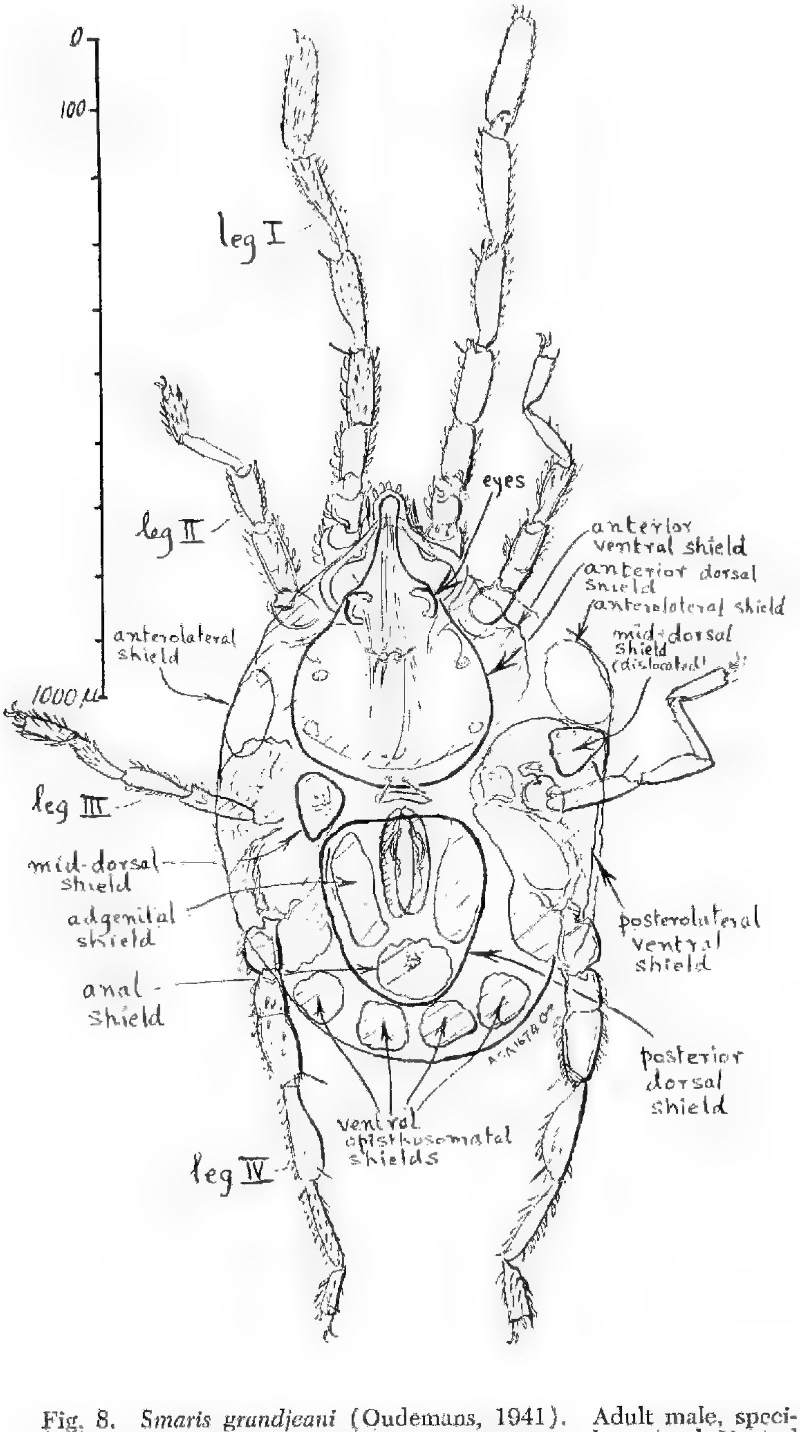

Fig. 8. *Smaris grandjeani* (Oudemans, 1941). Adult male, specimen ACA 1674, seen as a transparency, setae mostly omitted. Ventral structures shaded obliquely.

Posterior dorsal scutum large, widest anteriorly, a blunted triangle, with a somewhat sinuous edge. It is similar in structure to the anterior dorsal scutum, 281μ long by 258μ wide.

The idiosoma has other dorsal shields as figured (Fig. 8).

The dorsal idiosomal setae are typically smaridid in character, with a convex tectum and a tectal angle of about 120°; the tectum studded with short sharp spicules arranged fairly regularly in about 8 rows of 7-9 columns, except for the final 3 apical rows (see Fig. 9 A, B). The setae of the posterior part of the posterior dorsal scutum tend to be narrower than the others. Those idiosomal scobalae not arising on the larger shields arise individually in small polygonal seta-plates with excavated centres (Fig. 9 A, B). The dorsal idiosomal scobalae are in general less than twice as long as wide, the setae of the posterior part of the posterior dorsal scutum being an exception. A typical seta from near the posterior pole of the idiosoma dorsally, e.g. of Fig. 9 B, measure 14μ long by 10μ wide.

Venter with shields as figured (Fig. 8). The ventral idiosomalae are similar to the dorsal. Genitalia of specimen ACA 1674 of normal male smaridid character; adgenital shields are as figured. The anus is set in an anal shield as figured; the scobalae immediately adjacent to the anus are normal "analae" as described for other smaridids (pine-cone-like, with pointed spicules). Around the periphery of the opisthosoma in ventral view are 4 plates as figured; these are about equal in size, somewhat irregular, with rounded angles.

Legs fairly slender; leg lengths (including trochanter to tips of tarsal claws), I 765μ, II 470μ, III 470μ, IV 660μ. Tarsus I 173μ long by 52μ high; tibia I 180μ long, genu I 145μ long, tarsus II 76, 81μ long by 30μ high, tibia II 104μ long (left and right), tarsus IV 94μ long by 36μ high, tibia IV 150μ long, genu IV 153μ long (tarsal lengths exclude claws and pedicle). Tarsi with normal tarsal setation; tarsal claws ciliated along their sides, obliquely, except at tips. Scobopedalae of proximal segments similar to idiosomal scobalae but more elongate. Sensipedalae of normal smaridid type.

Gnathosoma appears normal, but as in ACA 1674 it is in the retracted position details cannot be clearly discerned.

Locality. The material referred to *Smaris grandjeani grandjeani* consists of three specimens:

One specimen, adult male, ACA 1674, in collection of United States National Museum, dated Nov., 1938, but without locality or other data, except details of slide mounting (2% KOH, acetic acid, absolute alcohol, clove oil, balsam).

Two adult specimens, serial ACA 1670, in collection of United States National Museum, the only data available being recorded on the slide as "Card No. 2961 . . . *Bufo* ⊟ *georgea*", of which the significance is not known.

Remarks. The figures and description given above match the specimen described by Oudemans (1941) in all essential details. As Oudemans gave no metric data for his mite except the length and breadth of the animal (1·04 mm. × 0·45 mm.) and the length of leg I (0·87 mm.) the present author has given the usual data he now gives in describing smaridid mites. Oudemans did not describe the system of dorsal plates of his specimen, but the pattern of setae shown in his Fig. 1 gives some indication of their presence. His Figs. 4 and 5 show the sensillae, rather inadequately, and he was not able to observe the eyes at all. The ventral surface was, however, quite well figured (his Figs. 8-15) and shows the ventral idiosomal system of plates quite well (from which it is concluded that Oudemans's specimen was described from a mite mounted with its venter upmost). However, Oudemans misinterpreted the relationships of the plates concerned with coxae III and IV, showing (Fig. 8) coxa III separated from IV, and showing also as separated the plates extending in front of coxa III and behind coxa IV. These are in *Smaris* all in continuity. The dorsal setae are not shown by Oudemans as pointed terminally (see his Figs. 1-7), but otherwise his figures show the general shape fairly well, and the setae on the nasus (his Fig. 3) are well drawn (compare with Fig. 9 A of the present paper).

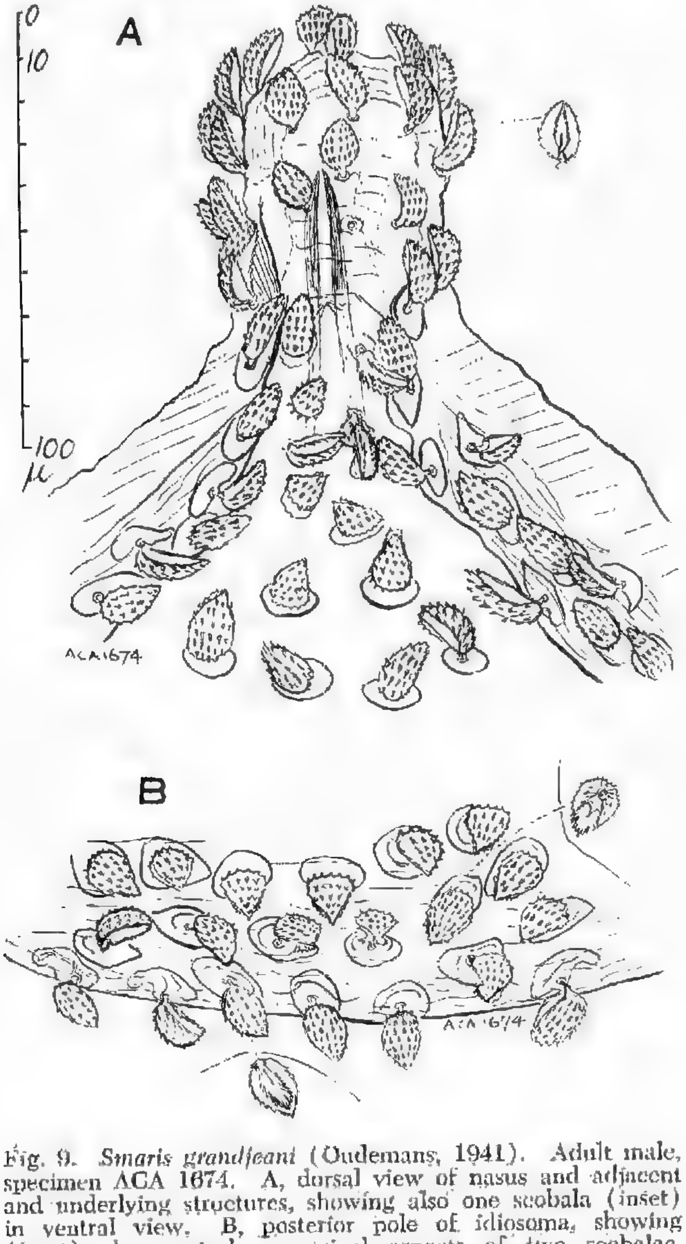

Fig. 9. *Smaris grandjeani* (Oudemans, 1941). Adult male, specimen ACA 1674. A, dorsal view of nasus and adjacent and underlying structures, showing also one scobala (inset) in ventral view. B, posterior pole of idiosoma, showing (inset) also ventral or carinal aspects of two scobalae. (All to scale shown.)

Oudemans stated that the following obtains with the leg lengths: I > II > IV > III. The present author, however, considers such a relationship unlikely to be correct in a smaridid mite, as leg IV is normally next in length after I. Reference to Oudemans's Fig. 2 shows that in the specimen described (the holotype) leg II is incomplete, and this would suggest that Oudemans estimated the length of leg II from the remaining parts rather than measured it in entirety, although he had actually two specimens available for study (the text does not state whether the second specimen was used in the description).

The only significant character in which *Leuchsia* was differentiated from *Smaris* by Oudemans lay in the fact that *Leuchsia* was alleged to possess "Keine Augen". The probable explanation for Oudemans's failing to recognize has been suggested above, apart from the deterioration of the standard of his work in that final paper of his career, which the author has commented upon elsewhere (1961*a*, p. 428).

The present author is satisfied with the identity of the material before him as conspecific with Oudemans's species. Oudemans stated, "Ich verdanke die 2 Exemplare dem Herrn F. Grandjean, der sie in moderndem Holze, August 1926, in der Umgebung von Colon, Panama, fand". It is to some extent regrettable that the slide mounts of the U.S.N.M. material do not carry more data. Presumably the specimens referred to originated in North or Central America.

From the above it may with confidence be concluded that *Leuchsia* Oudemans (December) 1941 is a junior synonym of *Smaris* (Latreille) Womersley and Southcott (July) 1941, as the author has provisionally indicated earlier (Southcott, 1961*a*, pp. 434, 435).

The holotype is in the Oudemans collection (not seen).

Smaris grandjeani subsp. **christensoni** subsp. nov.

Figs. 10 and 11

Description of Adult Male (from Holotype ACA 1667).

This subspecies is similar to the principal form of the species, but differs in having more elongate dorsal setae. These scobalae are, as Figs. 10 and 11 show, about twice as long as wide, or more.

The standard data of the holotype are:

ASens	PSens	SBa	SBp	ISD	DS
52	64	26	17	118	16-22

A typical measurement of a scobala near the posterior pole of the idiosoma, dorsally, is 18μ long by 8μ wide. The tectum setae has 5-8 (usually 5-6) columns of spicules in 7-8 rows.

Tarsus I is 128μ long by 78μ across, tibia I 135μ long, genu I 143μ long, tarsus II ca 90μ long by 41μ high, tibia II ca 100μ long, tarsus IV ca 95μ long by ca 40μ high, tibia IV ca 150μ long, genu IV ca 160μ long (tarsal lengths exclude claws and pedicle).

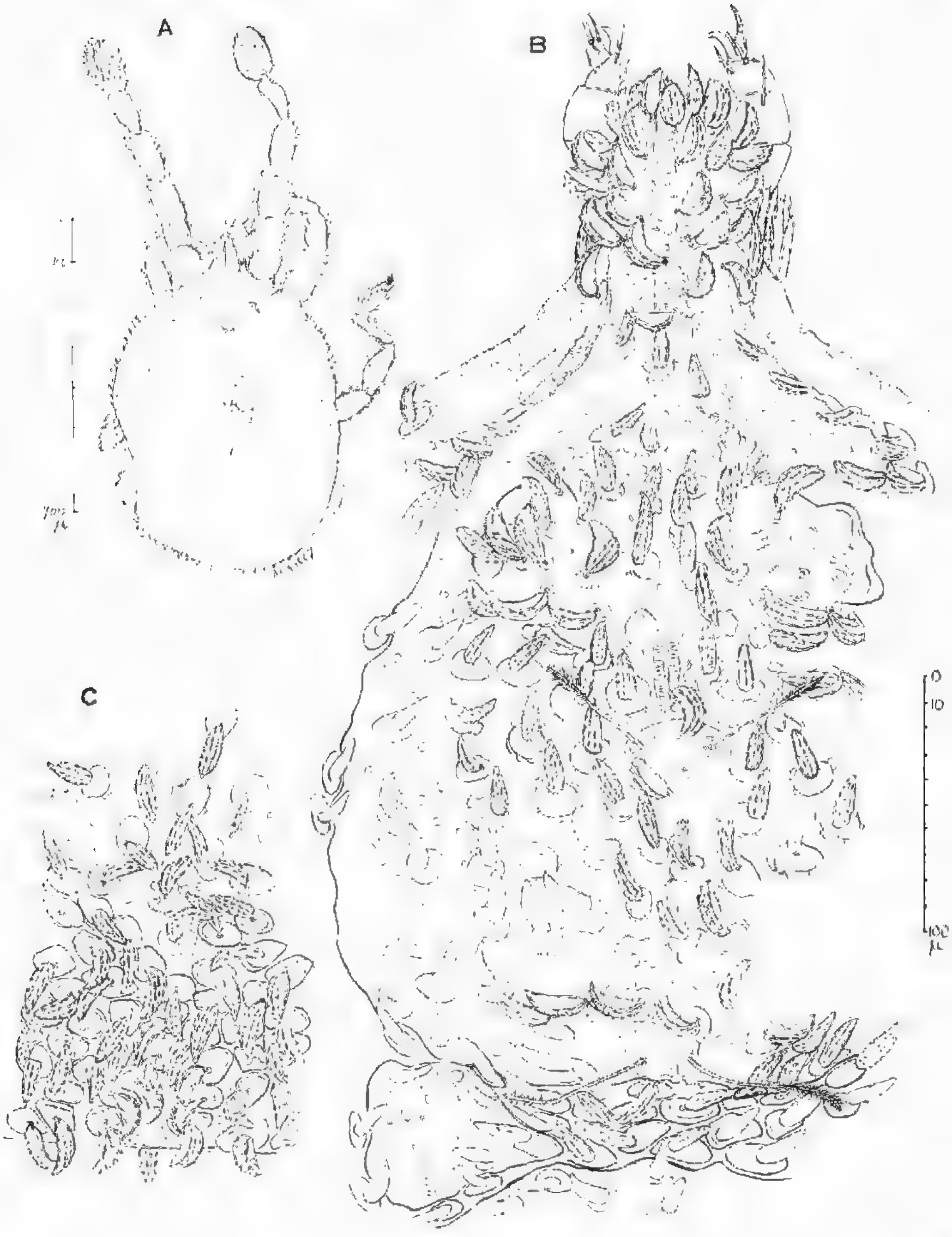

Fig. 10. *Smaris grandjeani* subsp. *christensoni*, subsp. nov. Adult male (holotype). A, outline of specimen in slide mount, mainly in dorsal view but partly as a transparency, setae mostly omitted. B, palpi, nasus, anterior dorsal shield, middle dorsal shield (left), and some adjacent structures, including the anterior edge of the posterior dorsal shield. Chelicerae are also outlined below the nasus, and the details of the eyes, sensillae, scobalae, etc., of the anterior dorsal scutum are shown. C, posterior pole of idiosoma in dorsal view, including part of posterior dorsal shield. (B and C to scale on right.)

Description of Nymph (from specimens ACA 1731 C, D).

The standard data of the two specimens studied are:

	ASens	PSens	SBa	SBp	ISD	DS
ACA 1731C	48	66	18	18	96	24-30
ACA 1731D	46	—	22	18	96	24-34

The dorsal idiosomal scobalae are similar to those of the adult, but are more elongate and the tectum setae has 5-6 columns of spicules in up to 14-15 rows. A typical dorsal scobala near the posterior pole of the idiosoma measures 28-30μ long by 7-8μ wide.

Specimen ACA 1731C has the idiosoma 810μ long by 590μ wide (somewhat compressed). Leg I is 435μ long inclusive of trochanter to tips of claws, tarsus I 102μ long by 56μ wide, tibia I 94μ long, genu I 90μ long, tarsus II 61μ long by 26μ high, tibia II 70μ long, tarsus IV 68μ long by 27μ high, tibia IV 94μ long, genu IV 94μ long (tarsi measured without claws or pedicle). (This specimen is in polyvinyl alcohol medium and is not ideal for description.)

Specimen ACA 1731D (mounted along with ACA 1731C and in similar condition) with idiosoma 805μ long, 570μ wide, tarsus I 104μ long by 60μ across by 49μ high, tibia I 94μ long, genu I 89μ long, tarsus II 61μ long by 28μ high, tibia II 73μ long, tarsus IV 65μ long by 26μ high, tibia IV 94μ long, genu IV 91μ long (tarsi measured without claws or pedicle).

Material Examined (all single adult specimens, except ACA 1731C, D).

ACA 1664, paratype, on *Neotoma,* Monterey, California, May 27, 1945, J. M. Linsdale, No. 562, Lot 46-865, in United States National Museum collection.

ACA 1665, paratype, on *Odontoglossum grande,* Guatemala: at Brownsville [, Texas], March 25, 1947, Lot 47-4989, in South Australian Museum collection ex U.S.N.M. collection.

ACA 1666, paratype, on orchid plants, "Mexico, D.F.", at Laredo, Texas, June 2, 1947, E. C. Harrison, Lot 47-8714, in South Australian Museum ex U.S.N.M.

ACA 1667, on orchid plants, Vera Cruz, Mexico: at Laredo, August 15, 1947, Jackson, Lot 47-12413. Male specimen, Holotype, in United States National Museum.

ACA 1668, paratype, on orchid plant, Guatemala, at Brownsville, October 27, 1947, Alexander, colr., Lot 47-16106, U.S.N.M.

ACA 1669, paratype, in soil, Mesilla, New Mexico, February 4, 1938, L. D. Christenson, 5775, Lot 38-13954, U.S.N.M.

ACA 1720, paratype, Petrero Grande, Mexico, January 15, 1943, F. Bonet, B689. Male, in South Australian Museum Coll.

ACA 1731A, paratype, Nevada de Colima, Jal[isco], Mexico, January 21, 1943, No. 715, S.A.M. Coll.

ACA 1731 C, D, two nymphs, same collection data as preceding, S.A.M. Coll. (described above).

Remarks. This species may be distinguished from *Smaris grandjeani grandjeani* as in the key to *Smaris* above. This subspecies is named for its original collector (see ACA 1669, above).

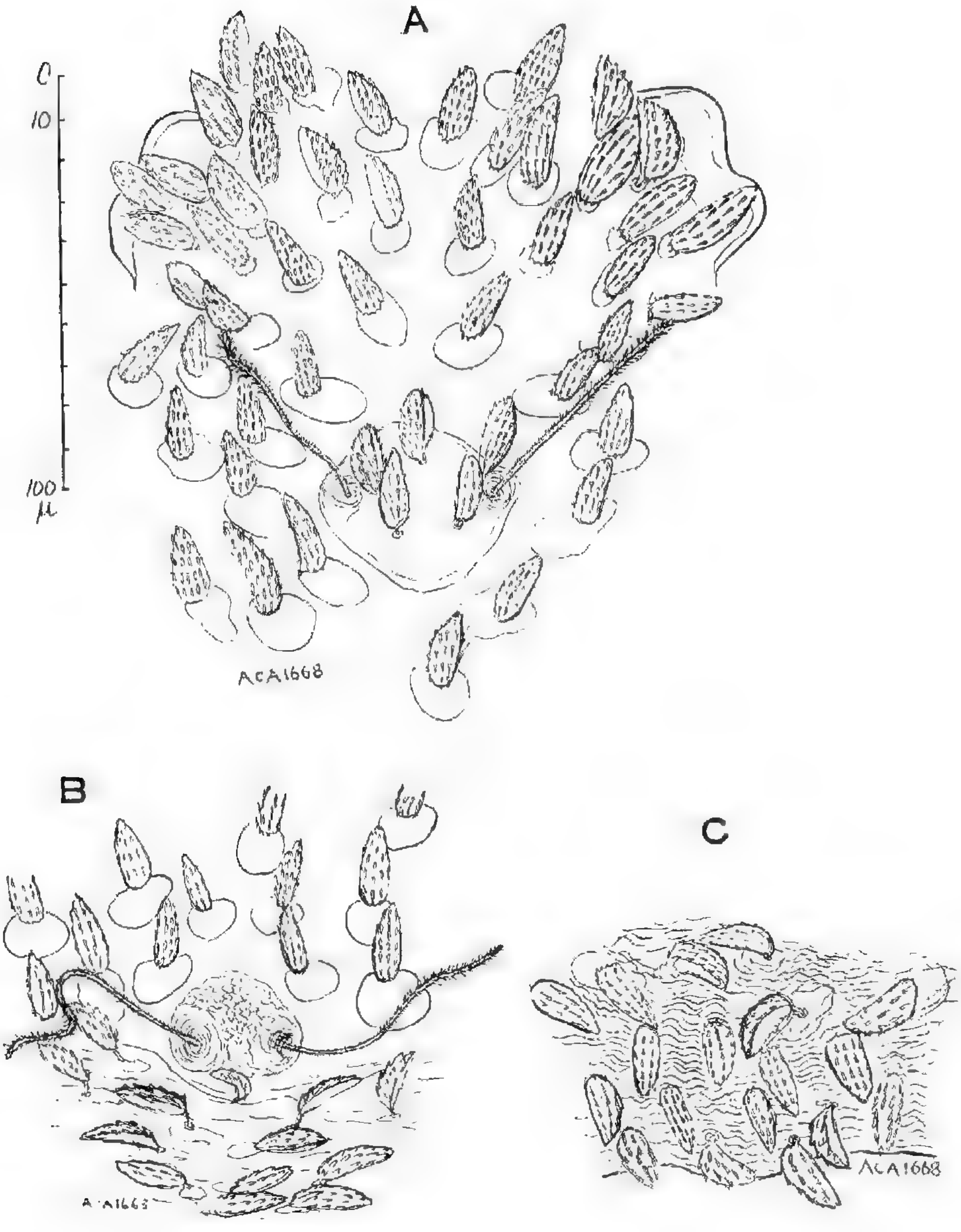

Fig. 11. *Smaris grandjeani* subsp. *christensoni*, subsp. nov. Adult, from paratype specimen ACA 1668. A, anterior sensillary area, eyes, and adjacent structures. B, posterior sensillary area and adjacent structures. C, posterior pole of idiosoma, in dorsal view. (All figures to scale shown.)

Smaris boneti sp. nov.

Figs. 12-14

Description of Adult Male (from the Holotype ACA 1731B).

Colour in life not recorded. Animal of normal smaridid shape, fairly robust, with a short nasus, and with lightly sclerotized plates. Idiosoma 1130μ long to tip of nasus by 760μ wide where widest.

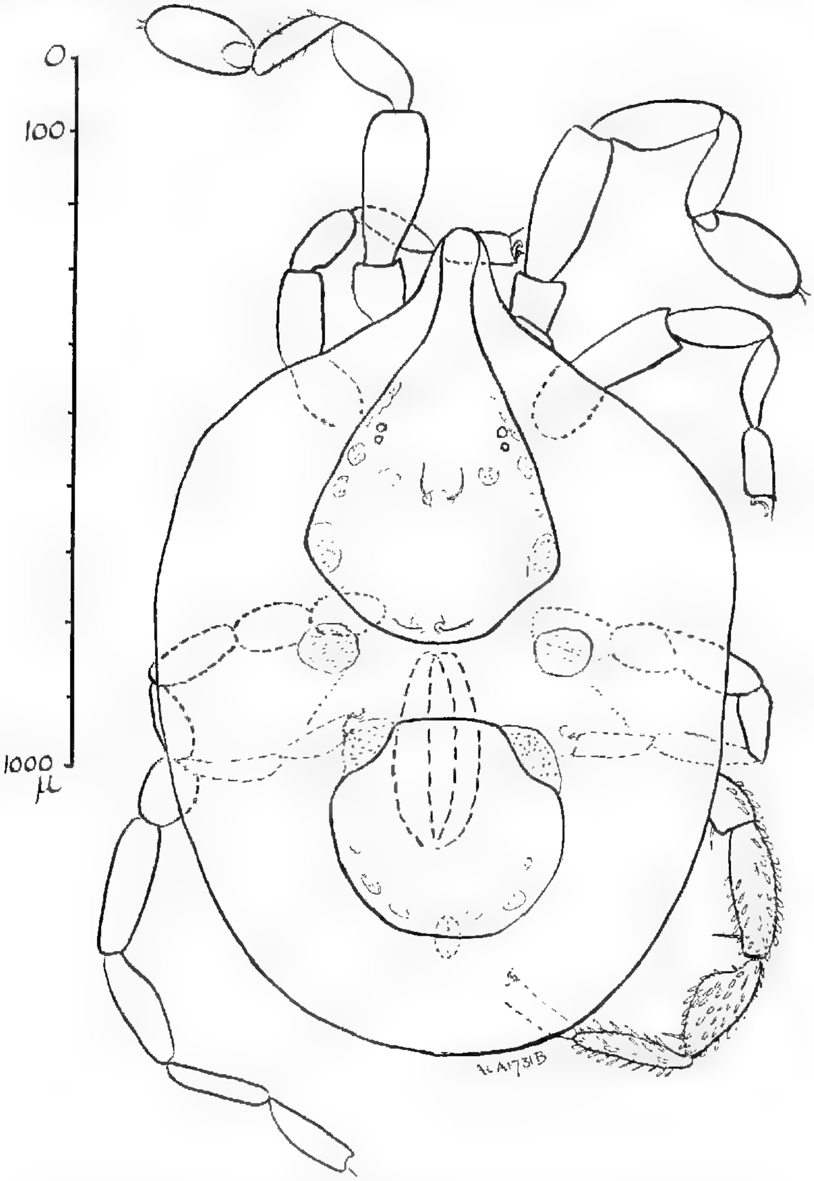

Fig. 12. *Smaris boneti*, sp. nov. Adult male (holotype), dorsal view, but showing some ventral structures (broken lines), setae mostly omitted

Anterior dorsal scutum present, 560μ long by 375μ wide, enclosing the sensillae and eyes, going forward on to the nasus; it is roughly pyriform, but with the edges somewhat irregular. There is practically no extension of the anterior dorsal scutum to form an ocular projection in the vicinity of the eyes. The shield has some punctate asetose areas, as figured (see Fig. 12), but these are not clearly demarcated on the scutum and they are difficult to elucidate. In the holotype the anterior and posterior dorsal idiosomal shields are well separated.

Eyes 2 + 2, each lateral pair closely approximated, but there is only a slight tuberosity on the anterior scutum for each lateral eye pair. Anterior eye the larger, cornea 24μ across, directed anterolaterally, posterior eye slightly lateral to anterior eye, with cornea 22μ across, directed posterolaterally. The eye tuberosity carries a few scobalae similar to the adjacent dorsal idiosomal scobalae, but slightly larger than those adjacent on the anterior dorsal scutum. Eyes fairly close to the lateral border of scutum, as figured (Figs. 12, 14A).

Anterior sensillary boss wide, carrying the two anterior sensillae and eight normal dorsal type scobalae. Anterior sensillae slender, parallel-sided, terminally blunted, ciliated, the terminal ciliations long. Posterior sensillary boss only lightly sclerotized, similar to anterior but slightly clavate in terminal part, and blunted terminally. The scutal scobalae have a convex tectum, lanceolate in outline, angled basally, and with the tectum setae with regularly arranged tuberous spicules. Each scutal scobala arises from an irregular pit; the scutum thus having the usual cribriform appearance of the anterior dorsal scutum.

The standard data of the holotype are as follow:

ASens	PSens	SBa	SBp	ISD	DS
80	85	47	26	170	22-30

Posterior dorsal scutum of moderate size, more or less rounded, of similar nature to the anterior dorsal scutum, ca 260μ long by 280μ wide. Attached to its anterolateral angles are two asetose areas which tend to project away from the remainder of the scutum; these overly muscular insertions. Some smaller asetose areas are present on the posterior part of the posterior dorsal scutum, as figured (Fig. 12). The scobalae of the posterior dorsal scutum are uniform in character and are similar to the other dorsal idiosomal scobalae. Two asetose areas are also present in the mid-dorsal position, and each is about halfway between the dorsal median line and the lateral edge of the idiosoma, as shown in Fig. 12.

Dorsal idiosomal scobalae are typically smaridid, with a wide tectum setae and a deep keel, the seta angled basally. The tectum setae lanceolate, widest about 1/3 along the scobillum, blunt-pointed apically; the tectum carries 6-8 columns of tuberous spicules, in 9-13 rows in the wider part of the tectum; distally the spicules diminish in number, but only a little in size. The setae arise either from pits (on the major shields) or from small individual setaplates, sclerotized, excavated centrally, resembling a coracle lying among the dorsal striations (see Figs. 13A,B; 14A,B).

Ventral sclerotization of normal type for genus, detail of shields similar to that of the dorsum (venter not clearly seen as the only specimen available is the holotype, mounted back uppermost). External genitalia and anus appear normal.

Legs robust, normal, moderately sclerotized. Leg lengths (including trochanter to tip of tarsal claws): I 750μ, II 605μ, III 600μ, IV 775μ. Tarsus I 155μ long by 93μ across, tibia I 142μ long, tarsus II 104μ long by 47μ high, tibia II 125μ long, tarsus IV 119μ long by 42μ high, tibia IV 165μ long (tarsal lengths exclude claws and pedicle). Scobalae of legs similar to those of idiosoma but the scobalae tend to be more elongate, particularly distally, with more outstanding spicules/ciliations. On the tarsi the scobalae are quite pointed with pointed ciliations. Sensalae of legs characteristic of Smarididae. Tarsal claws ciliated along their sides except at tip.

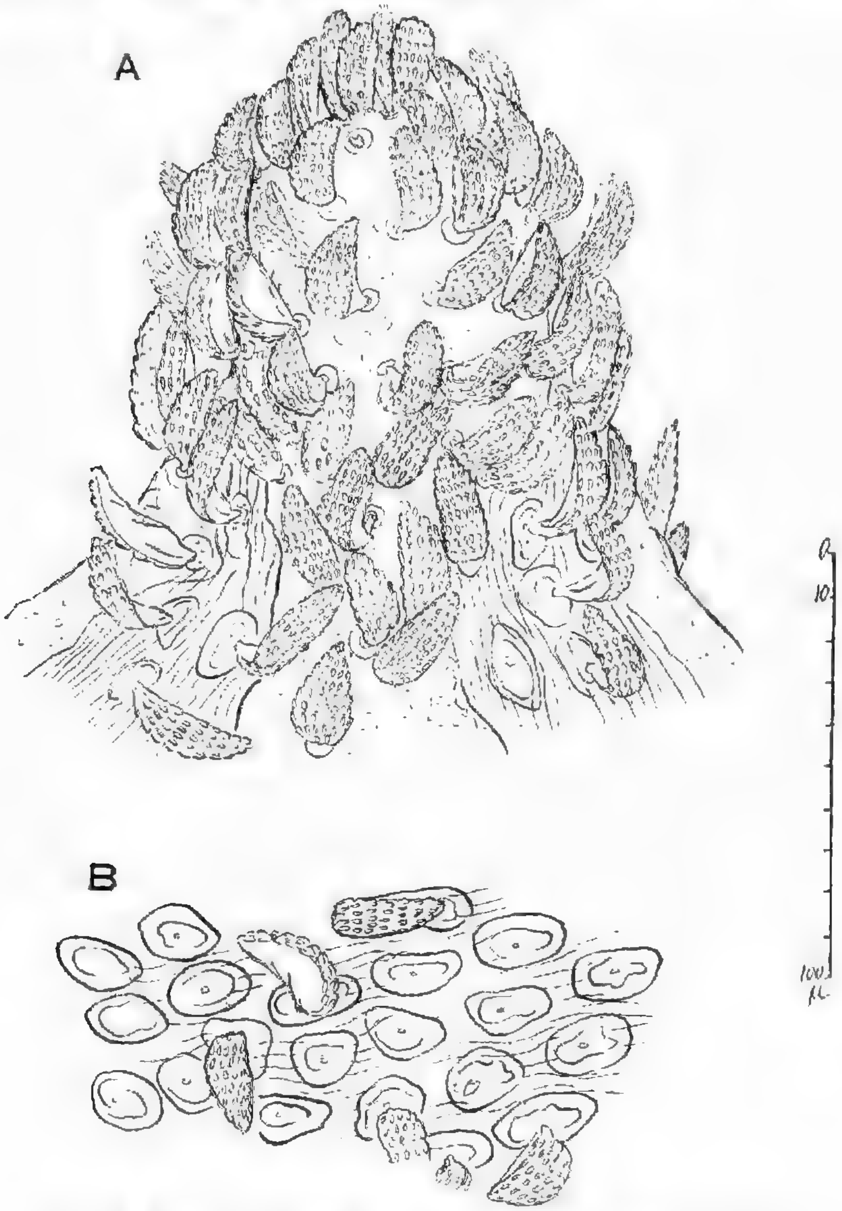

Fig. 13. *Smaris boneti*, sp. nov. Adult male (holotype). A, nasus and adjacent structures, dorsal view. B, scobalae near posterior pole of idiosoma dorsally. (Both to scale shown.)

Gnathosoma is in the retracted position in the holotype, and only the tip of the palp protrudes; palpal scobalae pointed, lightly ciliated.

Locality. This species is known from only the holotype, slide labelled Nevada de Colima, Jal[isco, Mexico], January 21, 1943, F. Bonet, No. 715; type slide in South Australian Museum collection, with identification number ACA 1731B. The mite was remounted from polyvinyl alcohol mountant to methyl cellulose medium on January 28, 1961, by the author, and to gum chloral medium on September 27, 1961; it is somewhat damaged.

Genus CALOREMA, gen. nov.

Unnamed new genus, undescribed Southcott 1961*a*, p. 438 (referred to in text on line 1; also referred to in second part of caption 3 (1) of the key).

Type species (original designation): *Calorema azteka*, sp. nov.

Definition. Octopod stages typically smaridid in shape. Eyes 2 + 2, placed level with or anterior to anterior sensillary area. The dorsal idiosomal sensillary areas enclosed by a paddle-shaped shield of prominent reticular structure, which does not enclose the eyes. Anterior sensillae behind middle of scutum. Coxae I and II do not fuse across the mid-line to form an anterior ventral shield, but have a narrow median gap between them. Chitin of legs, particularly coxae to tibiae, as well as dorsal scutum, with prominent reticular structure.

Larva not known.

Remarks. This genus may be separated from others of the subfamily Smaridinae in the adult and nymphal stages as in the key given earlier (Southcott, 1961*a*, p. 438, last entry).

Calorema azteka sp. nov.

Figs. 15-19

Description of Adult Male (from the Holotype ACA 1646) (Figs. 15, 16).

Colour in life not recorded. Of normal adult smaridid shape and dimensions, with a distinct nasus. Idiosoma 790μ long to tip of nasus by 480μ wide where widest.

Dorsal scutum paddle-shaped, the handle pointing anteriorly, and covering the dorsum of the nasus, 315μ long by 120μ wide where widest, a level about 230μ back from the anterior tip; the handle somewhat broadened over the nasus, and flattened along its anterior margin; a neck present about 60μ back from the anterior tip, the neck there 36μ wide. Anterior sensillary area present on scutum, behind its middle, and posterior to eye level. Posterior sensillae at posterior end of scutum.

The standard data are:

ASens	PSens	SBa	SBp	ISD	DS
30	(missing)	22	22	125	14-21

Anterior sensillae slender, slightly thickened in middle, distally tapering, ciliated throughout their length, the ciliations minute in the proximal third, ter-

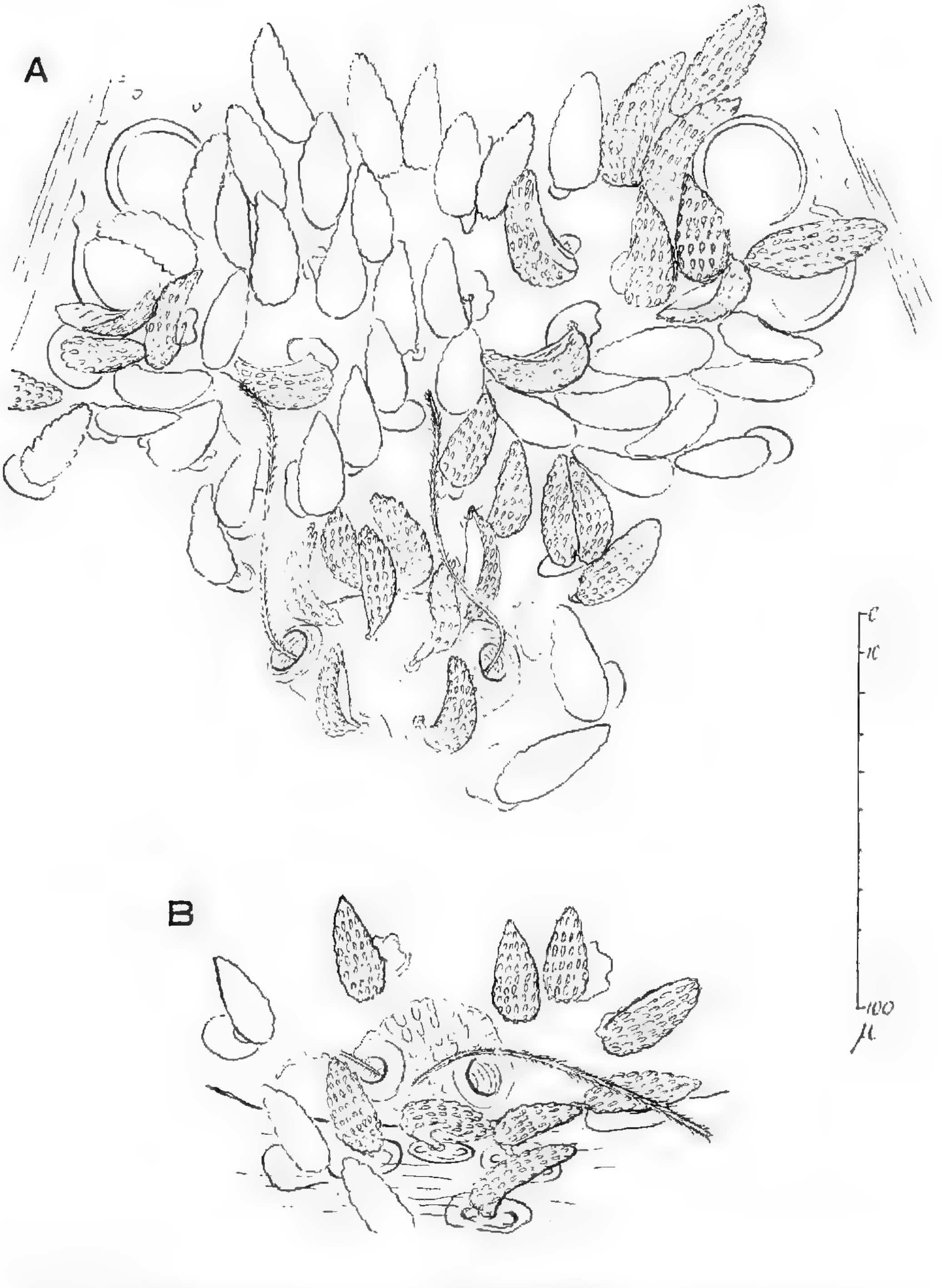

Fig. 14. *Smaris boneti*, sp. nov. Adult male (holotype). A, eyes, anterior sensillary area and adjacent structures. B, posterior sensillary area and adjacent structures; the right posterior sensillary seta has been dislocated from its socket. (Both figures to scale shown.)

minally the ciliations longer and there forming a spindle-shaped brush. Posterior sensillae missing in holotype, but in a paratype male specimen (ACA 1642) they are slender, slightly tapering, ciliated throughout, with ciliations longer in distal half of sensilla. Posterior sensilla 65μ long.

The chitin of the scutum has a prominent reticular structure, except for the track formed between the anterior and posterior sensillae, and around the anterior sensillae as figured (Fig. 16), thus outlining a crista incorporated in the scutum. The actual sensillary areas are differentiated by their having a separate pattern of smaller holes in their chitin. Scutum with setation in general similar to the normal dorsal idiosomal scobalae. Nasal setae 18-22μ long, other scutal scobalae 12-16μ long. Scutal scobalae behind the nasal setae and anterior to the anterior sensillary area are unpigmented (except for 4 scobalae at the anterior edge of the anterior sensillary area); one such unpigmented scobala seen 56μ anterior to posterior mid-sensillary point, and 20μ to right of mid-line, thus being about halfway between mid-line and lateral border of the scutum at that level, otherwise the scutal scobalae are light brown, the same as the majority of the idiosomal scobalae.

Eyes 2 + 2, the anterior eye larger and more medial, 22μ across. Posterior eye 16μ across. The eyes are placed at the ocular projection of the anterior part of the idiosoma dorsally, between the conjoined edges of coxae I and II, or slightly anterior to this vertical plane.

Dorsal idiosomal scobalae numerous, typically smaridid in structure, the tectum setae convex and with 4-5 irregular columns of coarse saw-teeth, these serrations or spicules projecting prominently; the carina or keel provided with an expanded flange, also cut at its edges into prominent curved saw-teeth. The dorsal scobalae longer posteriorly; most setae lightly pigmented with brown; among them, however, are several patches of unpigmented setae, these being (additional to those recorded for the dorsal scutum) (1) an irregular somewhat transverse patch behind the posterior sensillae; (2) a rounded patch about 120μ across by 90μ long, of about 22 setae, placed toward the posterior pole of the idiosoma behind the level of coxae IV, its mid-point level with the femoral (IV) pseudoarticulation (there is no sign of any underlying scutum to this patch or in this region, but the patch is placed where one would expect to find the normal posterior dorsal idiosomal scutum in the genus *Smaris*).

Venter: the anterior coxae I and II of each side form a conjoined anterolateral coxal plate, as applies in the Erythraeoidea generally. These two anterior lateral coxal plates nearly meet in the mid-line, the separation being only 8μ, and this almost straight medial border of each anterior coxal plate is made up in its anterior 2/3 from coxa I and the remainder from coxa II. Anteriorly there is also an oblique part of the medial border of coxa I. The posterior coxae (III and IV) form on each side a posterior coxal plate, as is usual in the Erythraeoidea, these being well separated (see Fig. 15). The posterior coxal plate has no flange or any additional plate in front of coxa III. All coxae with heavy chitin, with prominent reticular structure. External genitalia and anus normal. Ventral idiosomal setae normal, with pointed ciliations. Internal genital armature shows that the holotype is a male; the external genital orifice with the normal paired lips.

Legs normal, except that the chitin has a prominent reticular structure, present on all segments except tarsi, where it is less marked. Leg lengths (including trochanter and tarsal claws); I 715μ, II 515μ, III 590μ, IV 810μ. Tarsus I 131μ long by 52μ high, tibia I 170μ long, genu I 148μ long, tarsus IV 119μ long by 28μ high, tibia IV 203, 211μ long, genu IV 169μ long (tarsal measure-

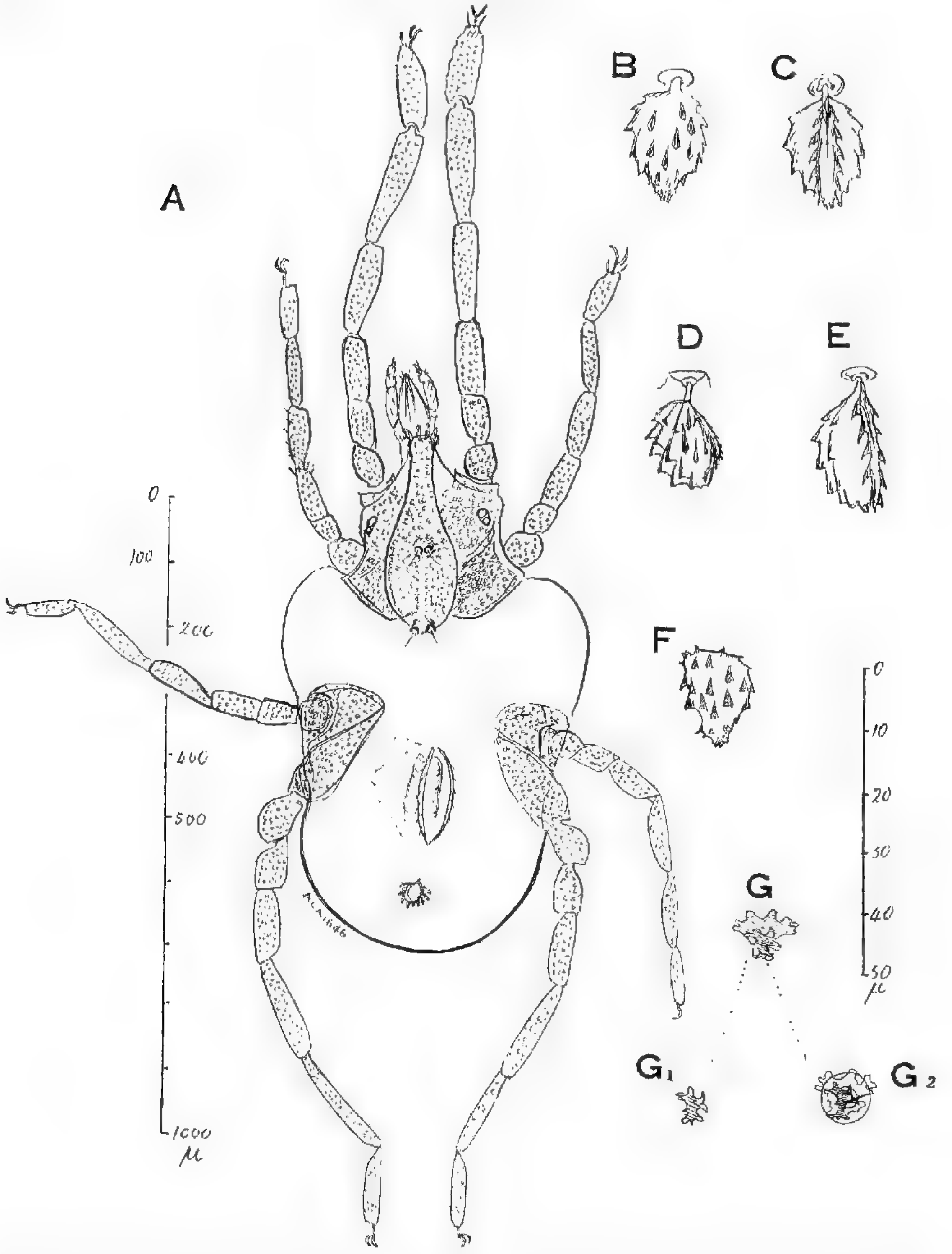

Fig. 15. *Calorema azteka*, sp. nov. Adult male (holotype). A, entire, by transmitted light, but giving preference to the dorsal view, setae mostly omitted. B-G, dorsal idiosomal scobalae, various aspects: B, scobala in dorsal or tectal aspect; C, scobala in ventral or carinal aspect; D, E, oblique views, D, tectal oblique view, E, carinal oblique view; F, end view, somewhat tectal; G, end view of scobala, showing inset: G_1, end view of the seta tip, G_2, the outline superimposed over the annulus (seta base) and bulb of the pedicle. (A to scale on left; setae to scale on right.)

ments excluding claws and pedicle). Tarsi with usual supraonychial setae. Tarsal claws ciliated obliquely along their sides, except at tip.

Gnathosoma as figured. Palpal scobalae moderately ciliated.

Description of Allotype Adult Female (from ACA 1649).

Similar to male in general structure. The standard data are:

ASens	PSens	SBa	SBp	ISD	DS
28	ca 55	24	21	127	14-22

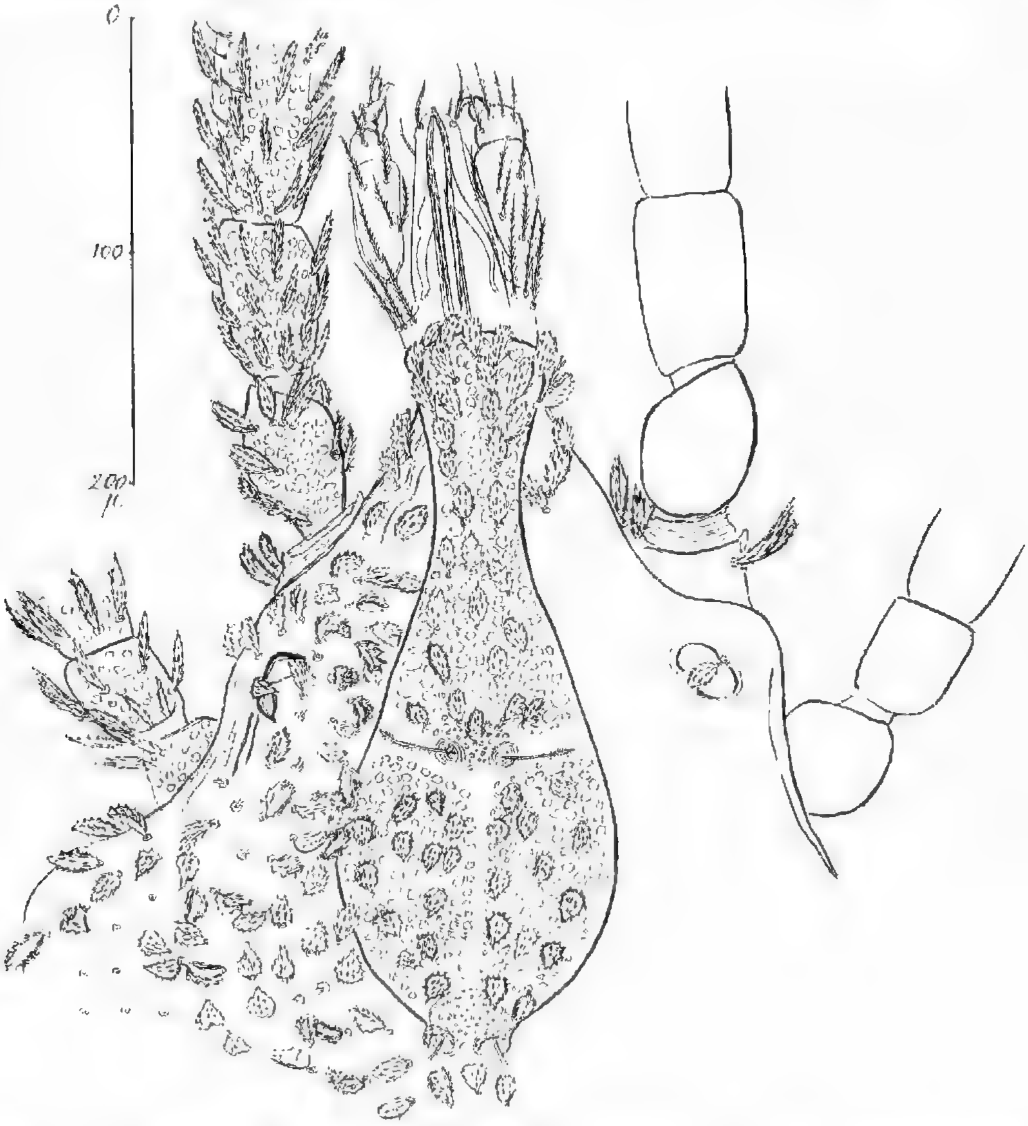

Fig. 16. *Calorema azteka*, sp. nov. Adult male (holotype), anterior part of idiosoma dorsally, and adjacent structures (setae mostly omitted on right).

Tarsus I is 121μ long by 46μ high by 60μ across, tibia I 164μ long, genu I 150μ long, tarsus IV 102μ long by 32μ high, tibia IV 175μ long, genu IV 158μ long (tarsal lengths exclude claws and pedicle).

Description of Nymph (from the "Nymphotype", ACA 1650) (Figs. 17-19).

Colour not recorded. The animal is of normal nymphal smaridid build. Idiosoma 770μ long by 490μ wide (the specimen is rather compressed in the slide mount; see Fig. 17). Dorsal scutum more slender than in adult, 236μ long by 36μ wide, where widest (about 1/3 back from anterior sensilla towards the posterior sensilla).

The standard data are:

ASens	PSens	SBa	SBp	ISD	DS
36	57	14	13	99	24-41

Sensillae of dorsal scutum similar to adult, but more slender. The scutum has only a few scobalae (see Fig. 18A); there are 4 setae forming a curved row at the nasal tip of the scutum, 28-30μ long.

Eyes 2 + 2, level with or a little anterior to anterior sensilla as figured (Fig. 18A). Anterior eye 22μ across, posterior 16μ across.

Dorsal idiosomal scobalae typical of a nymphal smaridid, elongate, with about 4 columns of saw-teeth; setae are fairly uniform in length over the dorsum, including the scutum, and none are unpigmented in the "Nymphotype".

Venter similar to adult, except that the genitalia are of the nymphal character.

Legs similar to adult, but more slender; the leg lengths are (including trochanters and tibial claws): I 615μ, II 445μ, III 455μ, IV 590μ. Tarsus I 106μ long by 51μ high, tibia I 148μ long, genu I 118μ long, tarsus IV 73μ long by 32μ high, tibia IV 146μ long, genu IV 123μ long (tarsal lengths exclude claws and pedicle).

Gnathosoma similar to adult, but more slender.

Material Examined and Locality and Other Data.

Holotype male, ACA 1646: On banana leaf debris. Panama: at Philadelphia, Philadelphia. October 9, 1933, A. B. Wells, U.S.N.M. Ref. No. Phila. No. 19392. In United States National Museum collection.

"Nymphotype", ACA 1650. Moss, Desierto de los Leones, Mexico. December 12, 1943. Collector not stated. In U.S.N.M. (This slide contains also an adult pachygnathid mite, ACC 824, ?*Nanorchestes* sp., but with the posterior sensillae somewhat clavate.

ACA 1642, paratype, adult male. On banana debris. Mexico: at Galveston, Texas, U.S.A. Coll. S. R. Morris, February 16, 1937. Lot 37-4801. Remounted in methyl cellulose mountant January 11, 1961.

ACA 1643, paratype, adult, ?sex. On *Laelia majalis*. Antiguo[-]Morelos, Mexico: at Brownsville, Texas. April 2, 1947. Lot 47-4992. Name of collector not stated. Specimen retained in South Australian Museum collection ex U.S.N.M.

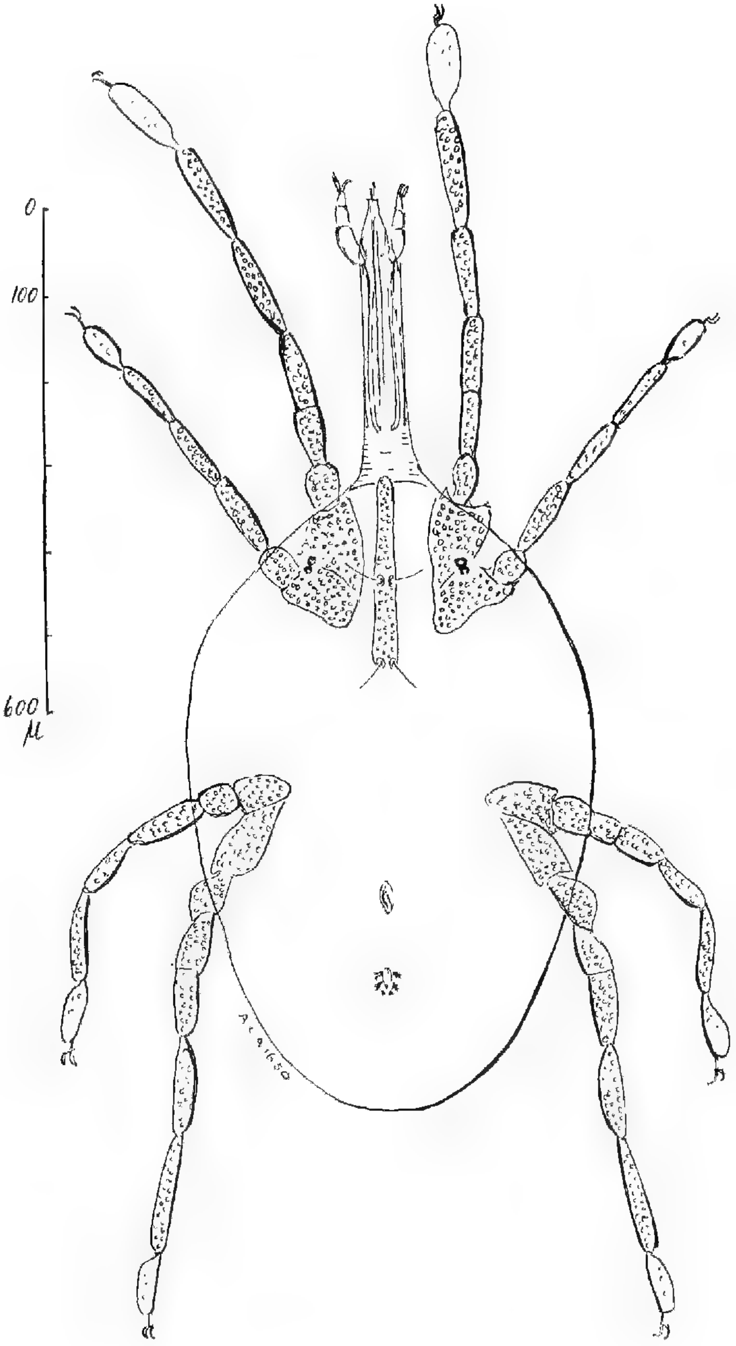

Fig. 17. *Calorema azteka*, sp. nov. Nymph (specimen ACA 1650), in transparency, viewed from dorsum, setae mostly omitted.

ACA 1644, paratype, adult, probably male. On orchid plant, S[an] L[uis] P[otosi], Mexico: at Laredo, Texas, May 14, 1946, Babb, coll. Laredo 39239, Lot 46-7030. In polyvinyl alcohol mountant (heated) according to slide data. Remounted in methyl cellulose mountant January 11, 1961.

ACA 1645, paratype, adult, probably female. On orchid plants, Mexico, at Laredo, Texas, December 29, 1945. Fouts, coll. Laredo 37961, Lot 46-542. PVA mountant, not heated, in South Australian Museum ex U.S.N.M.

ACA 1647, paratype, adult, ?female. On orchid plant, Tamazunchale, [S.L.P.,] Mexico: at Laredo, Texas, May 20, 1946. Babb, coll. Laredo 39613, Lot 46-7971. PVA—heated. U.S.N.M.

ACA 1648, paratype, adult, ?sex. On orchid plants, Maiz, S.L.P., Mexico: at Laredo, Texas, March 18, 1947. Fouts, coll. Lot 47-4243, retained in S.A.M. collection ex U.S.N.M.

ACA 1649, adult female, allotype, data as ACA 1648, in United States National Museum collection.

ACA 1658, paratype, adult, probably female. On *Laelia majalis*. Antiguo-Morelos, S.L.P., Mexico: at Brownsville, Texas, March 18, 1947. Name of collector not stated. Lot 47-4105; in South Australian Museum collection ex U.S.N.M. collection.

ACA 1717. Three specimens, small adults. Petrero Grande, [Mexico,] June 15, 1943, F. Bonet, Ref. B689 or No. 29, Bonet. In South Australian Museum collection (slide in poor condition).

Remarks. The nymph is correlated with the adult on morphological grounds, particularly the structure of the dorsal idiosomal scobalae.

The genus *Calorema* is somewhat intermediate between *Smaris* and *Fessonia*, as remarked previously by the author (1961*a*), and its discovery was the cause of the fusing of the Smaridinae and the Fessoniinae.

The geographical spread of this interesting monotypic genus may be noted. Its recorded distribution is at present Panama and Mexico, which is reflected in the specific name *azteka*.

Genus FESSONIA Heyden

Restricted by Womersley and Southcott (1941).

For synonymy see Southcott, 1961*a*, p. 441, and in addition, *Fessonia* Southcott, 1961*b*, p. 146.

For definition and discussion on the type species see Southcott (1961*a*).

Remarks. Previously described species of this genus are *F. papillosa* (Hermann) Berlese, 1884 (A.M.S. 16, 3) from Europe, with which the European *F. callitricha* (Grandjean, 1947) is probably synonymous, according to Grandjean (loc. cit.) (see Southcott, 1961*a*, p. 441), *F. australiensis* Southcott, 1946, described from northern Australia, and *F. taylori* Southcott, 1961 (1961*b*, p. 146) described from one locality in New South Wales.

In North America the evidence from the present study suggests that *Fessonia* is mainly a tropical or subtropical genus; this agrees with the distribution in Australia (Southcott, 1946, 1961*b*). However, in Europe *F. papillosa* (= *callitricha*) is found in cold climates (Grandjean, 1947, p. 39).

In the present paper *F. australiensis* is recorded from North America, in Hawaii ex China, as well as other Asian localities, and a further Australian

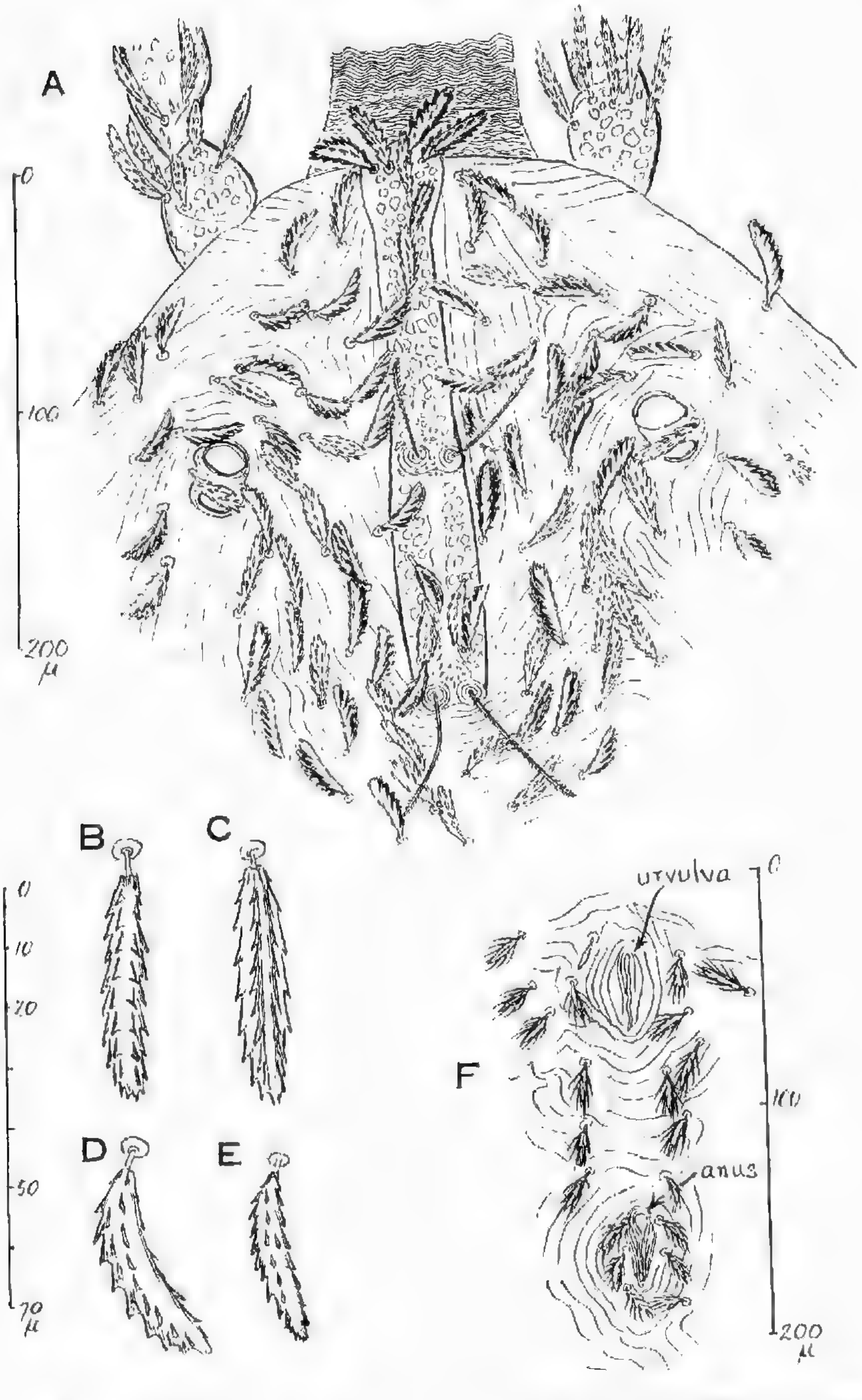

Fig. 18. *Calorema azteka*, sp. nov. Nymph (specimen ACA 1650). A, anterior dorsal part of idiosoma and adjacent structures, to scale on left. B-E, dorsal idiosomal setae (scobalae), various aspects, to scale on left. F, urvulva and anus, and adjacent structures, to scale on right.

specimen is recorded. In addition, four new species are described from North and Central America, and recorded for various localities, these species being *F. serrata*, sp. nov., *F. lappacea*, sp. nov., *F. scobina*, sp. nov., and *F. lacrimosa*, sp. nov.

In view of the wide distribution now recorded for *F. australiensis*, the following key to the species of the genus *Fessonia* for the world is submitted (accepting that *F. papillosa* and *F. callitricha* are synonymous).

Key to the World Species of the Genus *Fessonia*.

1. Spicules on tectum of dorsal idiosomal form consistently well-defined columns over at least part of the tectum setae 2

Spicules on tectum of dorsal idiosomala not consistently forming well-defined columns or rows; they are arranged irregularly or at most form ill-defined or inconsistent columns and rows 5

2(1). Dorsal idiosomalae lanceolate, and with tectum setae with a series of longitudinal columns of spicules, physically linked, and running to the apex of the seta 3

Dorsal idiosomalae without the preceding combination of characters 4

3(2). Tectum setae with four columns of strong serrate spicules, with transverse markings across the tectum setae, linking the columns of spicules. Dorsal setae 24-43μ long . . . *F. serrata*, sp. nov. (North America).

Tectum setae with 4-6 columns of fine serrations, and without transverse markings

F. papillosa (Herm.) Berl. (= *F. callitricha* (Grandjean) (Europe)).

4(2). Dorsal idiosomalae with 4-6 longitudinal columns of strong serrations or spicules, not linked to each other, with the two median columns usually regular, running to the apex of the seta. Dorsal idiosomalae clavate, the scobillum almost conical, the distal end blunted, setae 20-41μ long. Palpal scobalae slender, ciliated.

F. taylori Southcott, 1961 (1961*b*) (Eastern Australia).

Dorsal idiosomalae with tectum setae lanceolate-clavate, there being 6-8 well-defined columns of linked pointed spicules over the proximal 2/3 of the tectum setae, these columns tending to break up more distally, and in the distal 1/3 of the tectum setae the spicules are discrete, short, blunted, and irregularly arranged. Posterior dorsal scobalae 18-33μ long. Palpal scobalae elongate-lanceolate, ciliated.

F. australiensis Southcott (Australia, Mexico, India, South-East Asia, etc.).

5(1). Dorsal idiosomalae lanceolate or clavate, with strong projecting serrate spicules arranged irregularly over the convex tectum setae. Spicules of uniform character over the tectum setae. Carina narrow, with long ciliations. Dorsal scobalae 18-30μ long.

F. lappacea, sp. nov. (North and Central America).

Dorsal idiosomalae otherwise 6

6(5). Dorsal idiosomalae lanceolate, blunted, tending to elongate posteriorad over the idiosoma. Tectum setae with about 50 small triangular or blunted spicules of nearly uniform character (some of the proximal ones are slightly longer than the others), arranged evenly, and hence in some setae tending to be arranged in columns, rows, or oblique lines. Dorsal scobalae 20-42μ long *F. scobina*, sp. nov. (North America).

Proximal tectal spicules tend to elongate into the form of tear-drops. Dorsal scobalae 24-42μ long *F. lacrimosa*, sp. nov. (North America).

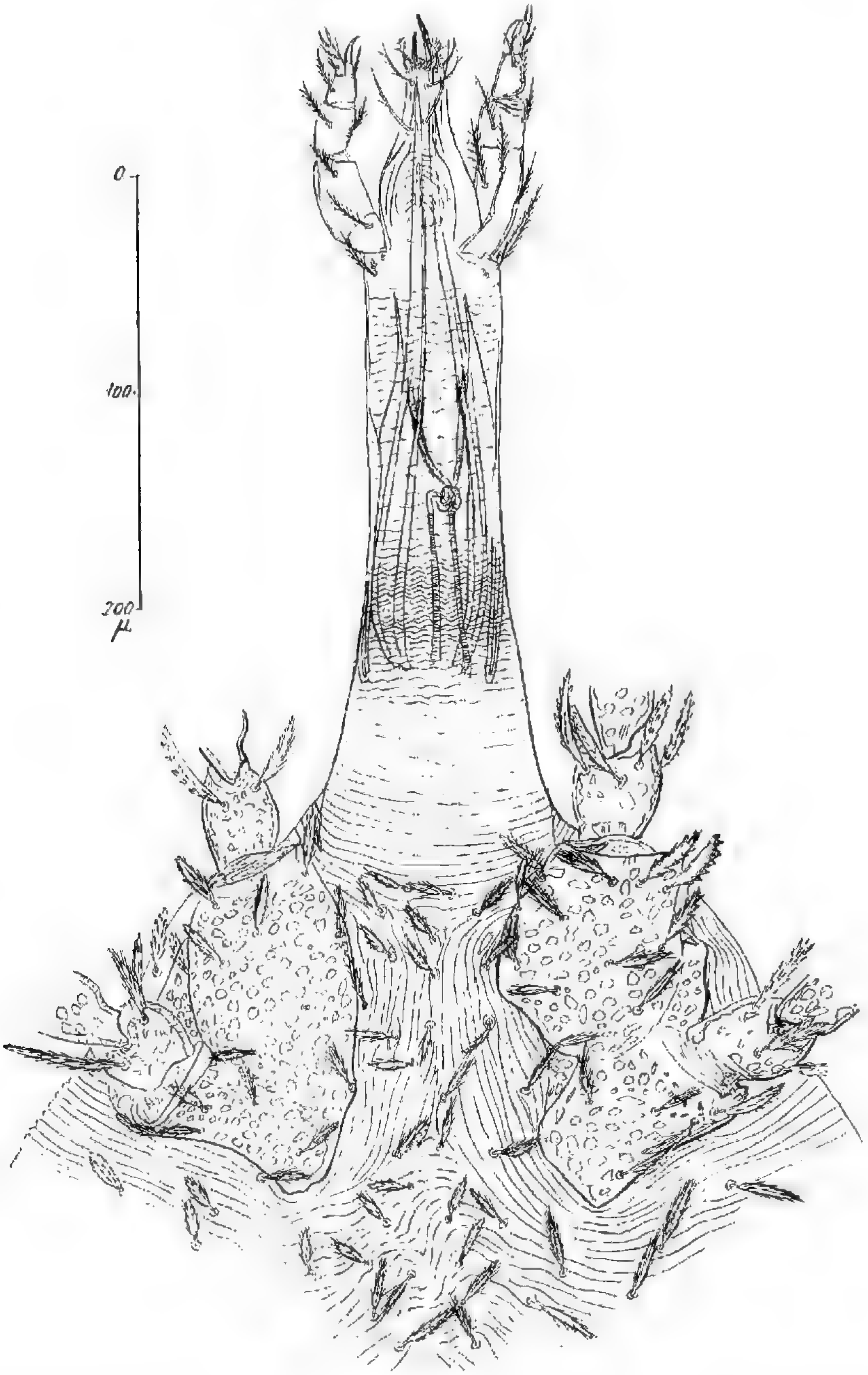

Fig. 19. *Calorema azteka*, sp. nov. Nymph (specimen ACA 1650). Anterior ventral part of idiosoma, and the extended armilla and gnathosoma in ventral view, showing internal structure.

Fessonia serrata sp. nov.

Figs. 20 and 21

Description of Adult Male (from Holotype ACA 1656).

Colour in life not recorded. Animal of normal smaridid shape and dimensions, with a normal nasus. Idiosoma 1130μ long to tip of nasus by 625μ wide where widest.

Crista normal, with two sensillary areas, the mid-point between the two anterior sensillae slender being placed 318μ behind tip of nasus and posterior to eyes.

The standard data of the Holotype specimen are:

ASens	PSens	SBa	SBp	ISD	DS
75	110	17	28	236	24-43

Anterior sensillae slender, ciliated throughout their length, ciliations small in proximal 20μ, then increasing in length except terminally, hence bushy. Posterior sensillae slender, long, ciliated throughout their length, ciliations small proximally, then longer, thickest in central part of sensilla, terminally sparser but equally long.

Eyes 2 + 2, placed as figured, anterior eye the larger, with cornea 20μ across, posterior cornea 15μ across.

Dorsal idiosomalae (scobalae) spindle-shaped or blunted terminally, with strong serrate pointed ciliations arranged in 4 tectal columns; carinal ciliations also long, strong, pointed; faint cross-striations seen across tectum setae between the columns of spicules; setae becoming longer at nasus and over posterior pole of idiosoma.

Venter not clearly seen, as the sole mount is dorsum uppermost, but appears normal. External genitalia normal; internal genitalia of male type.

Legs normal. Leg lengths (including trochanter and tarsal claws): I 1760μ, II 1040μ, III 1095μ, IV 1440μ. Tarsus I 222μ long by 75μ across, tibia I 375μ long, genu I 432μ long, tarsus IV 216μ long by 44μ high, tibia IV 360μ long, genu IV 327μ long (tarsal lengths excluding claws and pedicle). Tarsal claws normal, lightly obliquely ciliated along their sides except at tip. Scobopedalae and sensipedalae of normal smaridid type.

Gnathosoma as figured. Chelicerae digits blunted at tip, with 3 or 4 blunt barbs. Palpi as figured, with moderately ciliated non-expanded scobalae.

Locality. The sole specimen seen is the holotype, ACA 1656, labelled "With orchid plants. Guatemala: at Brownsville. Feb. 8, 1948. Lot 48-1708". Name of collector not stated. In United States National Museum collection.

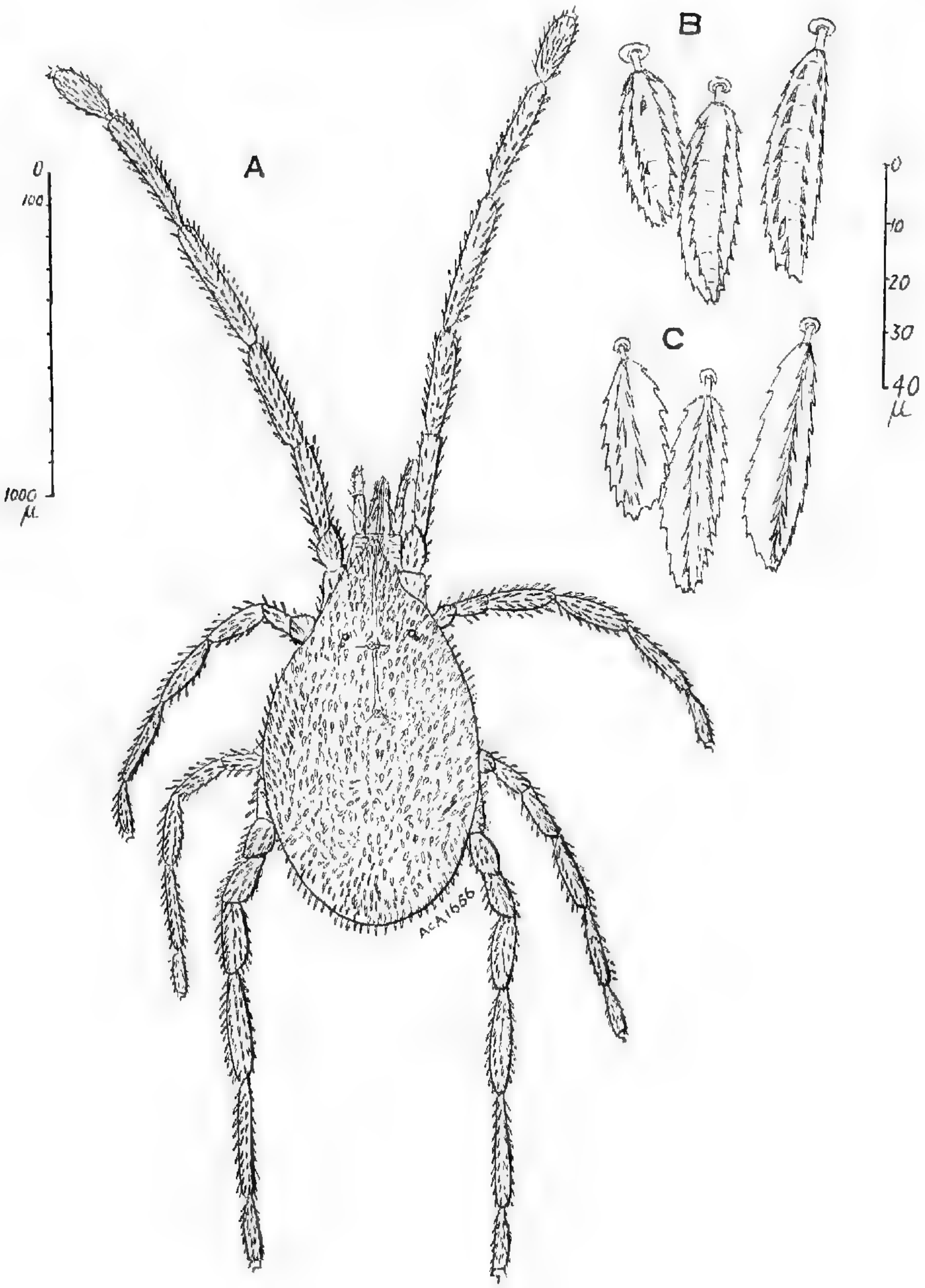

Fig. 20. *Fessonia serrata*, sp. nov. Adult male (holotype). A, entire, dorsal aspect, to scale on left. B, a group of dorsal idiosomal scobalae, toward posterior pole, dorsal (tectal) aspect. C, same setae in ventral (carinal) aspect. (All setae to scale on right.)

Fessonia australiensis Southcott

Fig. 1 J, K

Fessonia australiensis Southcott, 1946, p. 176.
Fessonia australiensis Meyer and Ryke, 1959, p. 322.
Fessonia australiensis Southcott, 1961*a*, p. 441.
Fessonia australiensis Southcott, 1961*b*, p. 150.

Remarks on the Type Series.

In addition to the detail of the dorsal idiosomalae recorded above for *F. australiensis* in the key to the genus *Fessonia* the following additional notes on the dorsalae of the holotype may be made: Cardinal flange of dorsal idiosomae broad and with long pointed ciliations; spicules and ciliations brown.

The following standard data and some other data (in micra) of the type series from Mataranka, Northern Territory, are now submitted:

	ASens*	PSens	SBa	SBp	ISD	DS	Ta I	Ti I	Ge I	Ti I/Ta I
Holotype ♀ ACA 1056 A	51	79	18	22	146	18-33	131	210	197	1·603
Paratype ♀ ACA 1055	53	ca 80	15	22	142	18-33	144	217	201	1·507
Paratype ♀ ACA 1056 B	55	86	19**	22	159	17-32	151	230	227	1·523
Paratype ♀ ACA 1056 C	48	77	16	22	141	19-32	137 135	220 205	199 205	1·606 1·519

*Abbreviations as in Southcott 1961*a*, and, in addition, Ta I = length of tarsus I, measuring as is customary between the chitinous end-points but excluding claws and pedicle; Ti I = length of tibia I, measuring between chitinous end-points, as usual, Ge I = length of genu I, similarly.

**Teratological specimen, see Southcott (1946).

The genu IV of the holotype, specimen ACA 1056A, is 178μ long.

Remarks on a Specimen from Queensland.

A specimen, adult ♀, reddish-pink in life, collected from the base of *Eucalyptus* sp. near a creek-bed, Montalbion, Irvinebank, north Queensland, October 11, 1944 (R. V. Southcott) has the following data (in micra):

ASens	PSens	SBa	SBp	ISD	DS	Ta I	Ti I	Ge I	Ti I/Ta I
48	ca 83	17	22	137	20-35	156	236	225	1·513

These data do not differ significantly from those of the type series.

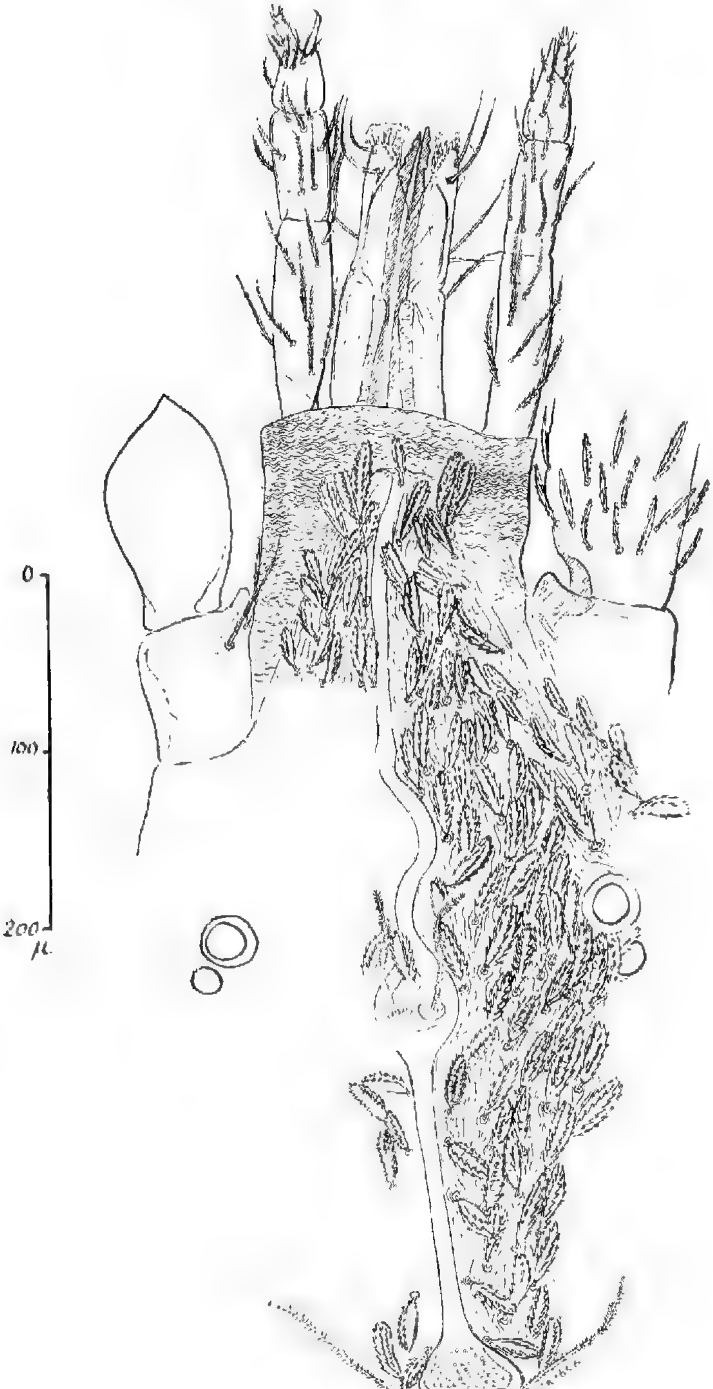

Fig. 21. *Fessonia serrata*, sp. nov. Adult male (holotype). Gnathosoma, crista, eyes and adjacent structures.

Remarks and Data of Three North American Specimens.

Three specimens, all adult female, are referred to *F. australiensis*, from North America. Locality and other collection data of these specimens are as follows:

ACA 1651, adult ♀, on garlic (dried), Apasco, G[uanajua]to., Mexico: at Laredo, Texas. C. P. Trotter, December 30, 1936. Lot 37-607. U.S.N.M. collection (potashed).

ACA 1653, adult ♀, on garlic, Apasco, G[uanajua]to., Mexico: at Laredo. February 7, 1937. C. P. Trotter, Lot No. 37-3792. U.S.N.M. collection. (Potashed, in poor condition.)

ACA 1661, adult ♀, on garbanzos (= chick-peas), Mexico, at Hidalgo, Texas. Williamson, collector. October 4, 1936. Lot 36-32424. This specimen contains one egg with a chitinized chorion, and measures 264μ by 150μ; however, the egg appears distorted and its transverse diameter may be estimated as ca 190μ; it is mounted in polyvinyl alcohol mountant. In South Australian Museum collection ex U.S.N.M. collection.

The metric data of these three specimens are as follow:

Specimen	ASens	PSens	SBa	SBp	ISD	DS	Ta I	Ti I	Ge I	$\frac{\text{Ti I}}{\text{Ta I}}$
ACA 1651	58	—	17	ca25	146	-32	157	245	259	1·561
ACA 1653	—	—	18	18	149	-32 {	146 148	217 224	232 225	1·486 1·514
ACA 1661	52	77	18	22	162	17-30	158	234	243	1·481

Remarks and Data on Seven Specimens Originating from Asia.

Seven specimens have been examined which have originated from Asia, which are referred to *F. australiensis*. Locality and other collection data of these specimens are as follows:

ACA 1652, two specimens, one ♂, one ♀, in mixed grain and rice, India: at Boston, United States of America, October 27, 1937. O. A. Hardy. Boston No. 13572, Lot 37-24930. In United States National Museum collection. Potashed.

ACA 1751, Nymph. Slide labelled "Soil I. Thunia" [Burma], December 16, 1946. Name of collector not stated. In South Australian Museum collection.

ACA 1654 A, B, C. Three adult specimens, A ?sex, B ♀, C ?♂. On *Dioscorea* sp. China: at Honolulu, Hawaii, 1928. Identification number Hawaii #1916. U.S.N.M. collection. Remounted in methyl cellulose medium January 11, 1961. Specimen ACA 1654C retained in S.A.M. collection, others in U.S.N.M.

ACA 1715, one specimen, adult ♀, gravid. On *Sagittaria* sp.; China: at Honolulu, Hawaii, date not recorded. Identification Hawaii # 1628C. In South Australian Museum collection ex U.S.N.M. collection. The idiosoma of the mite contains about 30 developing eggs, these measuring about 195μ long by 165μ across, ellipsoidal.

The metric data of these specimens are as follow:

Specimen	Sex	Origin	ASens	PSens	SBa	SBp	ISD	DS	Ta I	Ti I	Ge I	Ti I Ta I
ACA 1652A	♂	India	47	ca38	16	18	142	14-26	151	194	203	1·285
ACA 1652B	♀	India	47	—	17	17	148	14-27	140	184	203	1·314
ACA 1751	Nymph	Burma	—	43	12	17	100	16-32	101	154	144	1·525
ACA 1654A	?	China	—	—	ca20	20	194	-30	—	—	200	—
ACA 1654B	♂	China	54	—	19	24	213	-31	—	265	280	—
ACA 1654C	?♂	China	—	—	23	22	182	18-30	—	—	—	—
ACA 1715	♀	China	—	—	16	22	148	-28	150	224	230	1·493

Remarks on the Distribution and Variation of Fessonia australiensis.

Although specimens from three continents are referred here to *Fessonia australiensis*, the author does not consider it justified to make a further taxonomic division of them at present. The specimens from Australia, Mexico and India have almost identical dorsal idiosomalae, and the metric data tabulated give no firm indication of any differences. The specimens ascribed to eastern Asia (Burma and China at Hawaii) are more distinct in the character of the dorsal setae, which tend to be more distinctly ridged longitudinally, and are obtusely clavate rather than fusiform-lanceolate. However, in view of the poor state of the specimens and the incompleteness of the data associated with them, including locality, the author prefers to leave this question until more material and data (including possibly larval correlations) are available. It may be added that there appears nothing inherently improbable in a suggestion that smaridid mites may have been distributed by man in soil and plants within historical times. Such, if it has occurred, could modify considerably distributions depending on other more ancient or natural factors.

Fessonia lappacea sp. nov.

Figs. 22-25

Description of Adult Male (from Holotype ACA 1714) (*Figs.* 22 *and* 23).

Colour of mounted specimen reddish-brown. Animal of normal smaridid shape, somewhat robust, and with a short nasus. Idiosoma 920μ long to tip of nasus by 530μ wide where widest.

Crista normal for genus. Anterior end of crista expands into a Y-shaped piece which contains normal scobalae. The standard data of the holotype are:

ASens	PSens	SBa	SBp	ISD	DS
51	68	14	18	121	18-30

Anterior and posterior sensillae filiform, tapering, ciliated throughout their length; ciliations basally minute, lengthening over middle and distal parts.

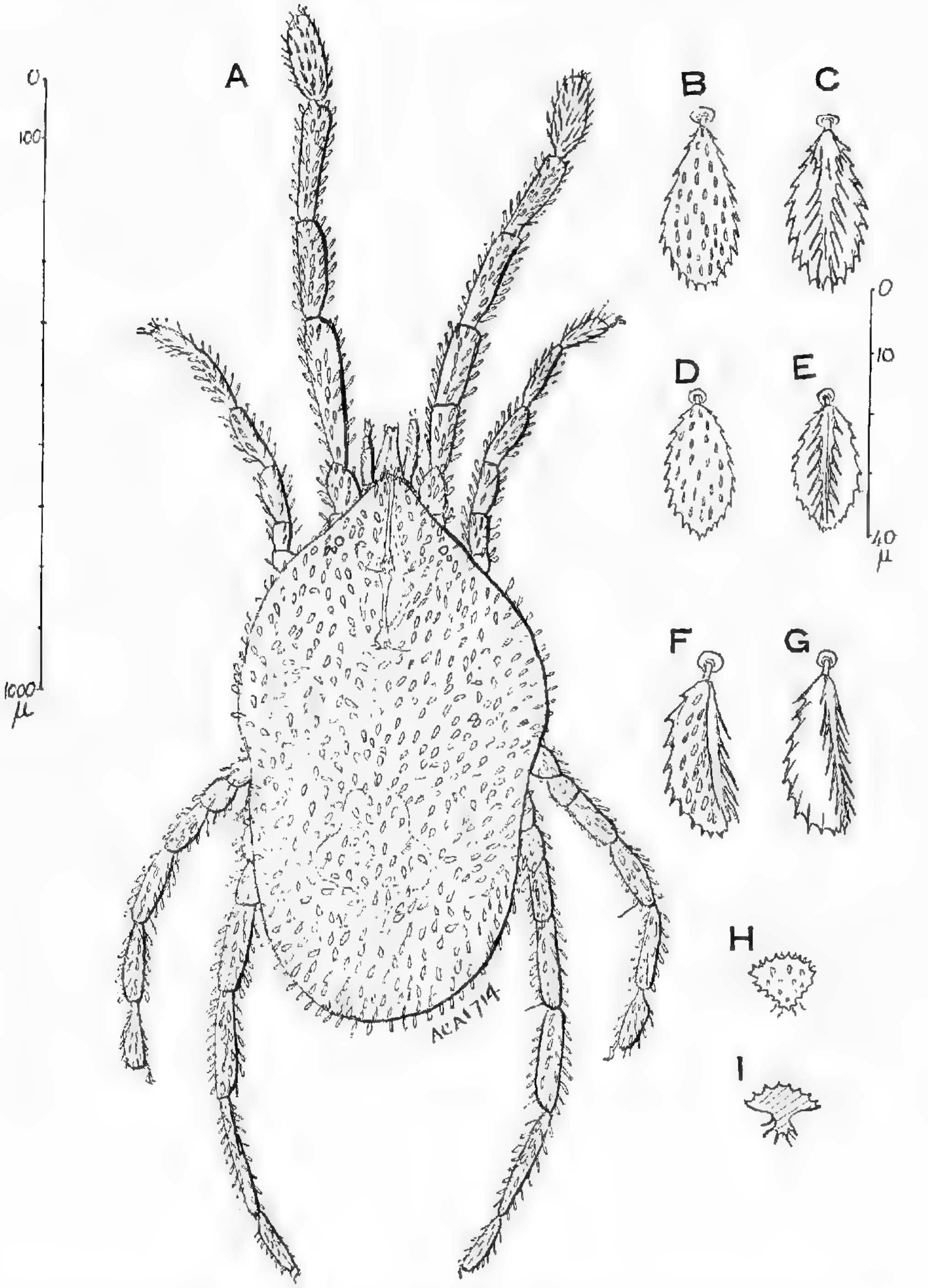

Fig. 22. *Fessonia lappacea*, sp. nov. Adult male (holotype). A, entire, dorsal view, to scale on left. B-I, views of dorsal idiosomal scobalae: B, dorsal view of a seta near posterior pole of idiosoma; C, ventral or carinal aspect of same seta; D, E, similar views of another more anterior seta; F, G, lateral views of setae; H, end view; I, optical cross-section of a seta. (All setae to scale on right.)

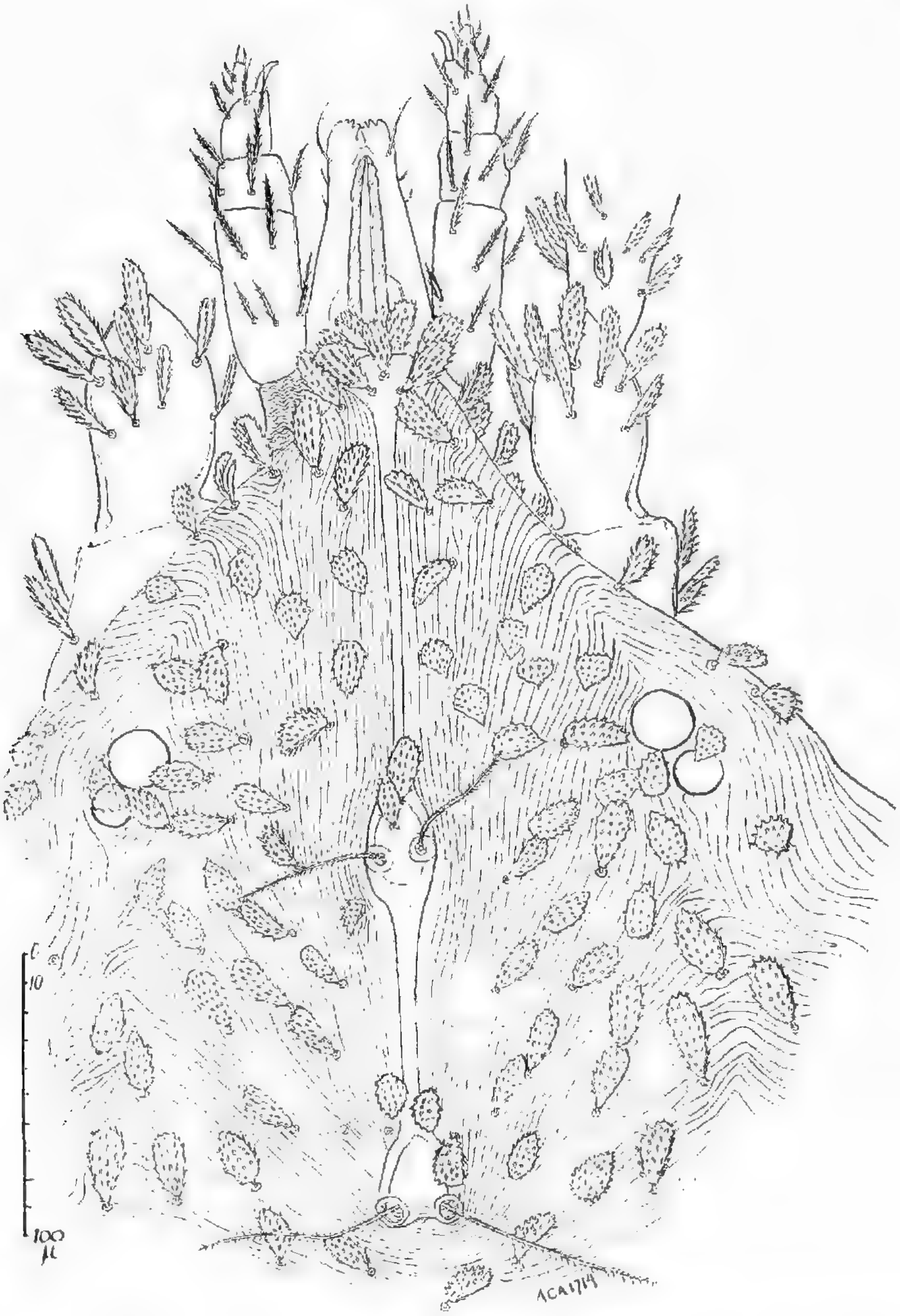

Fig. 23. *Fessonia lappacea*, sp. nov. Adult male (holotype). Dorsal view of propodosoma and adjacent structures.

Eyes placed normally, as figured (Fig. 23). Anterior eye 18μ across, circular, placed well anterior to anterior sensillae, posterior eye circular, 15μ across, posterolateral to anterior eye and a little anterior to the anterior sensillae.

Dorsal idiosomalae (scobalae), lanceolate or clavate, strongly spiculate, the spicules being projecting serrations, arranged in irregular rows or columns, with a maximum of 6-7 spicules in a row and a maximum of 10 in a column. Tectum setae convex, tectal angle about 120°. Carina and flange of scobala narrow, with long ciliations (see Fig. 22 B-I).

Venter appears normal, but is not clearly seen in the sole mount available. Internal genitalia of male type.

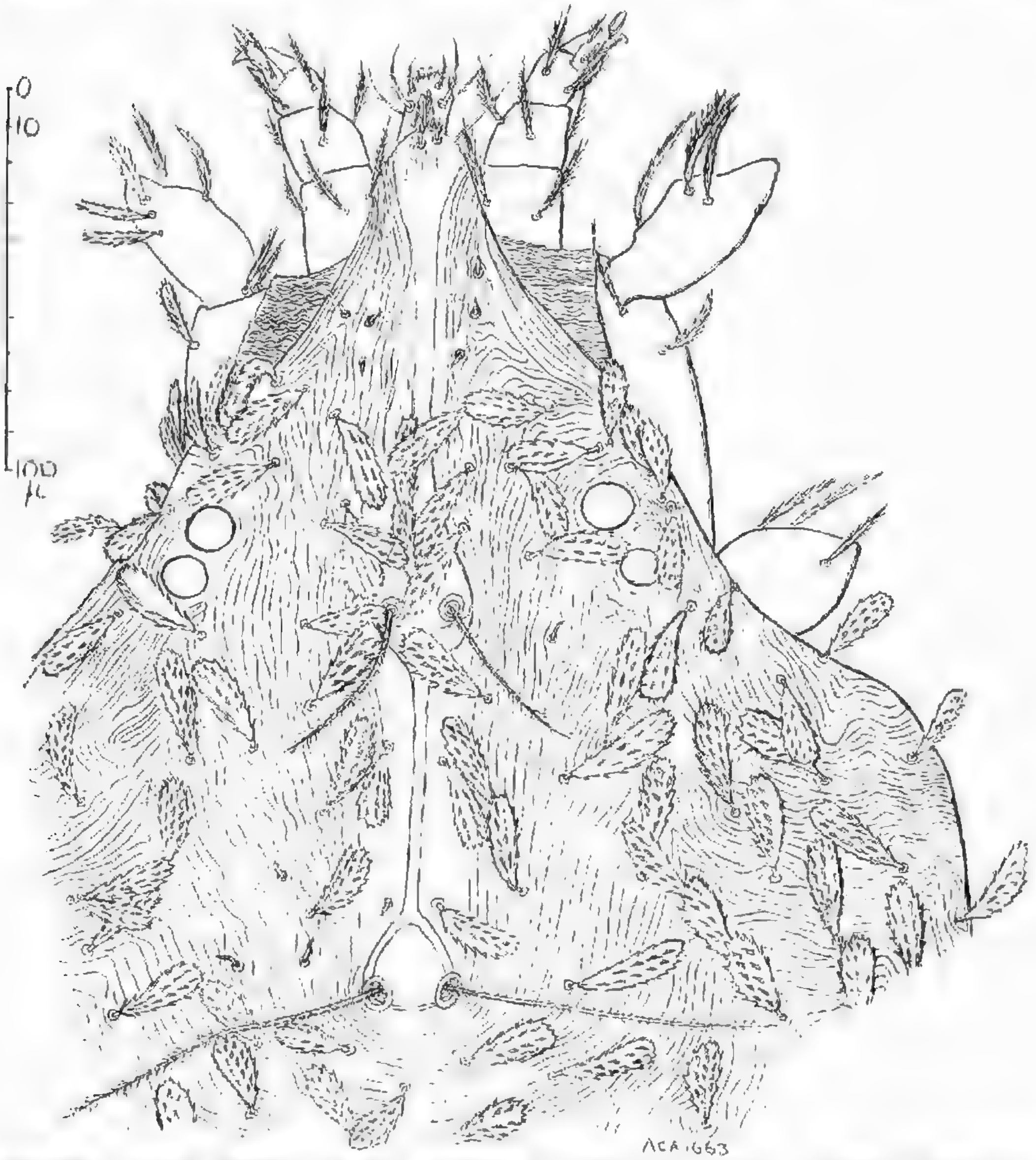

Fig. 24. *Fessonia lappacea*, sp. nov. Nymph (specimen ACA 1663). Dorsal view of propodosoma and adjacent structures (specimen a little compressed).

Legs robust. Leg lengths (including trochanter and tarsal claws): I 810μ, II 535μ, III 595μ, IV 805μ. Tarsus I 146μ long by 54μ high, tibia I 194μ long, genu I 178μ long, tarsus IV 106μ long by 34μ high, tibia IV 206μ long, genu IV 188μ long (tarsal lengths exclude pedicle and claws). Hence Ti I/Ta I = 1·329; Ti IV/Ta IV = 1·943.

Gnathosoma as figured. Palpi fairly robust, with comparatively robust ciliated scobalae, as figured (Fig. 23).

Description of Nymph (from Specimen ACA 1663) (*Figs.* 24 *and* 25).

Similar to adult but smaller and with more slender proportions; of the usual smaridid facies for a nymph. Idiosoma 565μ long, 290μ wide.

The standard data are:

ASens	PSens	SBa	SBp	ISD	DS
ca 60	83	15	16	99	20-34

Sensillae characters as in adult.

Eyes similar to adult, anterior 12μ across, posterior 10μ across.

Dorsal idiosomalae (scobalae) similar to adult but of more elongate proportions and with somewhat fewer spicules.

Venter normal for nymph.

Legs: I 660μ long, II 395μ, III 407μ, IV 550μ (lengths include trochanter and tarsal claws). Tarsus I 105μ long by 36μ high, tibia I 163μ long, genu I 150μ long, tarsus IV 75μ long by 32μ high, tibia IV 115μ long, genu IV 122μ long (tarsal lengths exclude claws and pedicle). Tarsal claws ciliated obliquely along their sides except at tip.

Gnathosoma as figured (Fig. 24), similar to adult.

Material Examined. ACA 1659, adult ♂, Paratype, with orchid plants, Mexico [no further locality data]: at Brownsville, Texas, July 23, 1947. Lot 47-11431 (collector not stated). U.S.N.M. collection. (The idiosoma of this specimen contains a single median large guanine body (110μ across), the pos-

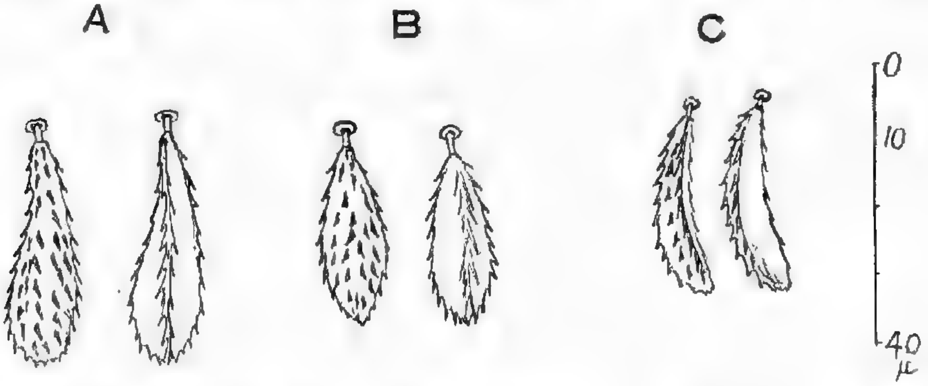

Fig. 25. *Fessonia lappacea*, sp. nov. Nymph (specimen ACA 1663). A-C, dorsal idiosomal scobalae: A, a longer seta seen in dorsal and ventral aspect; B, another seta, similar view; C, another seta, oblique lateral views (all to scale shown).

terior point of which is level with the anterior point of the chitinized male internal genital armature; so large a guanine body is somewhat unusual in smaridids; but see the comment on ACA 1660 below.)

ACA 1660, adult, ?sex, on cactus plant, S[an] L[uis] P[otosi], Mexico: at Laredo, Texas, January 9, 1946. S. H. Coleman, colr. Laredo 38119, Lot 46-4214. In U.S.N.M. (The idiosoma contains two large median guanine bodies, anterior 73μ across, posterior 50μ across.)

ACA 1662, two adults, Paratypes (one ♀, one ?♂), same data as ACA 1659, retained in South Australian Museum collection ex U.S.N.M.

ACA 1663, nymph, labelled "*Neotoma fuscipes*. Monterey, California. Feb. 14, 1946. J. M. Linsdale, colr. No. 651. Lot 46-3641", U.S.N.M. ("Nymphotype").

ACA 1714, adult male, holotype, Batesburg, South Carolina, "In trash under holly bush (in woods), sifted out in lab.", April 1, 1911, E. A. M[cGregor]. Slide No. (A-VI 23 (2)). In United States National Museum.

ACA 1718 (identification somewhat dubious; poor mount), ?adult, Colonia, Hidalgo, [Mexico], June 27, 1943, F. Bonet (No. 740—'2 ej.'). South Australian Museum collection.

Remarks. See the remarks in Section IV of the present paper.

Fessonia scobina sp. nov.

Fig. 26

Description of Adult (?Sex) (from Holotype ACA 1657).

Colour in life not recorded. Of normal smaridid shape and dimensions, with a short nasus to idiosoma. Idiosoma 870μ long by 425μ wide where widest (on further compression, some days later, the idiosoma was 890μ long).

Crista normal, the anterior sensillae placed 173μ behind nasus, and just posterior to eyes. The standard data are:

ASens	PSens	SBa	SBp	ISD	DS
ca 38	ca 70	16	18	125	20-42

Anterior sensillae slender, lightly ciliated throughout their length, ciliations longer in distal 2/3 of seta. Posterior sensillae similar.

Eyes 2 + 2, anterior the larger, 30μ across, posterior eye posterior and somewhat lateral to anterior eye, 20μ across.

Dorsal idiosomalae (scobalae) lanceolate, blunted terminally, with a convex tectum and tectal angle of about 180°, tectal spicules about 50 in number, small, fairly uniform in character, rounded in dorsal view, but in lateral view short and triangular, arranged evenly and hence on some setae tending to form columns, rows, or oblique lines, over the tectum; the proximal spicules slightly longer than the distal. Carina and flange narrow, with long strong ciliations. The dorsal scobalae tend to elongate posteriorly upon the dorsum.

Venter not clearly visible in the sole specimen available.

Legs normal. Leg lengths (including trochanter to tips of tarsal claws): I 950μ, II 530μ, III 630μ, IV 790μ. Tarsus I 155μ long by 55μ across, tibia I 210μ long, genu I 215μ long, tarsus IV 117μ long by 28μ high, tibia IV 185μ long, genu IV 195μ long (tarsal lengths exclude claws and pedicle). Tarsal claws normal, ciliated obliquely along sides except at tip.

Gnathosoma appears normal, but is not clear enough for figuring in the mount.

Material Examined. The sole specimen seen is the holotype, ACA 1657, "On orchid plants, Chilpancingo [de los Bravos], G[uerre]ro., Mexico: at Laredo,

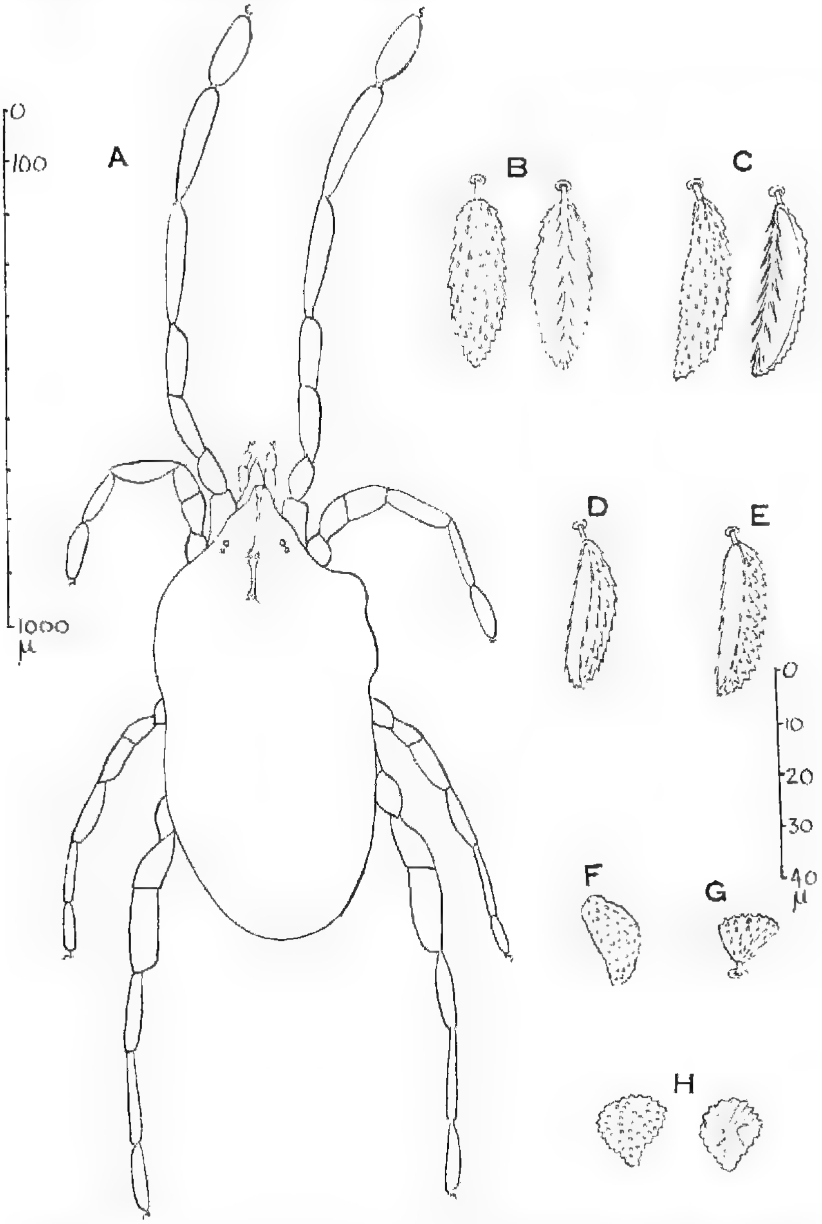

Fig. 26. *Fessonia scobina*, sp. nov. Adult (?sex), holotype. A, dorsal view, entire, setae mostly omitted, to scale on left. B-H, various views of individual dorsal setae (scobalae) (all setae to scale shown).

Aug. 29, 1946. Talbert, colr. Lot 46-14352". In United States National Museum collection.

The type was originally mounted in a polyvinyl alcohol medium. In January, 1961, the author remounted it into methyl cellulose medium, but in this process the swelling of the polyvinyl medium has damaged the specimen, making some features unsuitable for description and figuring; the figures of the legs are to some extent reconstructed.

Remarks. This species is nearest to *F. lappacea* and *F. lacrimosa*, but may be separated as in the key given earlier.

Fessonia lacrimosa sp. nov.

Figs. 1 L, M, 27 and 28

Description of Adult Male (from Holotype ACA 1655).

Colour in life not recorded. Of normal smaridid dimensions and shape, with a short nasus. Idiosoma 1186μ long to tip of nasus by 735μ wide (the holotype has been compressed by the mounting).

Crista normal, the anterior sensillae placed 188μ behind nasus and just posterior to eyes. The standard data are:

ASens	PSens	SBa	SBp	ISD	DS
—	—	14	20	132	24-42

Sensillae missing in holotype preparation.

Eyes 2 + 2, anterior the larger, 20μ across, posterior 12μ across, placed a little lateral to the anterior eye.

Dorsal idiosomalae (scobalae) with tectum lanceolate or fusiform, to slightly clavate. Spicules mostly 30-35 in number on tectum, tending to be more elongate basally (and there about 2·6μ long by 1μ wide in dorsal view, appearing as an isosceles triangle with apex pointing proximally; in profile about 1·5μ high), forming wedge-like serrations, which are arranged into fairly regular columns of up to about 10 or 11 spicules but less regular rows. Carina narrow with long somewhat adpressed ciliations. Posterior dorsal setae more elongate, to 42μ long.

Venter not clearly seen in the preparation. Internal genitalia have normal male character.

Legs normal. Leg lengths (including trochanter and to tarsal claw-tips): I 955μ, II 620μ, III 610μ, IV 855μ. Tarsus I 153μ long by 46μ high, tibia I 224μ long, genu I 221μ long, tarsus IV 105μ long by 32μ high, tibia IV 185μ long, genu IV 195μ long (tarsal measurements exclude claws and pedicle). Tarsal claws normal, ciliated obliquely along their sides except at tip.

Gnathosoma as figured (Fig. 28) the dorsal palpal scobalae ciliated and with the tectum setae somewhat expanded.

Material Examined. This species is known from only the holotype male, ACA 1655 (2 slides, A and B), labelled "On orchid plants, Tamazunchale, S[an]

L[uis] P[otosi], Mexico: at Brownsville [, Texas]. Aug. 28, 1947. Lot 47-13151", name of collector not stated. In United States National Museum collection. Specimen originally mounted in polyvinyl alcohol mountant; remounted in methyl cellulose medium January 11, 1961, by author.

Remarks. See the remarks for *F. scobina*, above.

Subfamily HIRSTIOSOMATINAE Southcott

For definition and synonymy see Southcott, 1961*a*, p. 442.

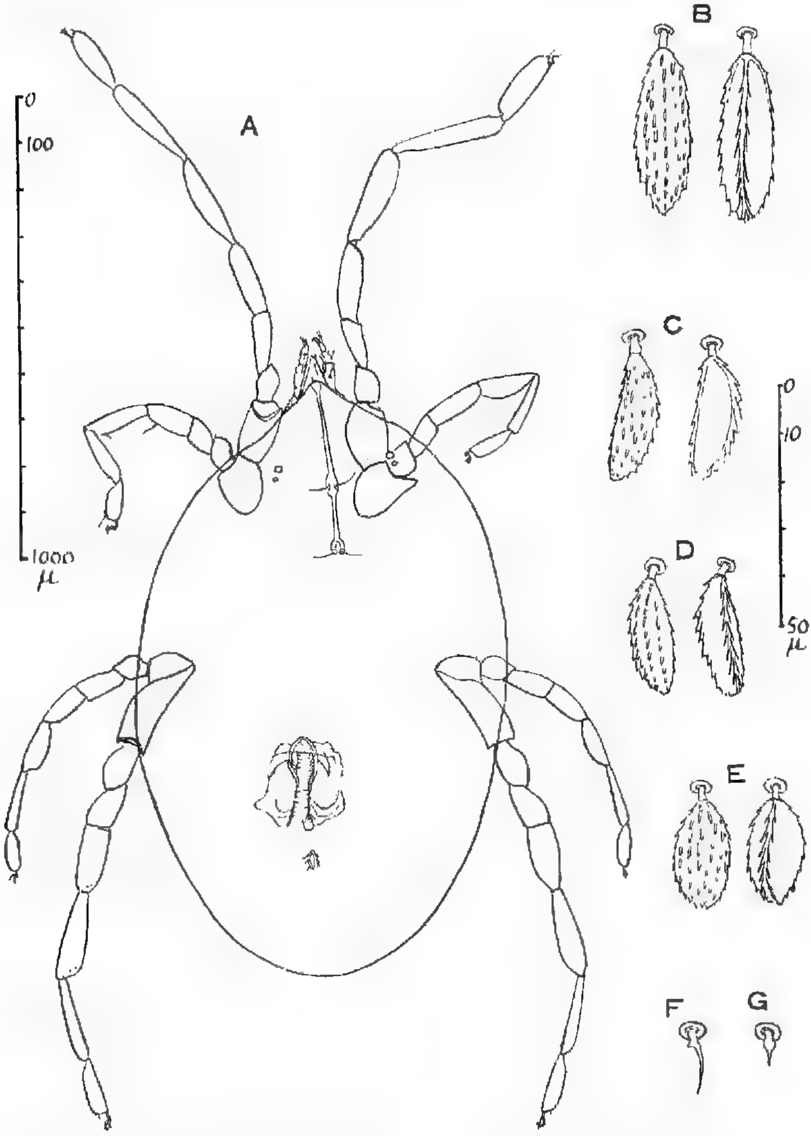

Fig. 27. *Fessonia lacrimosa*, sp. nov. Adult male (holotype). A, dorsal view, in transparency, setae mostly omitted, to scale on left. B-G, various aspects of individual dorsal idiosomalae (scobalae); F and G each show the annulus and pedicle only, the scobillum having been stripped away by swelling of the polyvinyl alcohol medium on remounting (all setae to scale on right).

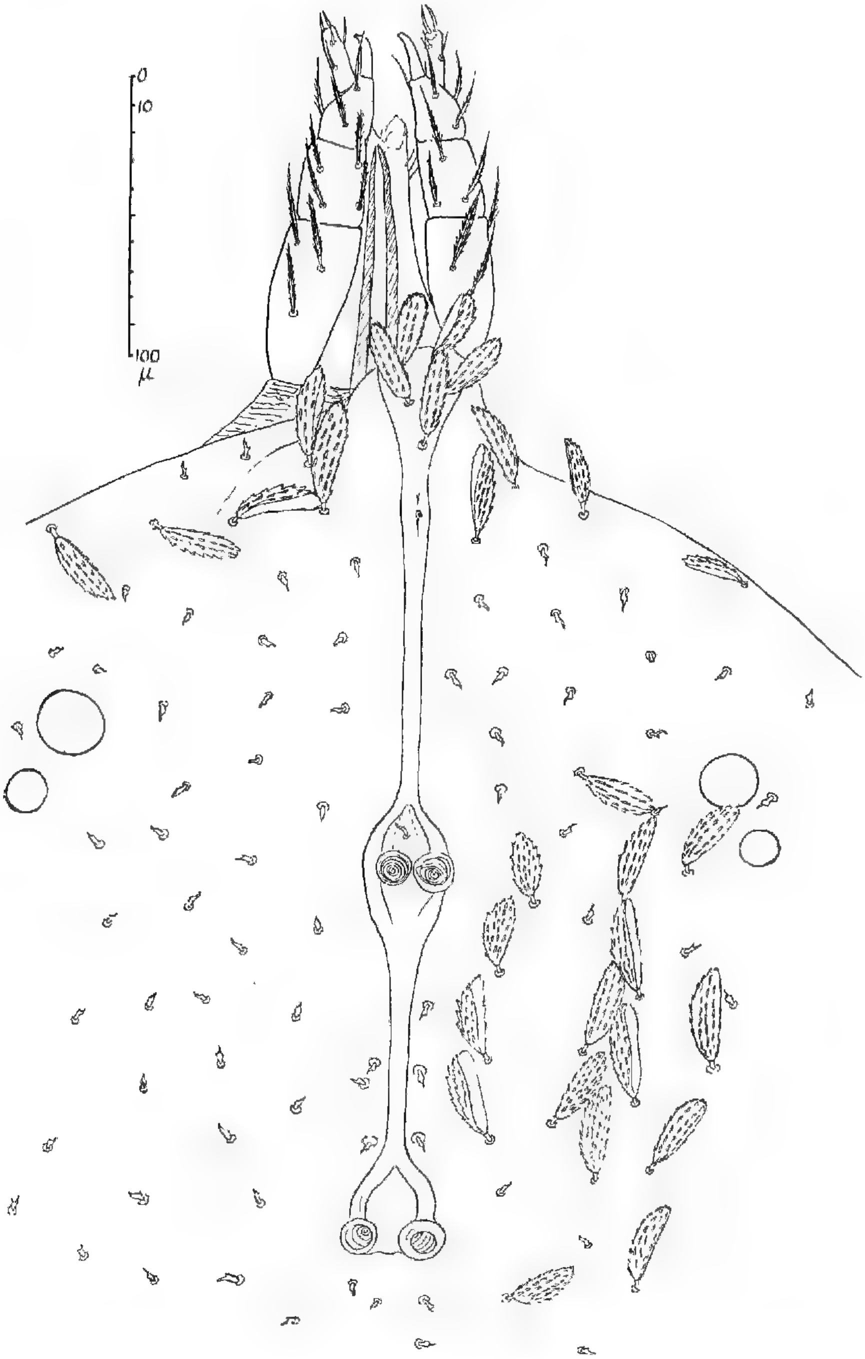

Fig. 28. *Fessonia lacrimosa*, sp. nov. Adult male (holotype). Dorsal view of propodosoma and gnathosoma. Remounting from polyvinyl acid medium has caused the loss of the sensillary setae, and has stripped away the scobillum from the dorsal scobala in many instances, leaving only the pedicle arising from the annulus.

Remarks. The Hirstiosomatinae have hitherto been considered as containing the post-larval genera *Hirstiosoma* Womersley, 1934, and *Sphaerotarsus* Womersley, 1936 (see Southcott, 1961*a*, p. 443). In that paper the author referred the described North American Hirstiosomatinae to *Hirstiosoma*. In the present study of a number of North and Central American Hirstiosomatinae one species is referred to *Hirstiosoma*, but the remainder are referred to two new genera, *Trichosmaris*, gen. nov., and *Clavismaris*, gen. nov. *Trichosmaris* is the commonest hirstiosomatine genus in the collections studied from North and Central America, and to it are referred specimens that have been described in the literature.

Key to the Genera of Adults and Nymphs of Hirstiosomatinae of the World

1. Whole or part of posterior sensillary setae of crista thread-like, tapering, and in the thread-like part ciliations are minute or absent. Tarsus IV of male normal. 2

Posterior sensillary setae of crista, clavate, ciliated 3

2(1). Posterior sensillae of crista gradually tapering, thread-like, with ciliations minute or absent *Hirstiosoma* Womersley, 1934

Posterior sensilla of crista consist of two elements, a proximal stronger ciliated parallel-sided or slightly expanded part (pars clavata or "clavum") to which a distal part or flagellum is joined, more or less abruptly. The flagellum is filiform, tapering, simple, of about the same length as the pars clavata. Tarsus IV of male normal *Trichosmaris*, gen. nov.

3(1). Tarsus IV of male greatly enlarged
Sphaerotarsus Womersley, 1936 (Australia)

Tarsus IV of male normal
Clavismaris, gen. nov. (North and Central America)

Genus HIRSTIOSOMA Womersley

Definition—see Southcott, 1961*a*, p. 443.

Remarks. Only one species of Hirstiosomatinae from North and Central America is now referred to this genus, *H. bolivari*, sp. nov., described below. Previously *Smaris longilinealis* Ewing, 1909, was placed in *Hirstiosoma* by Baker and Wharton (1952, p. 243), and doubtfully by Southcott (1961*a*, p. 443). This species is regarded by the author as of somewhat doubtful status, and is discussed elsewhere in the present paper; possibly it belong to *Trichosmaris*, gen. nov. *Smaris longilinealis* Ewing, 1910, is quite another species, and is possibly a species of *Fessonia* (see the discussion later).

Hirstiosoma bolivari sp. nov.

Figs. 29 and 30

Description of Adult, ?♀ (*from Holotype Specimen, ACA* 1723).

Colour in life not recorded. Animal of normal smaridid shape, rather elongate, with a normal nasus. Idiosoma 1680μ long by 825μ wide where widest.

Crista elongate, with two sensillary areas. Anterior sensillary area has two ciliated slightly clavate sensillae and carries also upon the nasus 22 scobalae

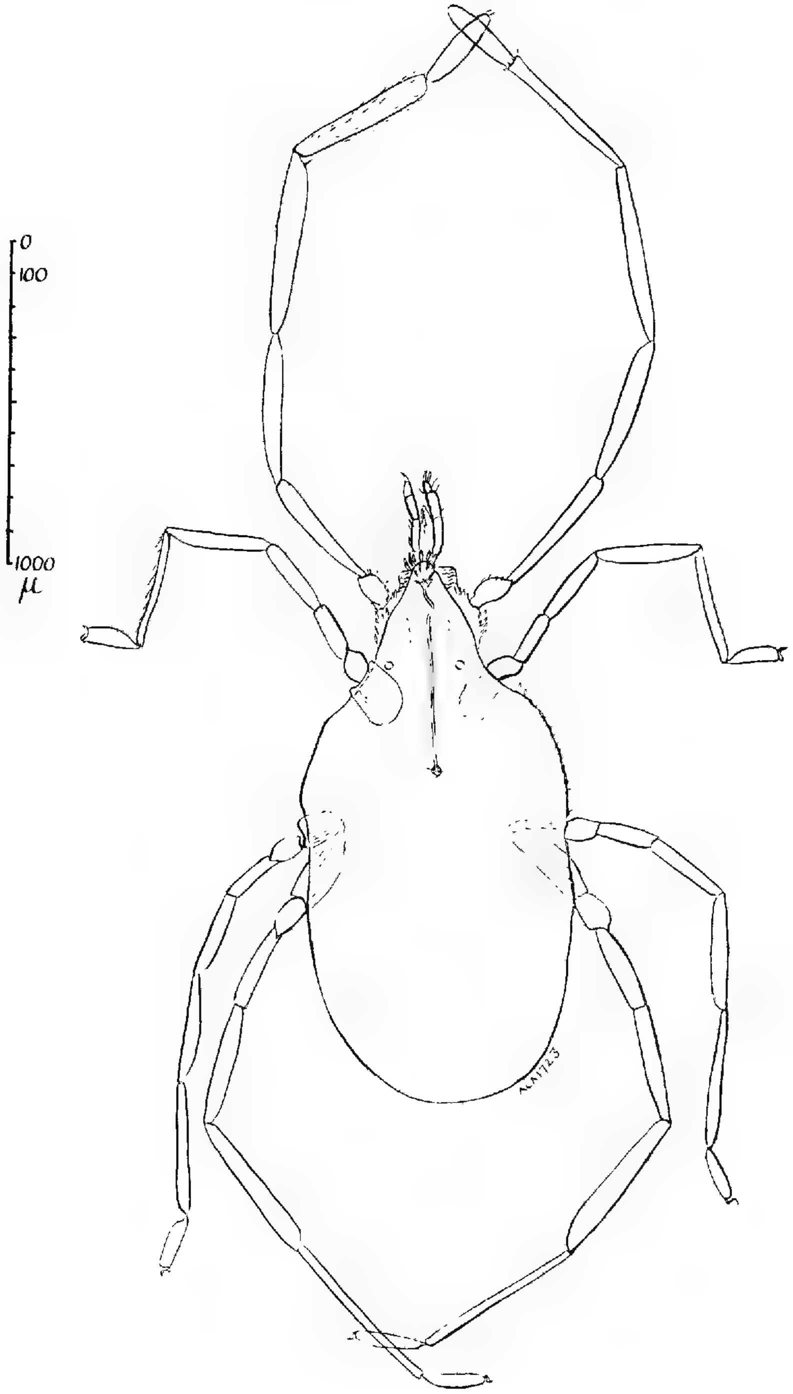

Fig. 29. *Hirstiosoma bolivari*, sp. nov. Adult (holotype). Dorsal view, in transparency, setae mostly omitted.

32-41μ long. Posterior sensillary area with two tapering filiform sensillae, seen to be faintly ciliated proximally when examined under oil immersion. The crista tapers to a point 58μ posterior to centres of posterior sensillae.

The standard data are:

ASens	PSens	SBa	SBp	ISD	DS
54	ca. 115	18	24	577	22-40

Eyes one on each side, circular, cornea 43μ across; eyes placed 14μ anterior to mid-point of ISD ($OAS = 275\mu$; $OPS = 302\mu$) ($OAS + OPS = ISD$).

Dorsal idiosomal scobalae typically smaridid. The tectum setae is excavated to a canoe form, of which the "gunwhale" is thickened with spicules along its inner and outer edges (see Fig. 30 C, D). The carinal flange tends to turn up and become complex along its borders; carinal borders with small serrations. In the more posterior setae the tectal borders are widened and the subtectum tends to form a gutter along each side of the seta. From above the dorsal seta is more or less triangular in outline, the outline being made up of the carinal flanges. The setae are almost unpigmented. Each seta arises from a papilla (see Fig. 30 E-G).

Ventral surface not clearly seen in the holotype, but appears normal.

Legs long; lengths (including trochanter to tips of tarsal claws): I 2315μ, II 1450μ, III 1560μ, IV 2080μ. Tarsus I 278μ long by 68μ across, tibia I 483μ long, genu I 570μ long, tarsus IV 232μ long by 47μ high, tibia IV 568μ long, genu IV 498μ long (tarsi measured without claws and pedicle). Hence the following ratios hold:

tarsus I/tibia I	tibia I/genu I	tarsus IV/tibia IV	tibia IV/genu IV
·5756	·8474	·4085	1·141

Setae of legs normal for Smarididae, tending to elongate.

Gnathosoma with normal armilla. Palpi with pointed slender scobalae, tapering, lightly and adnately ciliated. Tip of mouth-cone as figured, with its setae simple or almost so.

Locality. The species is known only from the holotype, adult, ? ♀, specimen ACA 1723, Palmira, Cuernavaca, Mor[elos], Mexico, May 14, 1943, C. Bolivar, per F. M. Bonet (without serial number), in South Australian Museum collection.

Remarks. This species is readily distinguishable from other described members of the genus on the character of the dorsal idiosomal scobalae. No other species has been described in which the tectum setae is canoe-like. By the key of Womersley and Southcott (1941, p. 73) for the Australasian forms *H. bolivari* keys down to *H. scalare* Womersley, 1934, from which, however, it may be separated by the character of the tectum setae, the much longer legs, the presence of only adnate ciliations on the dorsal palpal scobalae, the longer DS (22-40μ as against 16-24μ) and other characters.

The dorsal idiosomal scobalae of *H. bolivari* resemble those of the described members of *Trichosmaris*, gen. nov. If, however, in a specimen the posterior sensillae were lost it would still be possible to distinguish *H. bolivari* from *Trichosmaris* spp. on the more elongate characters of its legs and on the significantly lower tarsus I/tibia I ratio (0·58 as against 0·69-0·76).

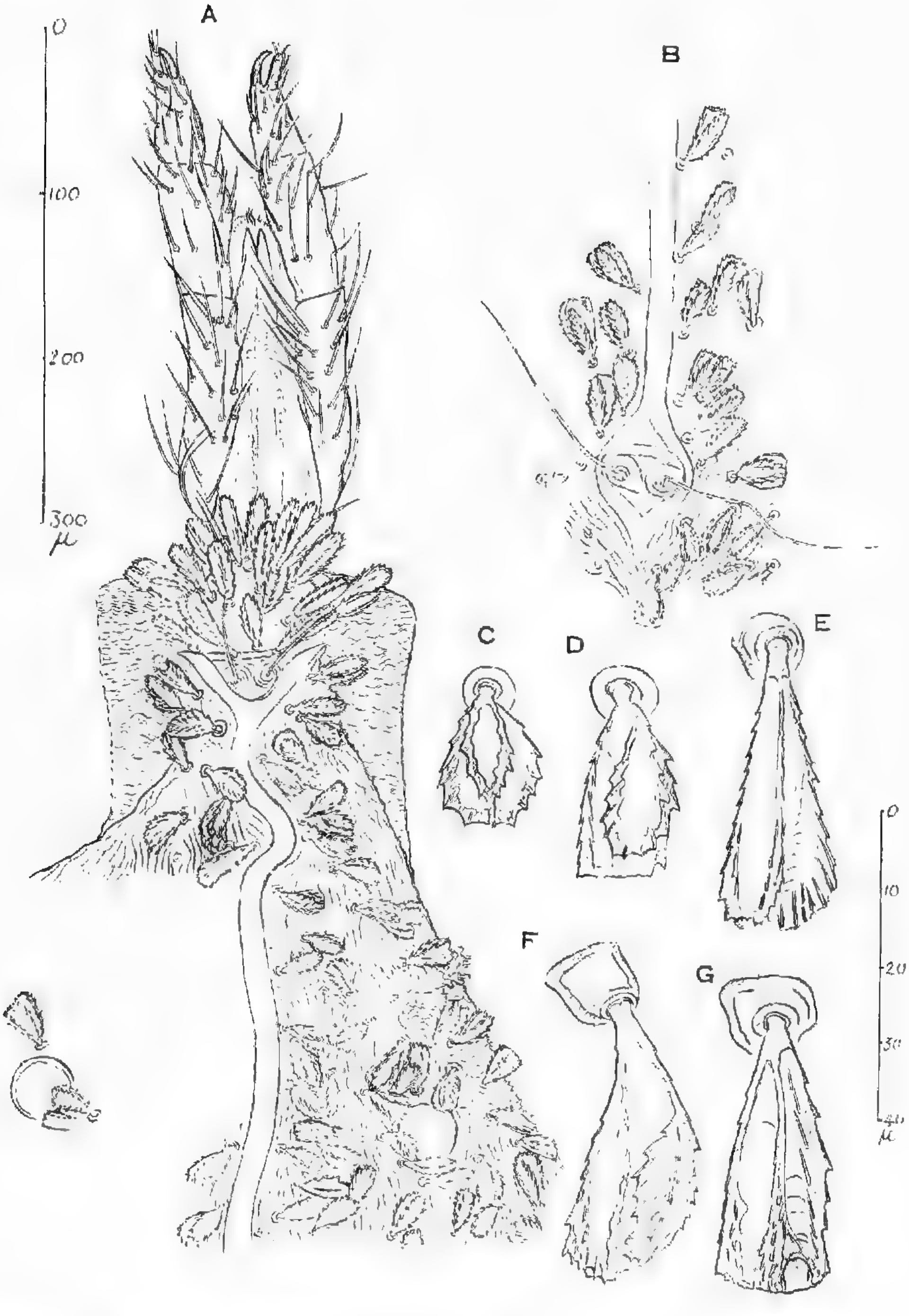

Fig. 30. *Hirstiosoma bolivari*, sp. nov. Adult (holotype). A, propodosoma and gnathosoma, dorsal view. B, posterior part of crista. C-G, various individual dorsal idiosomalae: C, D, setae laterally placed on dorsum above leg III; E-G, setae from posterior pole of idiosoma. (A, B to scale on left; C-G to scale on right.)

The undulations figured in the anterior part of the crista are possibly an artefact of mounting in the polyvinyl alcohol medium used; no attempt has been made to correct for this apparent shortening in the measurements given.

Genus TRICHOSMARIS, gen. nov.

Type species: *Trichosmaris dispar*, sp. nov.

Definition. Adult and nymph: One eye on each side placed about the level of the middle of the crista. Crista present, normal, linear, with anterior and posterior sensillary areas. Anterior sensillary area placed at anterior pole of idiosoma dorsally. Anterior sensillae ciliated, somewhat clavate. Posterior sensillary area at posterior end of crista, well in front of middle of idiosoma dorsally. Posterior sensillae consist of a proximal ciliated part, which expands slightly, from the end of which arises a long tapering filiform simple thread, of a length comparable with the proximal part of the sensilla. Leg tarsi of male normal, not markedly expanded or globular. (Larva not known.)

Remarks. (1) *Trichosmaris*, gen. nov., occupies somewhat of an intermediate position between *Hirstiosoma* Womersley, 1934, and *Sphaerotarsus*, Womersley, 1936.

Trichosmaris dispar sp. nov.

Figs. 31-34

Description of Adult Female (from Mounted Holotype Specimen ACA 1724) (Figs. 31 and 32).

Colour in life not recorded. Animal of normal smaridid shape, with a normal nasus. Idiosoma 1460μ long by 1005μ wide where widest (the specimen has the appearance of having been compressed during the mounting and it is considered these figures are somewhat greater than obtained during life).

Crista as recorded for genus, with two sensillary areas: anterior sensillary area placed in the fork of the dividing anterior end of the crista, and carries, besides the anterior sensillae, 18 scobalae similar to the other dorsal idiosomal scobalae, but more elongate, 28-34μ long: anterior sensillae clavate, ciliated throughout their length, with ciliations small basally but longer distally and forming a spindle-like brush around the distal part of the sensilla; posterior sensillary area with PSens as defined for genus, the proximal ciliated part or pars clavata expands only a little after its middle, then narrows again to a point, the ciliations distally on the pars clavata a little longer, pars clavata 57μ long, and from its distal end arises the flagellum, a filiform unciliated tapering thread, about 55μ long (its extremity is very delicate and very hard to discern even with the oil immersion), thus making a total length of ca 112μ.

The standard data are:

ASens	PSens	SBa	SBp	ISD	DS
45	ca 112*	14	21	402	14-28**

*Pars ciliata 57μ, flagellum ca 55μ (see text).

**Excludes, as is customary, the scobalae of the nasus (= anterior sensillary area for this genus, etc.).

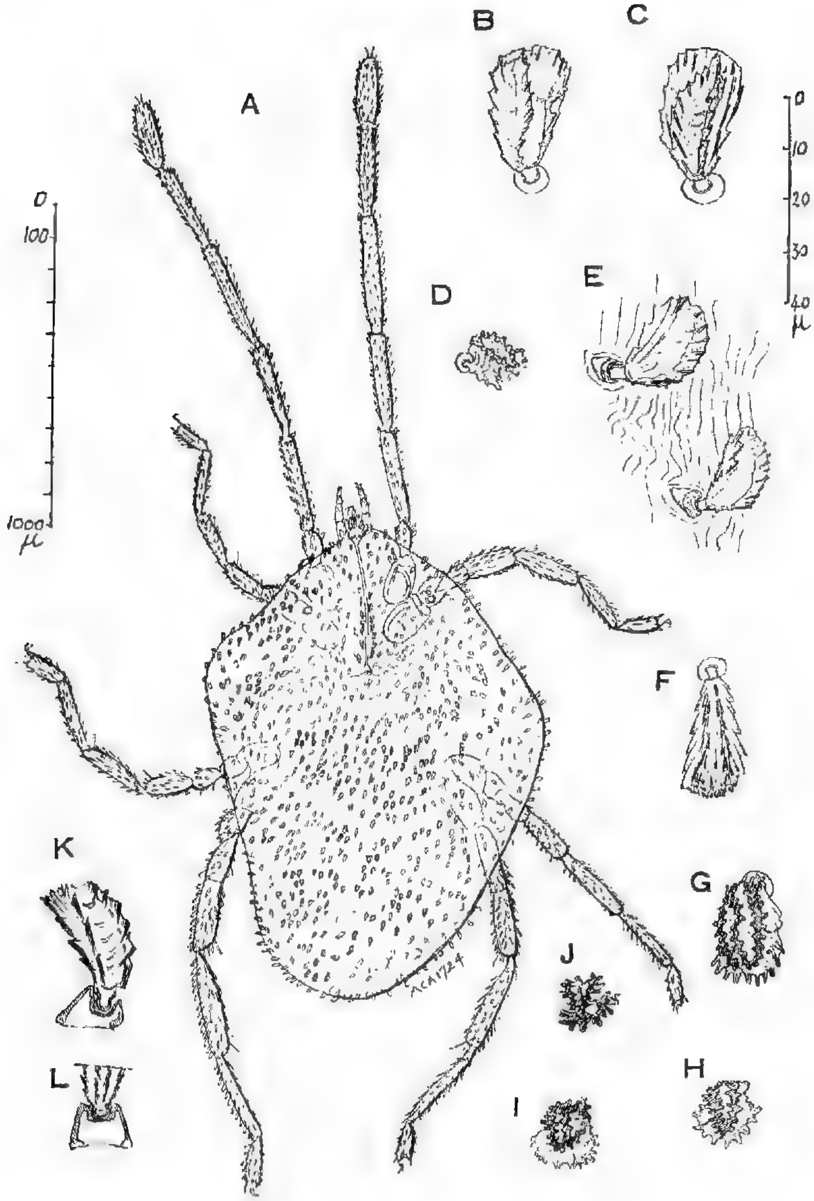

Fig. 31. *Trichosmaris dispar*, sp. nov. A-E, K, L, adult female (holotype), from Nebraska. A, dorsal view, entire, seen somewhat as a transparency; the idiosoma is compressed and distorted. B-E, dorsal idiosomal scobalae, in various views. F-J, aspects of dorsal idiosomal scobalae of another specimen, number ACA 1679, from North Carolina; F, dorsal aspect; G, oblique end view; H-J, end views. K, L, views of dorsal idiosomal scobalae of holotype, to show details of papilla (amphora). (All setae to scale on right.)

Eyes one on each side, circular, cornea 28μ across; eyes placed a little anterior to middle of crista. Distance OAS = 180μ, OPS = 222μ (OAS + OPS = ISD; the ISD is considered as divided by a line running transversely between the eye centres). Eyes fairly close to lateral margin of idiosoma, in dorsal view.

Dorsal idiosomal scobalae typically smaridid in character. The tectum setae is widened and canoe-like, the "gunwhale" along each side a double row of spicules. In lateral view each of these spicules is long and strong, running obliquely along the side of the seta or "subtectum". The setae are brown, uniformly and lightly pigmented. In lateral aspect the setae are almost semicircular, with the dorsal and ventral outlines broken by "saw-teeth". The carinal flange is broad and each lateral edge is cut into 3 or 4 coarse saw-teeth. From above, the seta is fan-shaped or roughly triangular, with a convex but serrated edge, the outline being made up of the expanded carinal flanges, the outline of the tectum setae superimposes itself on the edges of the carinal flanges only basally (see e.g. Fig. 31C). In end view of the scobala the tectum setae is seen to be deeply excavated, hence canoe-like. In addition, the scobala has a well-marked central cavity. Each seta arises from a chitinized papilla which is an expanded amphora setae (see Fig. 31K, L and compare with e.g. Fig. 1C). The dorsal setae are somewhat longer toward the posterior pole of the idiosoma. Over most of the dorsum the scobalae project anteriorly (this may be a distinct feature in smaridids), and only at the periphery of the opisthosoma, in dorsal view, do they project posteriorly.

Ventral surface normal. External genitalia 205μ long by 50μ across the closed external lips. The innermost row of setae (labialae) pointed, strongly ciliated basally. Internal genitalia with light chitinization and 4 rounded or ovoid lobes about 40μ long by 30μ wide; these contrast with the more heavily chitinized armature and two lobes forming a horseshoe of the smaridid male internal genital armature. Anus 75μ long, anal setae (analae) spindle-like, with long ciliations. The venter carries normal ventral setation; the scobalae are similar to the dorsal scobalae over ventral opisthosoma, but around the external genitalia, and more anteriorly are spindle-like heavily ciliated setae, normal for smaridid ventralae; around the anus (outside the group of analae) the ventralae are of intermediate character.

Legs normal. Leg lengths (inclusive of trochanter and tarsal claws): I 1570μ, II 900μ, III 995μ, IV 1290μ. Tarsus I 210μ long by 75μ across, tibia I 295μ long; genu I 382μ long, tarsus IV 142μ long by 46μ high, tibia IV 320μ long, genu IV 332μ long (tarsal measurements exclude claws and pedicle). Setae of legs appear to be normal for Smarididae; the proximal scobopedalae similar to idiosomalae, then becoming longer, more pointed and ciliated distally. On tarsal scobalae the spicules are strong and pointed and arranged in regular rows. Among the scobopedalae are various sensalae. Many fine spinalae are present on the telofemora to the tibiae. Tibia I with dorsodistal (somewhat posterior) vestigiala, genu I with dorsodistal neomedian vestigiala (other vestigialae not visible in holotype preparation). Tarsal claws normal, ciliated obliquely along their sides except terminally.

Gnathosoma with the normal armilla. Palpi with pointed scobalae, lightly ciliated with adnate ciliations, as well as the palpal tibial sensalae. There are no expanded palpal scobalae. The tip of the mouth-cone has a hypostomal lip as figured, and various prominent pointed setae as figured (Fig. 32), these setae being adnately ciliated.

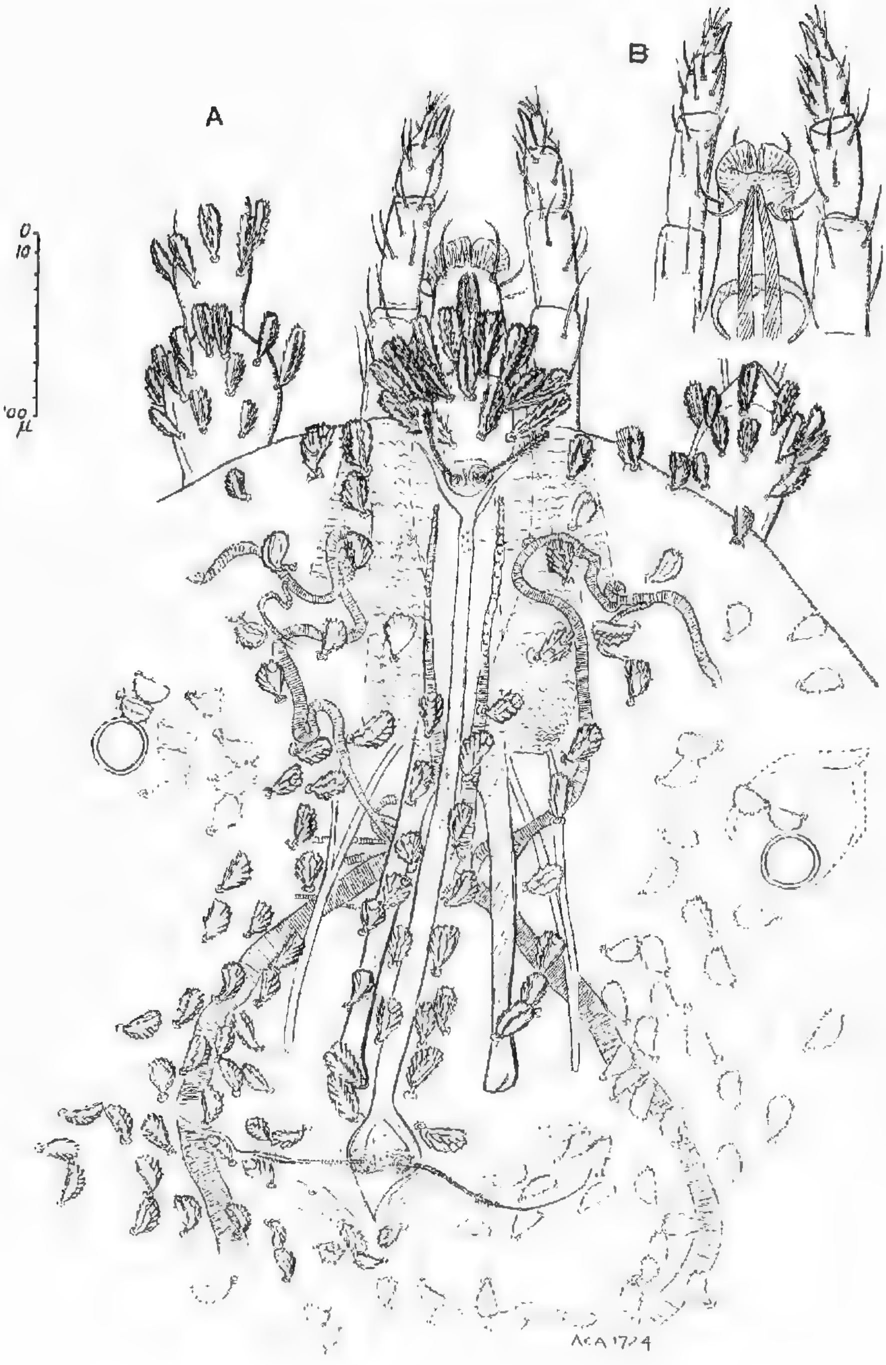

Fig. 32. *Trichosmaris dispar*, sp. nov. Adult female (holotype). A, anterior part of idiosoma in dorsal view, and some adjacent and underlying structures. Some setae indicated in outline only. B, gnathosoma, ventral aspect.

Description of Nymph (*from ACA* 1700) (*Figs.* 33 *and* 34).

Colour in life not recorded. Character in general similar to the adult female described, with normal smaridid shape. Idiosoma 710μ long by 425μ wide where widest. Crista and sensillae similar to adult female, also eyes. The standard data are as follow:

ASens	PSens	SBa	SBp	ISD	DS
28	ca 71*	10	14	243	16-26

*pars clavata 38, flagellum ca 33.

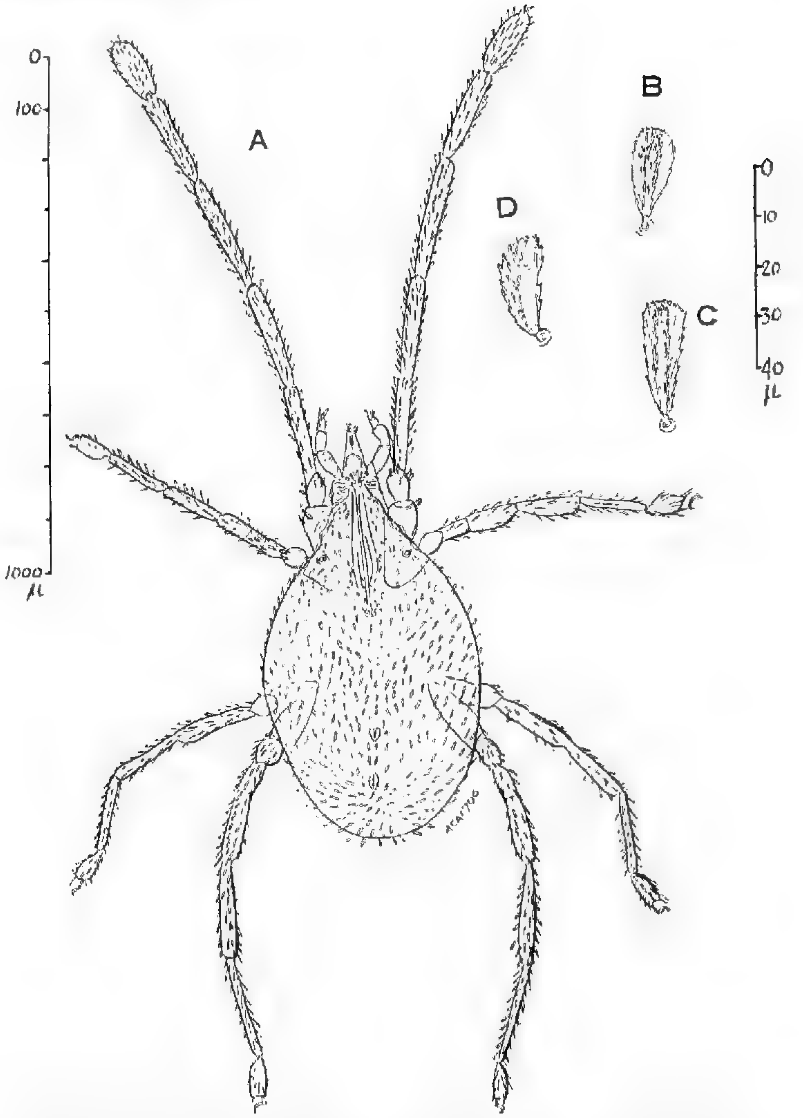

Fig. 33. *Trichosmaris dispar*, sp. nov. Nymph (specimen ACA 1700). A, entire, dorsal view, but also showing some ventral features; to scale on left. B-D, various aspects of dorsal idiosomal scobalae, to scale on right.

Dorsal idiosomal scobalae similar to those of adult female.

Ventral surface normal. External genitalia typical, an occluded urvulva with its median raphe present.

Legs normal. Leg lengths (inclusive of trochanter and tarsal claws): I 1025μ, II 565μ, III 620μ, IV 800μ. Tarsus I 133μ long by 54μ across, tibia I 194μ long, genu I 245μ long, tarsus IV 85μ long by 30μ high, tibia IV 203μ long, genu IV 203μ long. Leg setae similar to adult. Tarsal claws similar to adult.

Gnathosoma as figured (Fig. 34), similar to adult.

Material Examined. Specimens referred to this species (*T. dispar* f.p.) are as follows (adults unless otherwise stated):

United States National Museum Specimens

ACA 1675, Oxford, Miss[ouri], Sept., 1905, collector not stated, but label in writing of H. E. Ewing.

ACA 1676, ♂. North Beach, Maryland, Sept. 21, 1919, under dead limb of tree on ground, H. E. Ewing.

ACA 1677, Chesapeake Beach (North Beach), Maryland, December 19, 1920, 'in leaf mold', H. E. Ewing, retained in South Australian Museum collection.

ACA 1678, Brooksville, Florida, W. T. Owrey, Feb. 18, 1924 ('No. 260').

ACA 1679, two specimens (one adult, one nymph), Raleigh, North Carolina, Nov. 8, 1937, Brimley and Wray, [by] sifting decid[uous] woods.

ACA 1680, two adults, in soil, Savannah, Georgia, July 13, 1944, H. K. Gouck, Bish. 17564, Lot 44-17554, retained in South Australian Museum collection.

ACA 1681, Urbana, Illinois, "I. O. P. 10. 10. 44 Snow", Lot 45-9367.

ACA 1682, on orchids, El Monte. Tam[auli]p[a]s, Mexico: at Laredo [, Texas], 1 Jan., 1945, Chapman, colr. Laredo 35276. Lot 45-1571.

ACA 1683, on *Cattleya* sp., Mante, Tamps., Mexico: at Laredo [, Texas], 16 April, 1945. H. R. Cary, Laredo 36267. Lot 45-6985.

ACA 1684, ♂, on orchid plants, Mexico: at Laredo, 29 Dec., 1945. Cary, Chapman, colrs. Laredo 37960. Lot 46-541. (Retained in S.A. Museum collection, ex U.S.N.M.)

ACA 1685, on orchid plants, Mexico: at Brownsville [Texas], 14 Nov., 1946. Lot 46-18740. No collector named. Retained in South Australian Museum collection, ex U.S.N.M.

ACA 1686, on orchid plants, Maiz, S[an] L[uis] P[otosi], Mexico: at Laredo, 12 Nov., 1946, Fouts, colr. Lot 46-18314.

ACA 1687, same source, 19 Dec., 1946. Jackson-Walton, colrs., Lot 47-699, retained in South Australian Museum collection, ex U.S.N.M.

ACA 1688, ♀, on orchid plants C[iuda]d del Maíz, S. L. P., Mexico: at Laredo, 14 Jan., 1947, Leary-Fouts, colrs. Laredo 42262, Lot 47-1091.

ACA 1689, on orchid plants, Tamazunchale, S. L. P.: at Laredo, 3 Feb., 1947, Jackson *et al.*, colrs. Lot 47-2504, retained in South Australian Museum collection.

ACA 1691, on *Laelia majalis*, Antiguo[-]Morelos, Mexico: at Brownsville, 18 March, 1947. Lot 47-4105. No collector named.

ACA 1692 and ACA 1693 each with same data as ACA 1691, retained for South Australian Museum collection, ex U.S.N.M.

ACA 1694, on orchid plants, Maiz, S. L. P., Mexico: at Laredo, 18 March, 1947, Jackson, colr., Lot 47-4249.

ACA 1695, same data, 18 March, 1947, Cary, colr., Lot 47-4247.

ACA 1696, on orchid plant, Guatemala, at Brownsville, 23 March, 1947, Allen, colr. Lot 47-4566.

ACA 1697, on orchid plants, Maiz, S. L. P., Mexico: at Laredo, 28 March, 1947, Ostrem, colr. Lot 47-5303, retained for South Australian Museum collection, ex U.S.N.M.

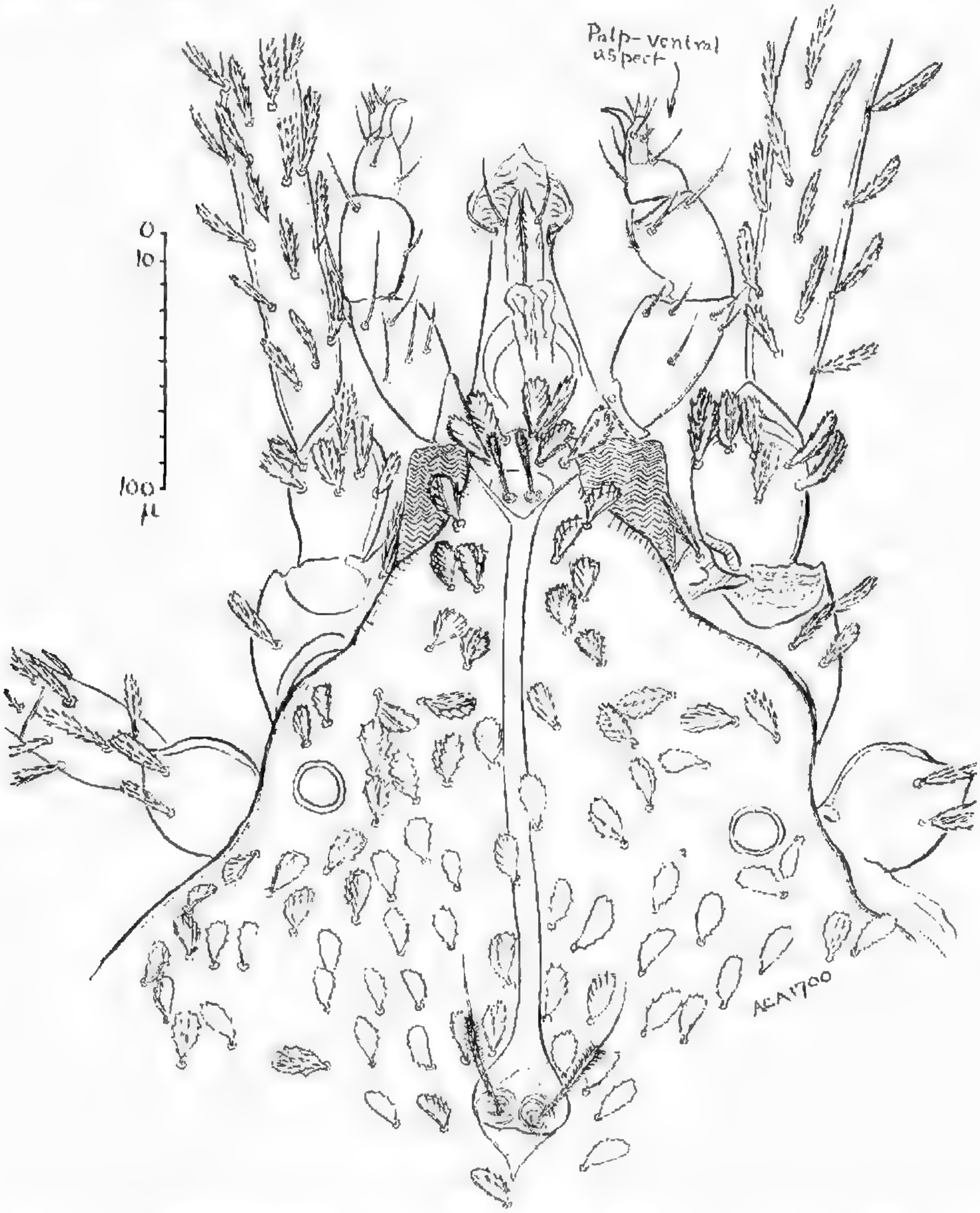

Fig. 34. *Trichosmaris dispar*, sp. nov. Nymph (specimen ACA 1700). Anterior part of idiosoma in dorsal view, and some adjacent structures (ventral view of palp shown on right).

ACA 1698, two specimens (one adult, one nymph), Maiz, S. L. P., Mexico: at Laredo, 28 March, 1947. Chapman-Jackson, colrs. Lot 47-5293.

ACA 1699, on orchid plants, Maiz, S. L. P., Mexico: at Laredo, 1 April, 1947, Cary-Leary, colrs. Lot 47-5307.

ACA 1700, nymph ("Nymphotype" of present paper), on *Laelia majalis*, Antiguo[-]Morelos, Mexico: at Brownsville, 2 April, 1947. No collector named. Lot 47-4992. In U.S.N.M. collection.

ACA 1701, same source, 23 April, 1947, Lot 47-5985 (slide marked in pencil "*Sphaerotarsus longilinealis* (Ewing), for size, O. K. ♂ type" (?in writing of Edward W. Baker). The specimen is a large one, with the idiosoma 1710μ long by 1030μ across in the somewhat compressed slide mount. Ewing (1909, p. 62) gives the type specimen of *longilinealis* as 1·68 mm. long and 1·00 mm. broad. The sex of specimen ACA 1701 cannot be determined in this slide mount, as the idiosoma is too opaque. For further comment on the possible synonymy of *longilinealis* Ewing see later in the present article.

ACA 1702, on orchid plants, San Luis Potosi, Mexico: at Laredo, 23 April, 1947 Cary *et al.*, colrs. Lot 47-6355.

ACA 1703 with same data as ACA 1702; retained for South Australian Museum collection, ex U.S.N.M.

ACA 1704, on *Laelia majalis*, Antiguo[-]Morelos, Mexico: at Brownsville, 23 April, 1947. Lot 47-5985. Collector not named. The specimen has only one PSens, which lacks a flagellum. However, the dorsal idiosomalae are quite typical, and the specimen is referred confidently to this species.

ACA 1705, two adults, with orchid plants, Maiz, S. L. P., Mexico: at Laredo, 6 May, 1947, Fouts, colr. Lot 47-6835.

ACA 1706, with *Laelia anceps*, Maiz, S. L. P., Mexico: at Laredo, 19 May, 1947. Leary, Cary, Fouts, colrs. Lot 47-7436. (Retained in South Australian Museum collection, ex U.S.N.M. collection.)

ACA 1708, ♂, North Beach, Maryland, 21 Sept., 1919, under dead leaves, H. E. Ewing (slide notation 'Berlese [funnel? No.] 1945').

ACA 1752, ♂, Ames, Iowa, September 11, 1909, under bark, H. E. Ewing. U.S.N.M. No. 20231. "Cotype." Specimen identified as *Smaris longilinealis* Ewing by Ewing and labelled in Ewing's writing. The slide label indicates also that the original mounting medium was gl[ycerine] j[elly] + ac[etic acid?]. The mite had been remounted in polyvinyl alcohol medium before receipt (in 1961) by the present author, and the mite had received some damage in loss of setae, but only of a minor nature. The sensillary setae have been detached from their sockets but remain near them. The specimen is conspecific with *T. dispar*.

For further discussion on the significance of this specimen see the remarks later in this article. Specimen in United States National Museum.

Department of Health, State of Nebraska: Specimens

(forwarded by William F. Rapp, Jr.)

ACA 1724, ♀, Table Rock, Pawnee Co., Nebraska, in humus, 3 Nov., 1954, W. F. Rapp, Jr., No. 54193 (Holotype specimen, to be deposited in the collection of the United States National Museum).

ACA 1725, ♂, data as ACA 1724, No. 54195, to U.S.N.M.

ACA 1726, ♂, data as ACA 1724, No. 54169; returned to collector.

ACA 1727, ♀, Leggett, Texas, 9 Feb., 1956, 'Ex duff'*; deposited in U.S.N.M.

ACA 1728, ♀, West Point, Cuming Co., Nebraska, 6 May, 1957, W. F. Rapp, Jr., ex humus (no serial number); returned to collector.

ACA 1729, ♀, Table Rock, Pawnee Co., Nebraska, 27 Dec., 1957, W. F. Rapp, Jr., ex oak humus. (Retained for South Australian Museum collection.)

ACA 1730, ♂, data as ACA 1727. (Retained for South Australian Museum collection.)

Remarks on Systematics. See later in this article.

Trichosmaris dispar subsp. **dentella** subsp. nov.

Figs. 35 and 36

Description of Adult Female (from Holotype Specimen ACA 1707)

Colour in life not recorded. Animal of normal smaridid shape. Idiosoma 1230μ long by 650μ wide where widest. Anterior sensillae similar to those of *T. dispar dispar* (in addition, there is a teratological third sensilla present, 15μ long, as figured in Fig. 36. See remarks made subsequently). Posterior sensillae normal for genus, somewhat obscured in the sole specimen available from an underlying opacity (guanine body). The standard data are:

ASens	PSens	SBa	SBp	ISD	DS
44L, 38R	76 pars clavata + ca 60 flagellum = ca 136 total	26*	ca 20	489	18-36

*teratological

Eyes circular, normal, cornea 34μ across. Distance OAS 210μ, OPS 278μ.

Dorsal idiosomalae similar to those of *T. dispar dispar*, but longer, stronger, the tectum comparatively more elongate, with about 6 serrations along each side; the serrations and spicules of the seta are more prominent, including the serrations of the carinal flange. Dorsal setae longer towards posterior pole of idiosoma.

Ventral surface normal. External genitalia normal. Anus and anal setae as in *T. dispar dispar.*

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* Mr. Rapp (pers. comm., 15 iii 1962) has explained that the term 'duff' means decaying vegetable matter under conifers, while 'humus' is used for decaying vegetable matter under deciduous trees, following the usage of his former teacher in ecology, Dr. Victor E. Shelford. Professor J. A. Prescott (pers. comm., 17 v 1962) has commented further that the term 'duff' "was introduced into the nomenclature of humus in 1931 by Lars-Gunner Romell and S. A. Heiberg for North American forest soils as an extension of the Scandinavian classification and as a substitute for 'raw humus'. Romell was uncertain already in 1932 whether the term would survive. It refers more particularly to the still fibrous humus layers in both coniferous and broad leaved forests. The more decomposed humus is referred to as 'mull'. The range of properties is indicated in the descriptions as:

Crumb mull	Root duff
Grain mull	Leaf duff
Twin mull	Greasy duff
Detritus mull	Fibrous duff."

Legs normal. Leg lengths (inclusive of trochanter and tarsal claws): I (incomplete, 1585μ except tarsus I, missing), II 1052μ, III 1210μ, IV 1590μ. Tarsus I missing, tibia I 370μ long, genu I 475μ long, tarsus IV 170μ long by 56μ high, tibia IV 422μ long, genu IV 410μ long (tarsal length excludes claws and pedicle). Tarsal claws normal. Setation of legs similar to *T. dispar dispar*, but the scobalae longer and with more pointed ciliations.

Gnathosoma normal, as figured. Palpal scobalae lightly adnately ciliated, the tectum not expanded. Palpal tibial claw with flexor tooth. Palpal tarsus with normal sensalae.

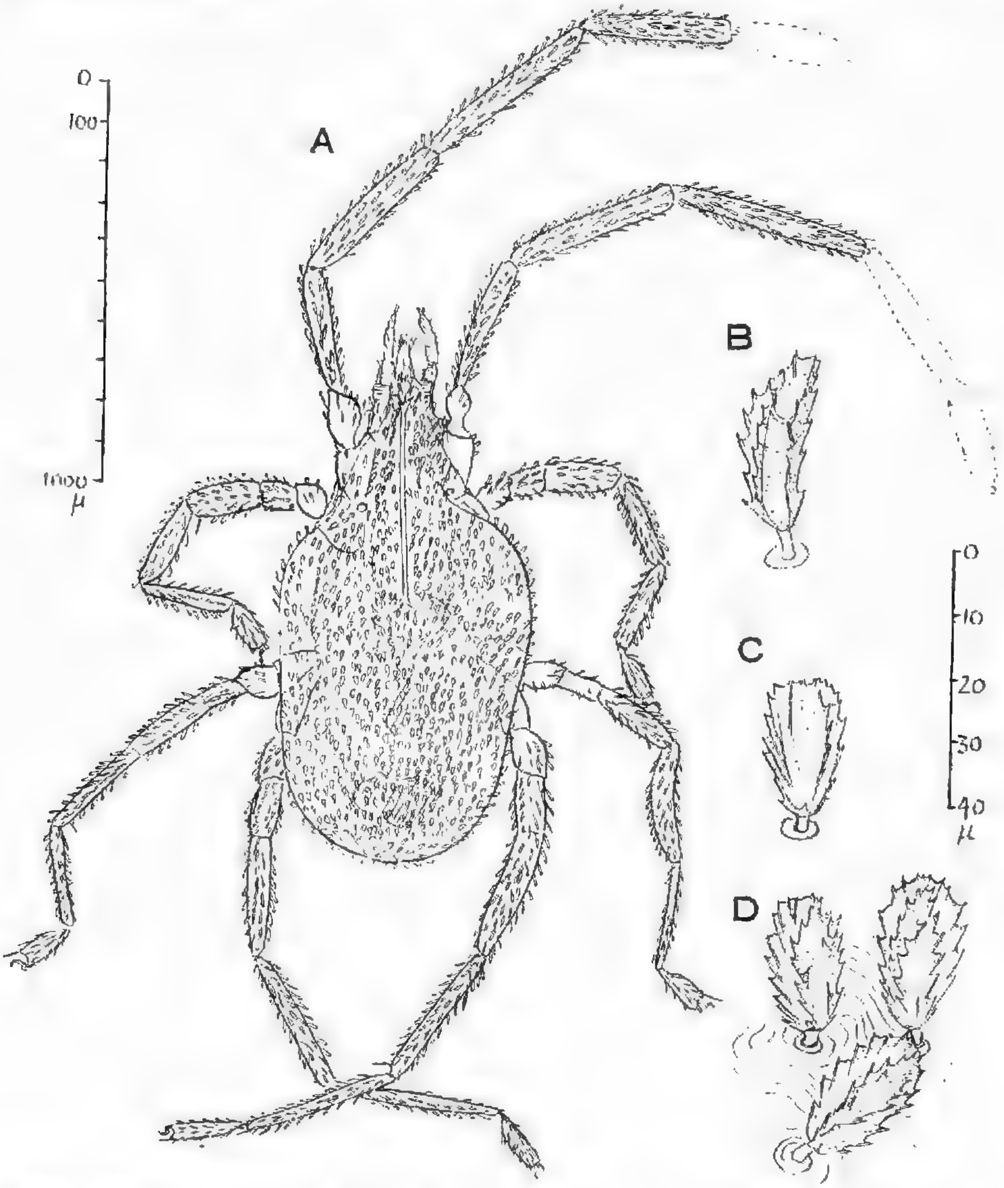

Fig. 35. *Trichosmaris dispar*, subsp. *dentella*, subsp. nov. Adult female (holotype). A, dorsal view of the slide mount (some ventral features shown in transparency), to scale on left. B-D, dorsal idiosomal scobalae, various aspects (to scale on right).

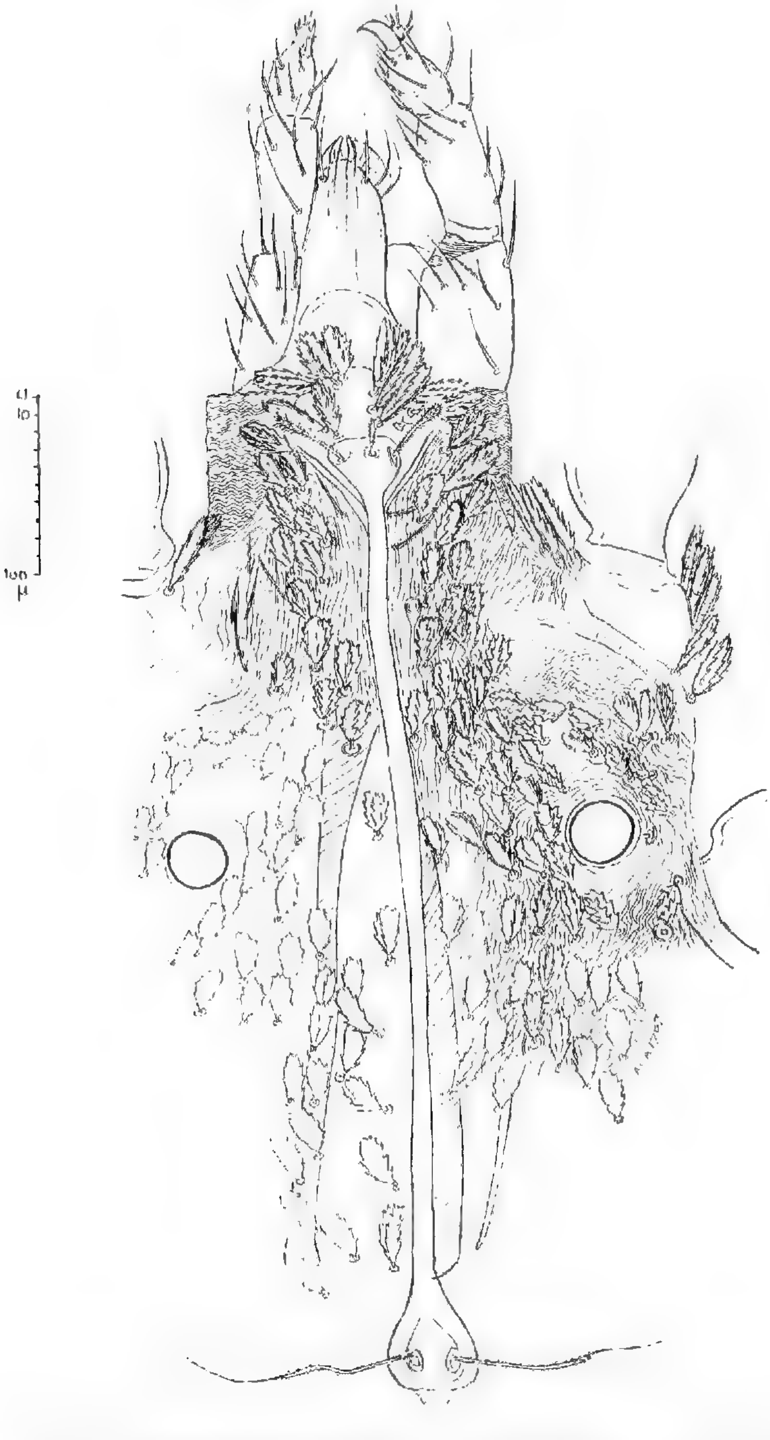

Fig. 36. *Trichosmaris dispar* subsp. *dentella*, subsp. nov. Adult female (holotype). Anterior part of dorsum of idiosoma and some adjacent and underlying structures. Note the teratological anterior sensillary area, with three sensillae.

Material Examined. The sole specimen referred to this subspecies is specimen ACA 1707, holotype, "On *Epidendrum pentolis,* San José de Guatemala [, Guatemala]: at San Francisco. April 12, 1946. S.F. 20756. Lot 46-4416"; name of collector not stated, in United States National Museum collection.

Remarks. 1. *T. dispar dentella* may be distinguished from *T. dispar dispar* by the former's possessing prominent denticulations on the dorsal idiosomal scobalae, both at the edges of the tectum setae and of the carinal flange. These are distinct characters in the material studied. Compare Fig. 35 B-D with Fig. 31 B-J.

2. The anterior sensillary area of the holotype of *T. dispar dentella* is teratological. Three anterior sensillae are present, as figured (Fig. 36), the middle sensilla being shorter than the other two, which are taken as representing the normal anterior sensillae. A similar teratological abnormality was recorded by the author in *Fessonia australiensis* Southcott (see Southcott, 1946, p. 176 and Fig. 4C).

3. See below for a further discussion on speciation and subspeciation in *Trichosmaris*, as well as of the nomenclatorial aspects.

Trichosmaris jacoti (Southcott, 1946) comb. nov.

Figs. 37 and 38

Smaris sericea Jacot, 1938, p. 123, non *Trombidium sericeum* Say, 1821, p. 70.
Hirstiosoma sericea Womersley and Southcott, 1941, pp. 63, 78.
Hirstiosoma jacoti Southcott, 1946, p. 177 (nom. nov.).

Redescription of adult, ? ♂ (from lectotype specimen ACA 1755, mounted in canada balsam, and remounted in same medium in October, 1961) (Figs. 37, 38).

"Color of body vermillion [sic], legs paler" (teste Jacot, 1938, p. 124) (the mounted specimen is now decolorized). Animal of normal smaridid shape, with a normal nasus. Idiosoma 1185μ long by 670μ wide where widest (the specimen is only very slightly compressed).

Crista as recorded for genus; anterior sensillary area carries the two sensillae and 10 scobalae, latter similar to other dorsal idiosomalae but stronger, longer, more parallel-sided, 24-34μ long. Anterior cristal sensilla a little clavate, ciliated throughout its length, ciliations a little longer distally. Posterior cristal sensillae ciliated, almost parallel-sided, then narrowing, terminating in a narrow thread which appears to be a broken flagellum, on left 3μ long, on right 7μ long; pars clavata (clavum) 45μ long. The standard data are:

ASens	PSens	SBa	SBp	ISD	DS
40	45 clavum 7+ flagellum 52+	16	19	370	18-27

Eyes one on each side, cornea 28μ across. Eye centres placed 25μ anterior to mid-point of ISD (OAS = 160μ). Eyes fairly close to lateral edge of idiosoma in dorsal view.

Dorsal idiosomal scobalae typically smaridid, similar to those of *Trichosmaris dispar*, sp. nov. (q. v.).

Ventral surface appears normal, but not seen clearly in specimen, which is now mounted back upmost.

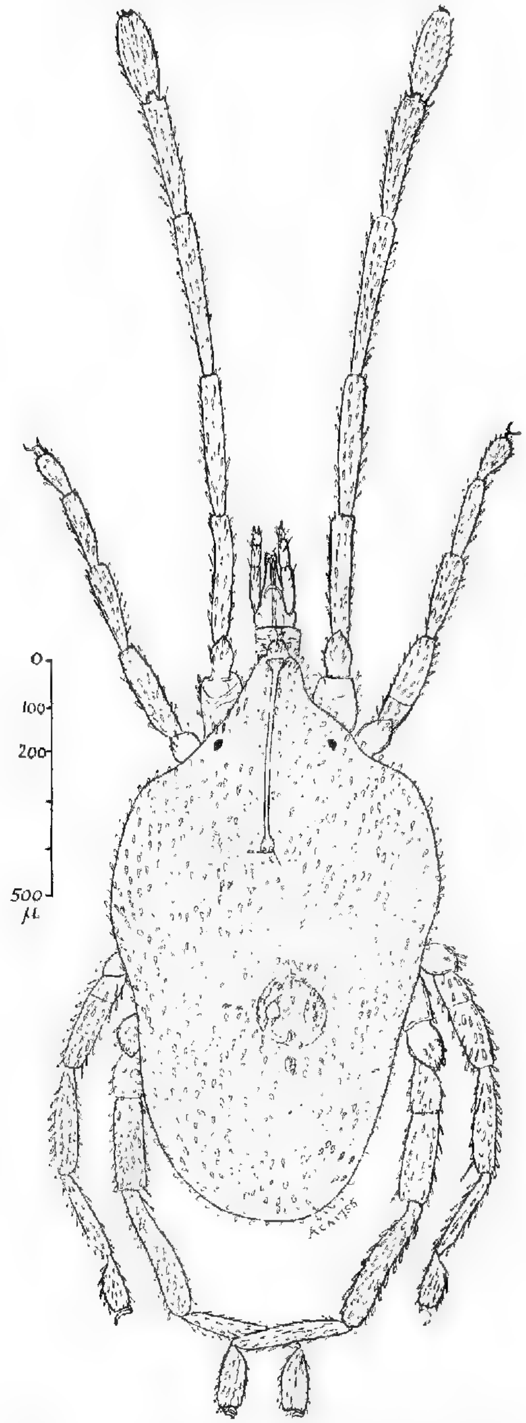

Fig. 37. *Trichosmaris jacoti* (Southcott). Adult, ?male (lectotype), dorsal view, somewhat in transparency, to show genitalia and anus.

Legs normal. Leg lengths (inclusive of trochanter—tips of tarsal claws): I 1430μ, II 790μ, III 895μ, IV 1160μ. Tarsus I 208μ long by 66μ across, tibia I 273μ long, genu I 341μ long, tarsus IV 133μ long by 44μ high, tibia IV 287μ long, genu IV 305μ long. For leg segment ratios see Table IV. Setae of legs appear normal for Smarididae.

Gnathosoma with normal armilla. Palpal scobalae slender, tapering, pointed, lightly (adnately) ciliated.

Localities (both specimens in Museum of Comparative Zoology, Harvard). Specimen ACA 1755, lectotype (here designated), adult, ?♂, 'From under bark of prone pines, north of Darien, G[eorgi]a, [United States of America], April, 1936, coll. by A. P. Jacot', slide labelled also '36 86—1', 'Topotypes'. '1 = *Smaris sericeum* Say 1821' (= ACA 1755), '5 = *Trombiculoides scabrum* Say 1821' (= ACB 639), and 'Figured Jacot 1937 Psyche', 'A. P. Jacot Det.' (all in (presumably) writing of Jacot, except for the additional numbers ACA 1755 and ACB 639 of the present author). (Note: Jacot (1938, p. 125) refers to this specimen as 'slide 3688-1'. See further under Remarks.)

Specimen ACA 1754, paratype (here designated), adult, ?sex, slide labelled '*Smaris sericeum* Say 1821 = *Hirstiosoma jacoti* n. n. Southcott 1945, Remounted P.V.A. Aug., 1949 H.W.' (L. H. label), and "A. P. Jacot Coll. 3655 Topotype, From under bark of large prone oak S. of Savannah, G. April 1936, Coll. A. P. Jacot" (R. H. label), all in Womersley's writing, to which the present author has added 'ACA 1754'. The specimen is in a damaged condition in the polyvinyl alcohol mountant, and no attempt to remount it has been made (nor should it be remounted in the future, as it is in a polyvinyl medium). Reference to Jacot (1938, p. 125) shows that this specimen was on slide 3683 of Jacot, which presumably Womersley misread (the original label of Jacot is no longer on the slide. Jacot (loc. cit.) refers to this specimen as "One specimen from under bark of a large prone oak, outskirts south of Savannah; slide 3683").

Remarks. Specimen ACA 1755 was mounted in balsam on a single slide as above, along with 5 specimens of '*Trombiculoides scaber* (Say) 1821' (sic, in Jacot (1938, p. 123); the slide label uses *scabrum*), which Wharton and Fuller (1952, p. 50) synonymize with *Trombicula splendens* Ewing, 1913. The smaridid mite was mounted upside down, and the (true) right palp was figured, the figure of Jacot (Plate XIV, Fig. 5) matching it accurately in structure, position and setation. The other figures given by Jacot do not certainly identify the specimen(s) used in the illustration(s). In view of the note on the slide by Jacot that this specimen was figured, and the confirmation from the figure of the palp, the author designates specimen ACA 1755 as the lectotype of *Hirstiosoma jacoti* Southcott, 1946. In order to redescribe the species the specimens (ACA 1755 and ACB 639 A-E) were remounted on to individual slides by the author, in October, 1961, to (xylol) balsam and ACA 1755 was placed back upmost. Unfortunately the specimen is apparently defective in one important particular, that being in the character of the posterior sensilla of the crista. It appears as if a flagellum had been present, and broken off fairly short on each side, but not evenly. Support for this viewpoint is given by an examination of specimen ACA 1754, also from Georgia, United States of America, where the flagellum is present on each side for the posterior sensillae. It is not, however, possible to be quite certain about the status of the lectotype in this particular, and the author believes that the best course to take to protect the stability of the genus *Trichosmaris*, gen. nov., is to base its definition upon a species and a specimen whose status is not likely to be called into dispute, even though it may be a species synonym of *jacoti*. Accordingly, *Trichosmaris* has been based upon *T. dispar*, sp. nov. See further in the following section.

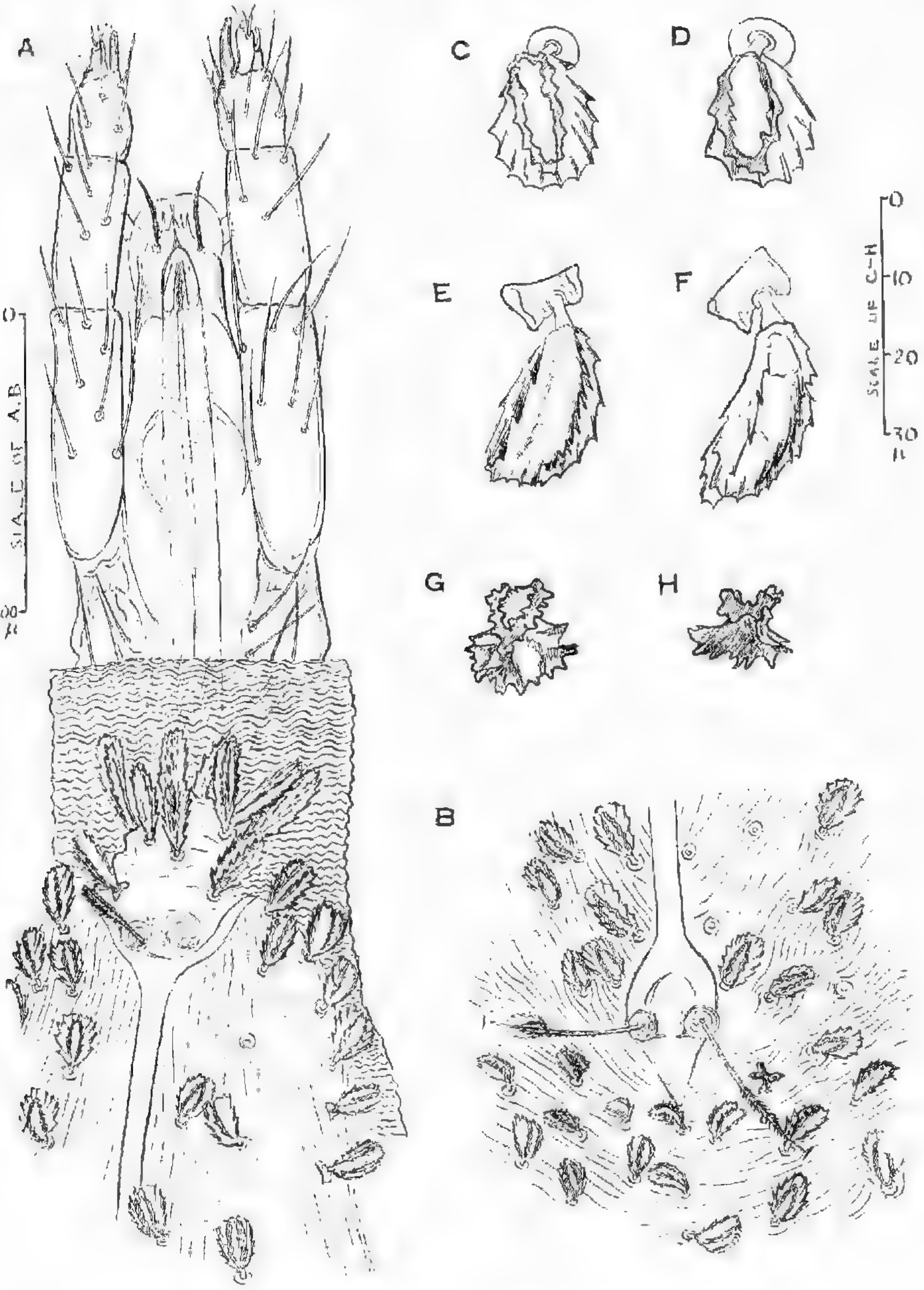

Fig. 38. *Trichosmaris jacoti* (Southcott). Adult, ?male (lectotype). A, gnathosoma and part of propodosoma, dorsal aspect, to scale on left. B, posterior sensillary area and surroundings, to same scale. C-H, dorsal idiosomal scobalae, to scale on right: C, D, tectal views; E, F, lateral views; G, H, end views.

REMARKS ON TAXONOMY AND NOMENCLATURE IN *TRICHOSMARIS*

Among the specimens referred in this paper to *Trichosmaris dispar* are some with variations in the size and character of the dorsal idiosomal scobalae, suggesting in fact that among them are incipient species (or subspecies) (see Dobzhansky, 1960). Thus some of the mites have shorter and more rounded setae, and others have a more denticulate character of the dorsal idiosomal setae than seen in the majority. Independent attempts have been made by the author, at intervals, to place the mites in subgroups, but these have in general not given consistent results. Only one specimen was considered distinct enough to warrant a subspecies, that being the holotype of *T. dispar dentella*.

The reasons for setting up *T. dispar* as a separate species from *T. jacoti* are given above; at present these are considered synonyms, but this will be discussed further below. It was finally concluded that further studies on subspeciation in *T. dispar* or *T. jacoti* might well be left until more extensive collections are available, and may be aided by adult-larva correlations.

Trichosmaris dispar is a large species of smaridid, and in North and Central America is surpassed in size only by *Hirstiosoma bolivari*, judging by the collections examined. Judging by these collections also, it is the commonest smaridid mite in North and Central America. It would therefore seem likely that it has been referred to in the previous literature of the Smarididae of this region (which is detailed at the beginning of the present article).

The author has referred earlier to *Smaris longilinealis* Ewing, 1909, described originally from a specimen collected in moss by L. M. Smith, at Marion, Illinois, United States of America. Of this specimen Ewing (1909, pp. 61-2) described the eyes as 1 + 1 ("A small single pair of eyes situated two-thirds the distance from the dorsal groove to the lateral margin"). He observed the posterior cristal sensillae, which he described as "two small simple hairs". He failed to observe the anterior cristal sensillae, remarking only upon a "whorl of bristles like those of the body" on the "anterior tubercle" (anterior sensillary area and nasus), and figured them diagrammatically.

In 1910 (p. 89) Ewing referred to a mite which he identified as the same species, from under bark, Urbana, Illinois (two specimens): "There is a double pair of eyes situated on the sides of the cephalothorax above the second pair of legs". If this is actually so, then this mite could not belong to the Hirstiosomatinae, and, in fact, by adding the character of the eyes to what is discernible of the crista from Ewing's Fig. 22 (Plate IV) of that paper, could belong only to *Fessonia* on the present knowledge of the North American Smarididae.

Thus in both 1909 and 1910 Ewing failed to recognize the anterior cristal sensillae. Many students of the Smarididae have similarly failed to recognize the correct status of the sensillae of the Smarididae (see Womersley and Southcott, 1941) for European and Australian members of the family. There is thus a distinct possibility that *longilinealis* Ewing, 1910, belongs to *Fessonia*. Perhaps however, too much should not be made of these differences in Ewing's accounts, as his work was at times of a superficial character. Unfortunately, the present author has not been able to locate any of these mites of Ewing in North America. According to Ewing (1909, p. 53) *Smaris longilinealis* Ewing, 1909, had its type specimen deposited in the Illinois State Laboratory of Natural History, whose collections have now been taken over into the Illinois Natural History Survey. According to Dr. L. J Stannard, taxonomist, Section of Faunistic Survey and Insect Identification (personal communication to the author, 1961), the Ewing

TABLE 1.

Metric data (length of segments and various proportions) of some Smarididae from North and Central America

	Specimen	Tarsus I	Tibia I	Genu I	Tarsus IV	Tibia IV	Genu IV	Tarsus I / Tibia I	Tibia I / Genu I	Tarsus IV / Tibia IV	Tibia IV / Genu IV
1.	*Trichosmaris dispar*, ♂, specimen ACA 1752, Ames, Iowa, 'Cotype' of *Smaris longilinealis* (see text)	199	279	362	133	287	314	·7133	·7707	·4634	·9140
2.	*Trichosmaris dispar*, ♀ Holotype, ACA 1724, Nebraska	210	295	382	142	320	332	·7119	·7723	·4438	·9639
3.	*Trichosmaris dispar*, nymph, ACA 1700, Mexico	133	194	245	85	203	203	·6856	·7918	·4187	1·000
4.	*Trichosmaris dispar dentella*, ♀, Holotype, ACA 1707, Guatemala	—	370	475	170	422	410	—	·7789	·4028	1·029
5.	*Trichosmaris jacoti*, ?♂, lectotype, ACA 1755	208	273	341	133	287	305	·7619	·8005	·4634	·9410
6.	*Trichosmaris jacoti*, ? sex, adult, ACA 1754, Paratype	200	291	377	—	—	—	·6873	·7719	—	—
7.	*Smaris longilinealis* Ewing, 1909, Holotype, Marion, Illinois (from Ewing, 1909)	—	—	—	—	—	—	$\frac{2}{3}$	<1	$\frac{1}{2}$	slightly >1
8.	*Smaris longilinealis* Ewing, 1910, Urbana, Illinois (from Ewing, 1910)	177*	275*	—	—	—	—	$\frac{3}{4}$ (·6438*)	>1†	ca $\frac{1}{2}$	$\frac{2}{3}$†
9.	*Fessonia lappacea*, adult, male, Holotype, ACA 1714	146	194	178	106	206	188	·7526	1·090†	·5146	1·096
10.	*Fessonia lappacea*, nymph, ACA 1663	105	163	150	75	115	122	·6442	1·087†	·6522	·9426

*Estimated from Ewing's Fig. 23 of Plate IV (1910).

†Values considered discrepant from others without dagger in same column.

mite types are not in the collections of the Illinois Natural History Survey, Urbana, Illinois, having been taken away by Ewing when he left the Survey.

A specimen identified by Ewing as *Smaris longilinealis* and labelled "Cotype" has been made available to the author and is referred to above as specimen ACA 1752, under *Trichosmaris dispar*. Since this mite came from Ames, Iowa, and not Illinois, it is clearly not the holotype, and its conspecificity with *Smaris longilinealis* Ewing, 1909, is uncertain, particularly in view of *longilinealis* Ewing, 1910 (upon which further comment is made below). At most, specimen ACA 1752 can be regarded as a homeotype (see Schenk and McMasters, 1936, p. 7) of *longilinealis* Ewing, 1909, if later work shows these two specimens are conspecific.

Ewing (1909, p. 62) stated of *longilinealis* Ewing, 1909, tibia I is 'not as long' as genu I, and tibia IV is 'slightly longer' than genu IV. Ewing (1910, p. 89) stated of *longilinealis* Ewing, 1910, that tibia I is 'longer than' genu I, and tibia IV is 'two-thirds as long as' genu IV. These differences may be of significance, and may help to identify these species in the absence of the actual specimens. Table V gives certain metric data of specimens of *Trichosmaris dispar*, sp. nov., *T. jacoti* (Southcott, 1946), and compares them with the available similar data for *Smaris longilinealis* Ewing, 1909, and *Smaris longilinealis* Ewing, 1910. Since the eye character and other features described for *Smaris longilinealis* Ewing, 1910, suggest *Fessonia*, similar data are included of *Fessonia lappacea*, sp. nov., this being the only species of *Fessonia* which has so far been recorded for the United States of America (California and South Carolina).

Examination of Table I suggests that the proportions of the leg segments selected may be useful for systematic purposes among these mites. The segments were selected primarily because Ewing refers to them, and it was hoped that their study might help to clarify the status of *longilinealis* Ewing, 1909, and *longilinealis* Ewing, 1910. The figures given of the proportions do not conflict with the hypothesis that *jacoti*, *dispar* and *longilinealis* Ewing, 1909, are conspecific. The proportion Tibia I/Genu I in *longilinealis* Ewing, 1910, is in agreement with *Fessonia lappacea*, but is markedly discrepant from *jacoti*, *dispar* and *longilinealis* Ewing, 1909. However, in the column of proportions for Tibia IV/Genu IV the only value not in the range ·91-1·10 is that for *longilinealis* Ewing, 1910. If the estimate of Ewing for that proportion, as 2/3, is correct, then it suggests that *longilinealis* Ewing, 1910, is not conspecific with any other mite listed in Table I.

Genus CLAVISMARIS, gen. nov.

Type species (original designation): *Clavismaris conifera*, sp. nov.

Definition (Adults and Nymphs).

Smaridid mites with one eye on each side. Posterior cristal sensillae clavate, ciliated, without flagellum. Tarsus IV of male normal, not enlarged.

Larva not known.

Remarks. Among the Hirstiosomatinae studied from North and Central America was a small number in which the anterior and posterior cristal sensillae were clavate, and the posterior sensillae were without a flagellum. Owing to the general similarity between the dorsal idiosomal scobalae of a number of the Smarididae of this region, as well as other factors, it was at first thought that these specimens in which the flagellum was absent represented specimens of *Trichosmaris* in which the flagellum had broken off (see e.g. the account of the lectotype of *Trichosmaris jacoti*). More careful study showed, however, that this view was untenable, and it was possible to distinguish a small number of specimens which were not conspecific with the *Trichosmaris* specimens studied, and in which at least one posterior cristal sensilla appeared to be intact, and resembled that of the Australian genus *Sphaerotarsus*. Among these specimens both males and females were present. The tarsus IV of the males was not enlarged. It was finally concluded that this group of Smarididae constituted a separate genus. At the present time the female cannot be distinguished from *Sphaerotarsus*, but since there is no evidence that *Sphaerotarsus* occurs outside the Australian region, and none that *Clavismaris* occurs outside North and Central America, females are identifiable as long as their region of origin is known. The author recognizes two species, separable as in the following key.

Key for the Separation of the Species of *Clavismaris*

Dorsal palpal scobalae adnately ciliated. Tectum setae of dorsal idiosomal setae solid, convex, with, apart from the tectal borders, 6-8 spicules, projecting, arranged in two or three columns, but the pattern of columns not strongly defined. ISD 381μ long. Ratio Tibia IV/Genu IV 0·85
C. conifera, sp. nov.

Dorsal palpal scobalae somewhat expanded, with outstanding ciliations. Tectum setae of dorsal idiosomal scobalae with four projecting columns of spicules, two being along the tectal borders and two along the tectum setae about midway between the neomedian line and the tectal borders; these two non-bordering (paramedian) columns comprising 15-20 spicules. ISD 267μ long. Ratio Tibia IV/Genu IV 1·00-1·02 *C. cybaea*, sp. nov.

Clavismaris conifera sp. nov.

Figs. 39 and 40

Description of Adult Female (from Holotype ACA 1690).

Colour in life not recorded, in slide mount brownish with moderately pigmented setae. Animal of typical smaridid shape, fairly robust. Nasus normal. Idiosoma 1070μ long by 555μ wide where widest.

Crista linear, normal, with two sensillary areas. Anterior sensillary area has two clavate sensillae, ciliated, and carries also on the nasus 17 scobalae 20-26μ long. Posterior sensillary area of crista with two clavate ciliated sensillae, as figured, the ciliations longer over the expanded part. The crista extends about 25-30μ behind centres of PSens (a little obscured in the preparation).

The standard data are:

ASens	PSens	SBa	SBp	ISD	DS
22	43	12	13	381	16-24

Eyes one on each side, approximately circular, cornea about 20μ across. Line between eye centres 7·5μ anterior to mid-point of ISD (OAS = 183μ, OPS = 198μ).

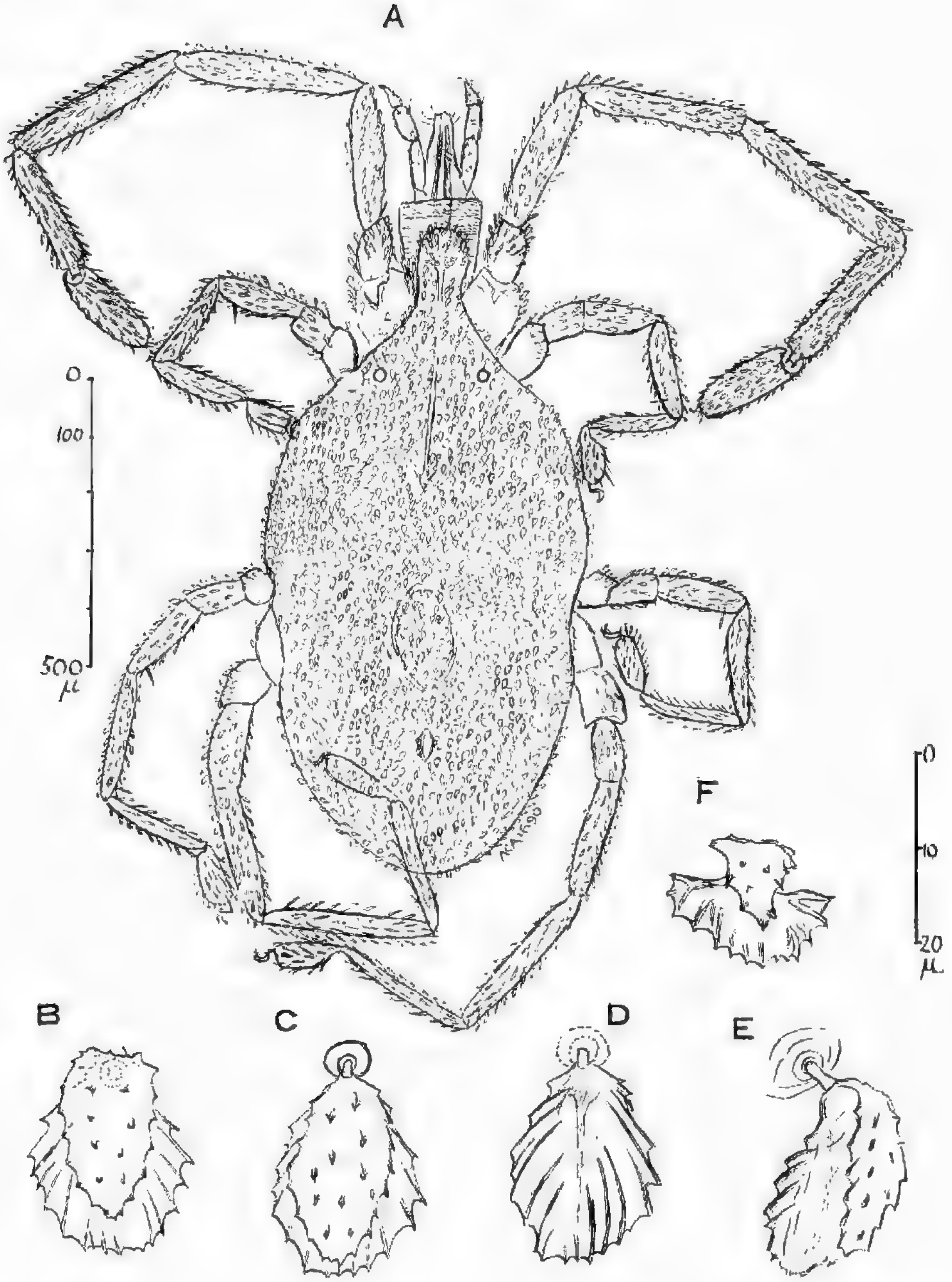

Fig. 39. *Clavismaris conifera,* sp. nov. Adult female (holotype). A, entire dorsal view of slide mount (slightly in transparency), to scale on left. B-F, dorsal idiosomal scobalae, various aspects, to scale on right: B, C, tectal views; D, carinal view; E, lateral view; F, end view.

Dorsal idiosomal scobalae uniform, typically smaridid, moderately pigmented. The tectum setae is solid, convex, with the tectal borders cut into coarse serrate teeth, each with a proximal stiffening rib. In addition to these the tectum setae carries 6-8 spicules which may form two or three more or less regular columns, or they may be irregular. Carinal flange expanded into coarse serrations with stiffening chitinous ribs, outline of carinal flange from above almost circular, with serrations.

Ventral surface normal. Central ventral idiosomalae bushy, with long ciliations. External genitalia 210μ long by 110μ wide (lips open). (The specimen is dorsum uppermost and details of the ventral surface are not clear. However, the internal genitalia are not chitinized, hence the animal is a female.) Anus 65μ long by ca 40μ across.

Legs normal. Leg lengths (inclusive of trochanter, to tips of tarsal claws): I 1450μ, II 770μ, III 895μ, IV 1210μ. Tarsus I 200μ long by 62μ across, tibia I 265μ long, genu I 337μ long, tarsus IV 112μ long by 43μ high, tibia IV 270μ long, genu IV 318μ long. Hence the following leg segmental ratios are derived:

$\frac{\text{tarsus I}}{\text{tibia I}}$	$\frac{\text{tibia I}}{\text{genu I}}$	$\frac{\text{tarsus IV}}{\text{tibia IV}}$	$\frac{\text{tibia IV}}{\text{genu IV}}$
·7547	·7864	·4148	·8491

Setae of legs normal for Smarididae. Distal scobalae of leg segments (except tarsi) tend to be clavate or foliose. Dorsal tarsal setae with long strong ciliations, setae tending to be lanceolate, foliose, with 4-5 columns of linked ciliations. Terminally on tarsus II, III and IV are some modified scobalae, expanded distally ('spoon-like setae').

Gnathosoma normal, with normal armilla. Dorsal palpal scobalae pointed, lightly ciliated. Hypostomal setae tapering, pointed, adnately ciliated.

Locality. Known only from the holotype female, specimen ACA 1690, on orchid plants, Chilpancingo [de los Bravos], G[uerre]ro, Mexico: at Laredo, United States of America, February 4, 1947, Jackson, colr. Lot 47-3559. In United States National Museum collection.

Remarks. See under *Clavismaris*, and under the following species.

Clavismaris cybaea sp. nov.

Figs. 41-43

Description of Adult Male (from Holotype ACA 1711).

Colour in life not recorded. Animal of normal smaridid shape, with a normal nasus. Idiosoma 1160μ long by 565μ wide (the holotype is somewhat compressed in the slide mount, but these figures are an estimate of the uncompressed state based on the fixed idiosomal contents—see Fig. 41).

Crista linear, normal. Anterior sensillary area of crista with two clavate ciliated sensillae, and carries also on nasus 8 strongly ciliated scobalae, about 3-4 times as long as wide, 30-34μ long. Posterior sensillary area with two ciliated

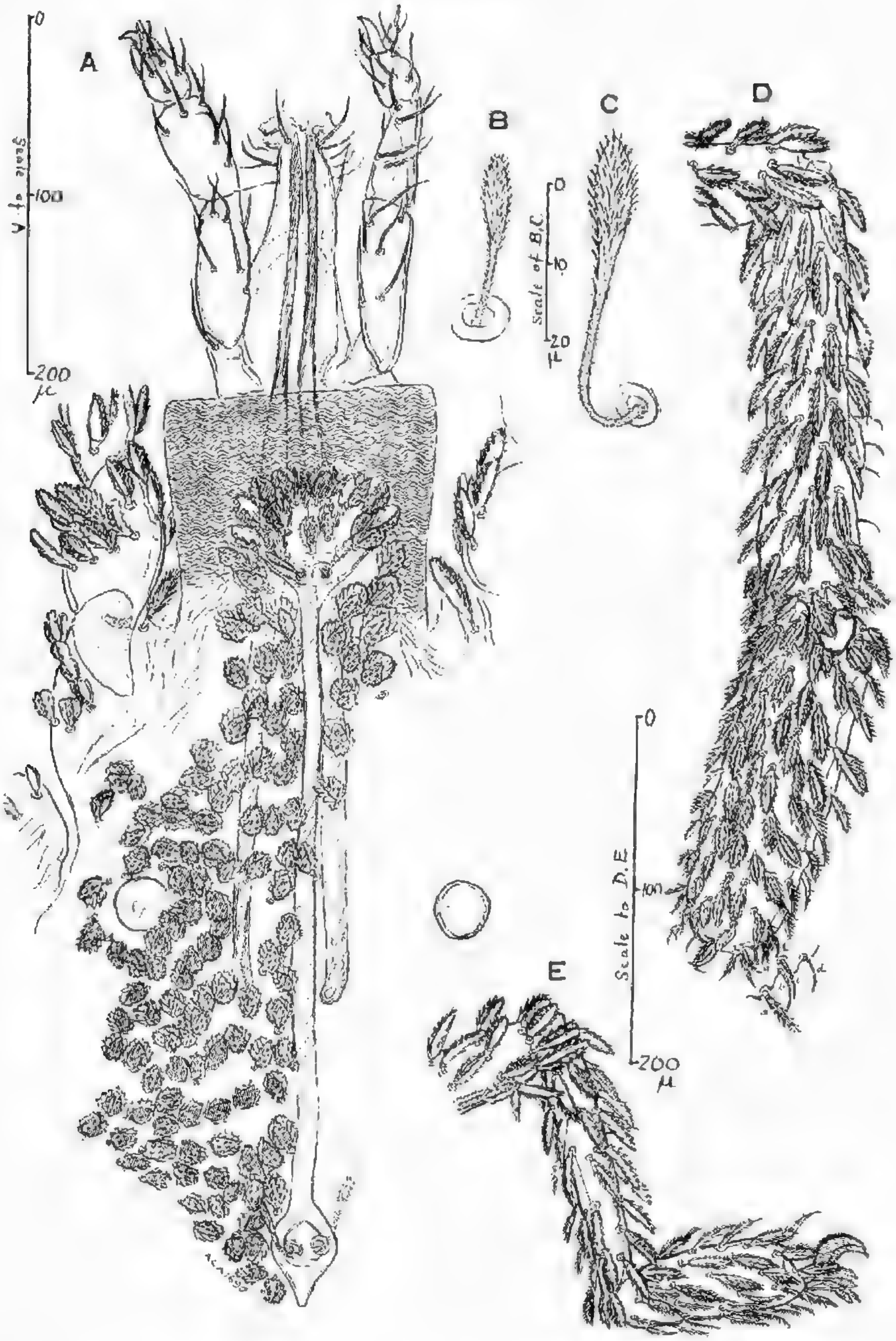

Fig. 40. *Clavismaris conifera*, sp. nov. Adult female (holotype). A, propodosoma and gnathosoma, dorsal aspect. B, anterior cristal sensilla. C, posterior cristal sensilla. D, distal part of right leg I, posterodorsal aspect. E, distal part of right leg II, posterior aspect. (All figures to adjacent scales, as shown.)

clavate sensillae, the expanded part somewhat fusiform (see Fig. 42A). Crista extends 28μ behind centres of PSens. The standard data are:

ASens	PSens	SBa	SBp	ISD	DS
28	47	14	13	267	12-24

Eyes one on each side, cornea 18μ across, but with the surrounding part included the eye is 26μ across (see Fig. 42A). Line joining centres of eyes is 31μ behind mid-point of ISD (OAS = 164μ, OPS = 103μ).

Dorsal idiosomal scobalae lightly chitinized, variable in character, but typically smaridid. Tectum setae forms an oblong or oval band with four projecting columns of spicules, two being along the tectal borders, and two being placed in a paramedian situation along the tectum setae, these two comprising together about 15-20 spicules. Distally the paramedian columns may become somewhat irregular. The appearance of the dorsal scobala is therefore strongly prismatic in some views, and in end view the tectum has an excavated appearance between the columns. The carinal flange is moderately expanded, with strong spicules or ciliations; from above it is roughly triangular or obovate.

Ventral surface normal, the central ventralae bushy with long ciliations. Internal genitalia clearly of male type. External genitalia 200μ long. Anus oval, 63μ long by 33μ across with the lips open.

Legs normal. Leg lengths (inclusive of trochanter–tips of tarsal claws): I 1370μ, II 890μ, III 1010μ, IV 1430μ. Tarsus I 188μ long by 66μ across, tibia I 270μ long, genu I 305μ long, tarsus IV 115μ long by 41μ high, tibia IV 350μ long, genu IV 344μ long. Hence the following ratios are derived.

$\frac{\text{tarsus I}}{\text{tibia I}}$	$\frac{\text{tibia I}}{\text{genu I}}$	$\frac{\text{tarsus IV}}{\text{tibia IV}}$	$\frac{\text{tibia IV}}{\text{genu IV}}$
·6963	·8852	·3286	1·017

Tarsus IV not enlarged. Setae of legs typically smaridid, scobalae strong, well ciliated, setae on distal parts of segments (except tarsi) tending to be clavate or foliose.

Gnathosoma normal, with normal armilla. Palpi with dorsal scobalae somewhat expanded, well ciliated with outstanding ciliations, pigmented. Setae of mouthcone tapering, pointed, adnately ciliated.

Locality. Holotype male specimen ACA 1711, in banana debris, Costa-Rica, at New York, August 5, 1935, Goolsby, New York No. 46057. In United States National Museum collection.

Paratype male specimen ACA 1712, on onion leaf, France; at New York, March 19, 1936, McMaster colr., N.Y. 55936, Lot 36-6392, United States National Museum collection (see remarks below).

Adult female specimen ACA 1713, Camp Bullis, Texas, United States of America, October 19, 1943, J. M. Brennan, Lot 43-14596 (see remarks below); U.S.N.M. collection.

Remarks. (1) The holotype male has only one posterior cristal sensilla, the clavate part of which is somewhat fusiform. At first examination it was thought

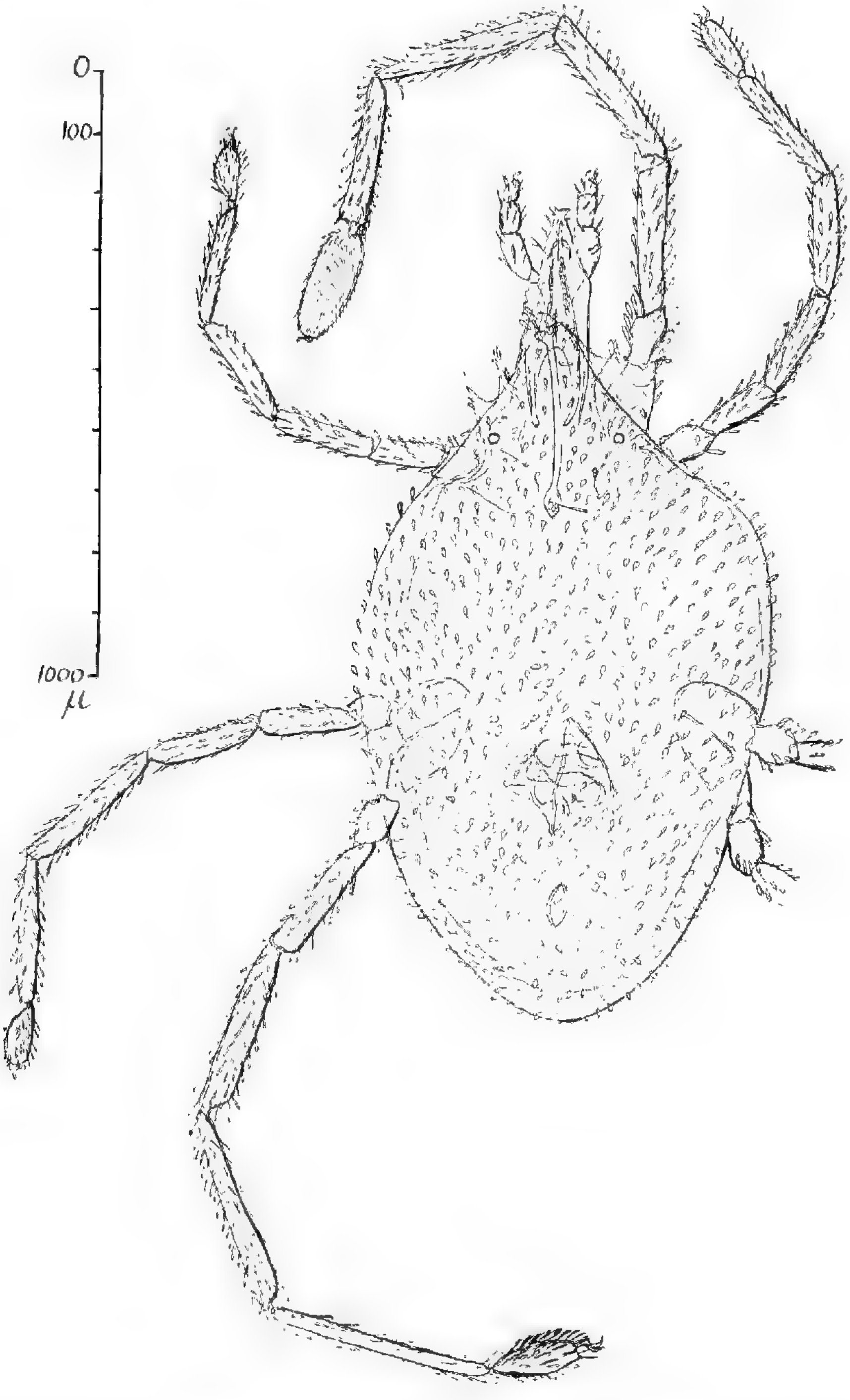

Fig. 41. *Clavismaris cybaea*, sp. nov. Adult male (holotype), dorsal aspect, partly in transparency.

that this specimen was one of *Trichosmaris dispar* in which the flagellum had broken off the pars clavata (clavum) of the PSens. The dorsal idiosomal scobalae resemble those of *T. dispar* to some extent. More careful examination showed this mite represents a separate species. One distinct feature which separates it off from all the other North American Hirstiosomatinae is the tendency to expansion of the dorsal palpal scobalae. In this feature the specimen possibly resembles *Smaris* sp. Jacot (1938, p. 125). Jacot referred to but did not figure this feature. He did, however, give a figure of the dorsal idiosomal scobala of his species, and these appear to resemble those of *C. cybaea.* Further comparison is not possible, as Jacot gave no further detail of his specimen, and this has not become available for restudy.

As indicated above, but for the character of the male tarsus IV, this mite would answer to the Australian genus *Sphaerotarsus*; however, see the earlier comment.

(2) Specimen ACA 1712 has the following standard data:

ASens	PSens	SBa	SBp	ISD	DS
26	36	13	14	267	15-20

The following are some further data:

tarsus I	tibia I	genu I	tarsus IV	tibia IV	genu IV
179	254	291	106	328	328

tarsus I / tibia I	tibia I / genu I	tarsus IV / tibia IV	tibia IV / genu IV
·7047	·8729	·3232	1·000

Although the dorsal setae are rather smaller than in the holotype, and in most instances there appears to be a distinct gutter down the neomedian plane of the tectum setae, it appears justifiable to identify this male specimen as *C. cybaea.*

The two PSens differ from each other. One is distinctly clavate, while the other is only a little swollen distally. In neither case is there any evidence of a flagellum, and it may therefore be accepted that there was none. It may therefore be accepted with confidence that this specimen belongs to the genus *Clavismaris.*

The slide label indicates the belief of the collector that the specimen which was collected at New York had originated in France. Since, however, up to the present no European smaridid mite has been described with a clavate PSens, and since it may justifiably be identified as *Clavismaris* which, so far, is known from only North and Central America, the possibility that this mite originated in North America should be examined. Assuming that the ship concerned belonged to the north Atlantic run one possibility is that the mite was taken aboard in North America in vegetables, and that further vegetables were added in France for the return trip. The nymphal and adult stages in the Smarididae are quite long (see Womersley and Southcott, 1941; Southcott, 1960, 1961*a*), and there is the further possibility of a pupal stage having occurred between a

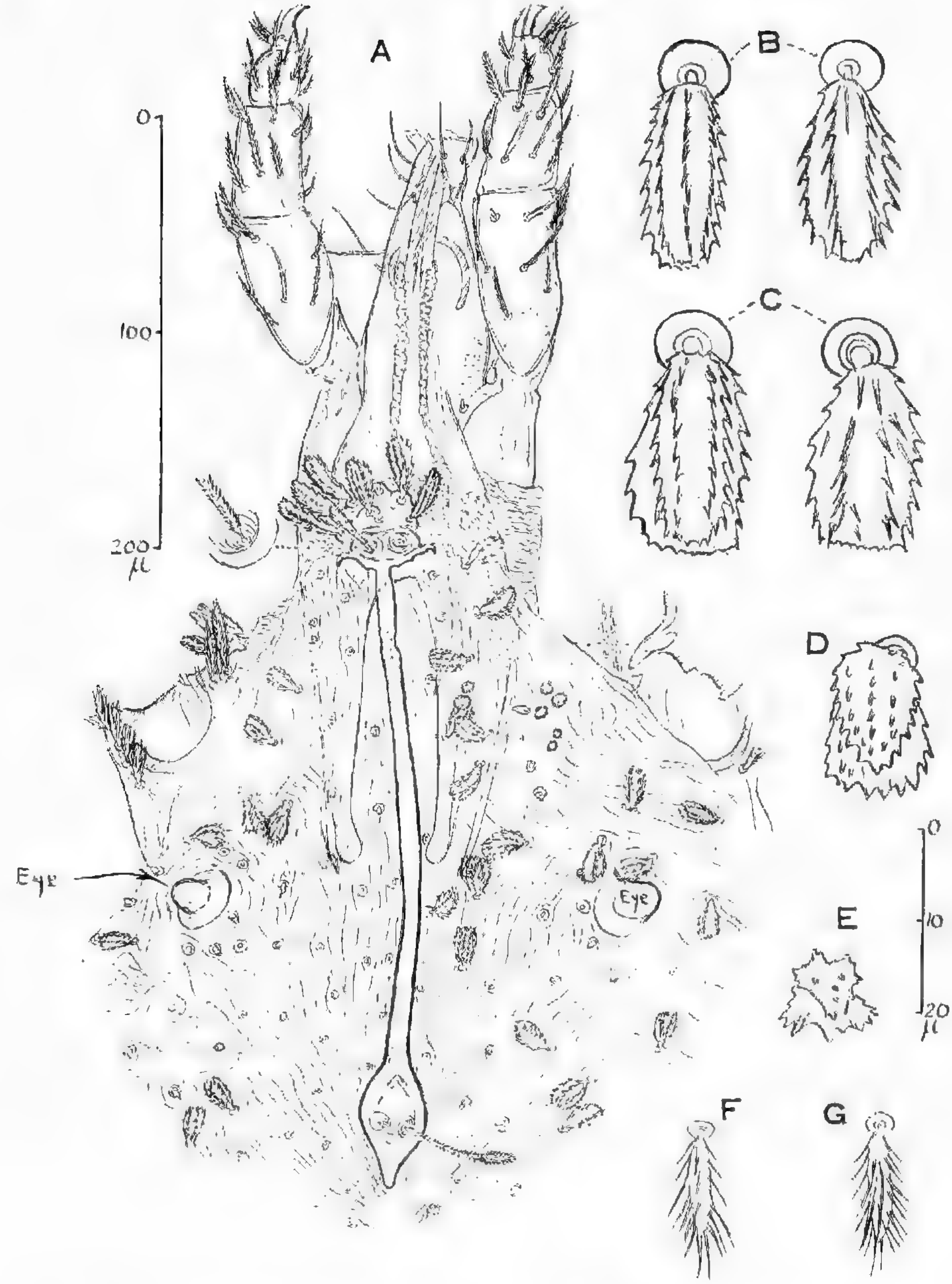

Fig. 42. *Clavismaris cybaea*, sp. nov. Adult male (holotype). A, propodosoma and gnathosoma, to scale on left. Some fungal spores are shown on the right of the anterior half of the crista. Such spores are not uncommonly attached to the surface of erythraeoid mites. B-E, dorsal idiosomal scobalae, various aspects: B, a seta from above and below (left and right side respectively); C, another seta, similarly; D, oblique end view; E, end view. F, G, ventral idiosomal setae. (B-G to scale on right.)

nymphal and adult instar. Even if sterilization of vegetable racks were attempted by, e.g. steam or other means, it would not necessarily be completely successful. The author therefore considers that at present this mite is on the evidence available most likely to have originated in North or Central America.

(3) The adult female specimen ACA 1713 contains in the mounted preparation four eggskins; one of these is not crumpled and measures about 230μ long by 175μ across, with its skin smooth, brown (but burst at one end). The data of the mite are as follow:

ASens	PSens	SBa	SBp	ISD	DS
21	38	13	12	351	15-20

tarsus I	tibia I	genu I	tarsus IV	tibia IV	genu IV
175	228	255	125	257	275

$\frac{\text{tarsus I}}{\text{tibia I}}$	$\frac{\text{tibia I}}{\text{genu I}}$	$\frac{\text{tarsus IV}}{\text{tibia IV}}$	$\frac{\text{tibia IV}}{\text{genu IV}}$
·7675	·8941	·4864	·9345

The PSens are ciliated, very little expanded (tapering distally), and without flagellum.

Although the specimen in general answers to *C. cybaea*, in some characters it is intermediate between that species and *C. conifera*. It will be noted that *C. conifera* is erected on a female specimen, while *C. cybaea* is erected on a male, but on the characters of other smaridid mites it is thought unlikely this difference in the sexes of the two specimens would be of much significance in external morphology. In view of these considerations this specimen is placed somewhat dubiously in *C. cybaea*, and is not designated an allotype. The selection and description of an allotype should be left until further specimens are available, and possibly more is known of the genus. The discovery of the larva of this genus, and its comparison with the larval *Sphaerotarsus*, would be of considerable interest.

IV. DOUBTFUL OR EXCLUDED SPECIES

Smaris longilinealis Ewing, 1909

Smaris longilinealis Ewing, 1909, p. 61.

Smaris longilinealis Jacot, 1938, p. 125 (in part).

Smaris longilinealis Southcott, 1946, p. 178.

Hirstiosoma longilinealis Baker and Wharton, 1952, p. 243.

non *Smaris longilinealis* Ewing, 1910, p. 88.

Remarks. The status of this species was discussed above, under the remarks on the taxonomy and nomenclature in *Trichosmaris*, gen. nov. This species probably belongs to *Trichosmaris*, and is possibly a synonym of *T. dispar*, sp. nov., and *T. jacoti* (Southcott, 1946), but this question must be left for the future, depending firstly on the type of *longilinealis* Ewing, 1909, becoming available for restudy.

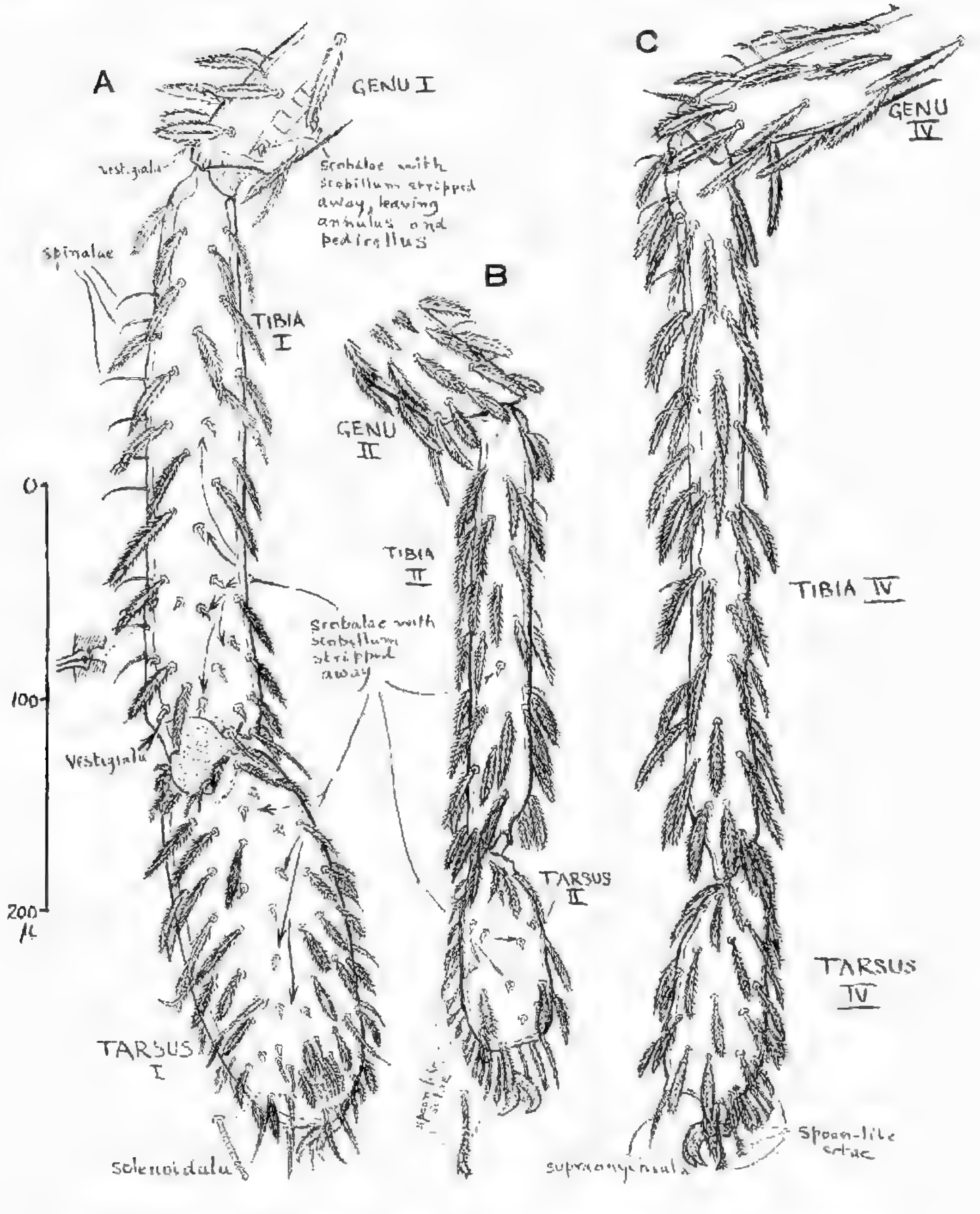

Fig. 13. *Clavismaris cybaea*, sp. nov. Adult male (holotype). A, posterodorsal aspect of left leg I, distally. B, anterior aspect of left leg II, distally. C, anterior aspect of right leg IV, distally. (All to scale shown.) In A, B the short peg-like structures are the pedicles of the scobalae from which the scobillum has in each case been stripped away, from expansion of the polyvinyl alcohol mounting medium on attempted remounting (through water to methyl cellulose medium). Other setae–solenoidalae, spinalae and intermediate type scobalae have not suffered in the process. In C, some spoon-like setae are seen distally on the tarsus.

Smaris longilinealis Ewing, 1910

Smaris longilinealis Ewing, 1910, p. 88.

Smaris longilinealis Jacot, 1938, p. 125 (ex Ewing, 1910, p. 88 (in part)).

non *Smaris longilinealis* Ewing, 1909, p. 61.

Remarks. The status of this species was discussed earlier in this paper, when it was compared with *longilinealis* Ewing, 1909 (q.v., supra, also the remarks on taxonomy and nomenclature in *Trichosmaris*, earlier). This species possibly belongs to *Fessonia*, and it is possible it is a synonym of a species described in this paper, but some features are doubtful. Its generic and specific placing can be determined only by a restudy of the material upon which Ewing's (1910) account was based, if it can be located.

Smaris mamillatus (Say)

Erythraeus mamillatus Say, 1821, p. 70 (teste Jacot, 1938, p. 123; Oudemans, 1937, K.H.O.A. IIIC, p. 952).

Smaris mamillatus Oudemans, 1937, p. 952.

Erythraeus mamillatus Jacot, 1938, p. 125 (allotted doubtfully to *Labidostoma* (sic)) (for *Labidostomma* Kramer, 1879, family Labidostommatidae).

Smaris mamillatus Southcott, 1946, p. 175.

Labidostomma mamillatus Banks, 1947, p. 129.

Labidostomma [*mamillatum*] Southcott, 1961*a*, p. 574.

non *Smaris mamillatus* Baker and Wharton, 1952, Fig. 179, p. 242.

(? = *Smaris lanceolata*, sp. nov., of the present paper.)

Remarks. The position of Say's species was discussed by the author earlier (1961*a*, pp. 573-4), where it was considered that in the interests of stability of nomenclature Banks (1947) should be accepted as the first reviser of Say's species (which should therefore be named *Labidostomma mamillatum*, nom. emend.).

The possible synonymy of the species figured by Baker and Wharton (1952, Fig. 179, p. 242) was discussed earlier; see the remarks under *Smaris lanceolata*, sp. nov.

Smaris sp. (unnamed) Jacot

Smaris sp. Jacot, 1938, p. 125.

Hirstiosoma sp. Womersley and Southcott, 1941, pp. 63, 78.

Remarks. Jacot (1938, p. 125) referred briefly to this form "from under bark at base of hickory trees, Coseob Headland, Conn.", and gave some figures of the dorsal idiosomal scobalae. The specimen or specimens were discussed above, under the remarks for *Clavismaris cybaea*, sp. nov. The species is certainly a member of the Smarididae, but is not placeable further with certainty. Jacot's material will need to be restudied before it can be decided whether this species belongs to *Clavismaris* or some other genus.

A NOTE ON MOUNTING MEDIA SUITABLE FOR SMARIDIDAE

The author has had over 25 years' experience in the use of various mounting media for the miscoscopic examination of smaridid (and other mites). It has been found that in general gum chloral media are the most satisfactory for permanent use. In these further clearing agents such as acetic acid or lactic acid may be incorporated, or the mite may be mounted permanently in the medium after an initial examination in temporary media, such as lactic acid, glycerol-lactic or lactophenol. Some of the older mounts in balsam are still good after over 50 years from the older students of the Acarina, and such mites can if necessary be remounted through xylol back to (xylol)-balsam. The lectotype of *Trichosmaris jacoti* has been thus remounted, and is in good condition. Such balsam mounts have the disadvantage that the body contents are not digested, and thus there is insufficient flattening of the specimen for the use of the oil immersion lens on critical parts of the animal. Against this may be set the minor advantage that the natural shape of the animal is fairly well preserved. Attempts to transfer from balsam to other (water soluble) media are not always successful, and the specimen remains with a precipitate of resin which obscures details.

Polyvinyl acid media give good clearing of mite specimens, and often allow better positioning of the limbs of the animal than e.g. gum chloral media. After the medium is completely set, its refractive index rises and fine details may not be visible. Attempts to remount the specimen at that stage may be disastrous —the medium expands to a jelly, but does not liquify. With the differential expansion the animal's setae are torn off freely in many cases, and the same may occur with the limbs. An appearance of an endocast of the limb segment or seta is often left in the medium. With differential changes in the refractive index of the medium, which may last for months, possibly longer, many details of the animal may be obscured, in addition to the damage. The author attempted to remount a large batch of such slides on one occasion, damaging a number, and regrettably found himself in a position of not being able to give detail of e.g. palp structure, sensillae, etc., which should be given if available. From this experience it has been decided to abandon completely the use of polyvinyl alcohol media in acarology.

VI. ACKNOWLEDGMENTS

The author is indebted to Dr. Edward W. Baker, formerly attached to the United States National Museum, for suggesting this revision, and to him and the Museum for arranging the loan of material; to the Director, South Australian Museum, and Mr. H. Womersley, Honorary Acarologist, for access to the Acarina collection of that institution; to Mr. W. F. Rapp, Jr., Entomologist, Department of Health, State of Nebraska, for material; to the Museum of Comparative Zoology, Harvard, for the loan of a slide of Jacot's material.

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[*] See Southcott, 1961*a*, p. 608, for further remarks on the Berlesian references.

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POST-WINTON SEDIMENTS OF PROBABLE UPPER CRETACEOUS AGE IN THE CENTRAL GREAT ARTESIAN BASIN

BY H. WOPFNER

Summary

In the central part of the Great Australian Artesian Basin, a sequence of torrentially bedded sandstones was observed, resting disconformably on the Cenomanian Winton Formation. The sandstone sequence comprises about 150 feet of white, medium- to coarse-grained, torrentially bedded sandstone with some interbeds of shale and "shale conglomerate". The contact between the sandstone sequence and the underlying Winton Formation is a marked disconformity showing strong post- Winton erosion. It is proposed to term this sandstone formation the Mt. Howie Sandstone. The stratigraphic type-section and the type locality are situated at Mt. Howie in north-easternmost South Australia. It is shown that the Mt. Howie Sandstone is of fluviatile origin. It was deposited in channels, which were scoured from the flat-lying beds of the Winton Formation.

Plant fossils, collected from the type locality, are described. They consist of several specimens of Brachyphyllum sp. and remnants of cycads. The fossil flora has Mesozoic affinities.

The evidence is briefly discussed and an Upper Cretaceous age (Post-Cenomanian) is assigned to the Mt. Howie Sandstone.

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[Read 10 May 1962]

SUMMARY

In the central part of the Great Australian Artesian Basin, a sequence of torrentially bedded sandstones was observed, resting disconformably on the Cenomanian Winton Formation.

The sandstone sequence comprises about 150 feet of white, medium- to coarse-grained, torrentially bedded sandstone with some interbeds of shale and "shale conglomerate". The contact between the sandstone sequence and the underlying Winton Formation is a marked disconformity showing strong post-Winton erosion.

It is proposed to term this sandstone formation the Mt. Howie Sandstone. The stratigraphic type-section and the type locality are situated at Mt. Howie in north-easternmost South Australia.

It is shown that the Mt. Howie Sandstone is of fluviatile origin. It was deposited in channels which were scoured from the flat-lying beds of the Winton Formation.

Plant fossils, collected from the type locality, are described. They consist of several specimens of Brachyphyllum sp. and remnants of cycads. The fossil flora has Mesozoic affinities.

The evidence is briefly discussed and an Upper Cretaceous age (Post-Cenomanian) is assigned to the Mt. Howie Sandstone.

INTRODUCTION

Hitherto it was thought that the Mesozoic sedimentary history of the Great Australian Artesian Basin was concluded by the deposition of the Cenomanian Winton Formation. Thus the sediments of the Winton Formation were regarded as being the youngest Mesozoic strata represented within the Great Artesian Basin. In numerous localities, particularly within South Australia, the Winton Formation is disconformably overlain by coarse, clean, often cross-bedded sandstones and siltstones of Lower Tertiary age. A basal grit or conglomerate, consisting of highly polished pebbles of quartz, agate and chert, is typically associated with these Lower Tertiary sediments. In some places (e.g. Innamincka) pebbles of dark, silicified wood are abundant.

However, there were no records available to testify to events which had taken place over the long period between the close of the Cenomanian and the beginning of the Tertiary, a time span which comprises about two-thirds of the Upper Cretaceous.

In May, 1961, while revisiting the area north of Cordillo Downs (S.A.), the author took the opportunity to check some outcrops of white, torrentially bedded sandstones which previously were regarded to be of Lower Tertiary age (Wopfner, 1960 and 1961). For some time the author doubted whether it was correct to assign these sandstones to the Lower Tertiary, and new evidence now suggests that these sediments are of pre-Tertiary age and therefore older than the Lower Tertiary sandstones and quartz-agate conglomerates (Innamincka, west limb of Haddon Syncline, etc.), with which they were previously correlated.

THE MT. HOWIE SANDSTONE*

Lithology and Distribution

On the north-eastern slope of Mt. Howie (a very prominent hill on the eastern side of Haddon Valley, about 30 miles north-east of Cordillo Downs) a beautiful exposure of torrentially bedded sandstone about 100 to 150 feet thick was found. The sandstone rests disconformably on flat-lying Winton beds (see Fig. 1). The contact between the Winton sediments and the overlying sandstone is extremely irregular and the contact-surface of the Winton exhibits deeply gouged channels and troughs with large hump-shaped erosional remnants

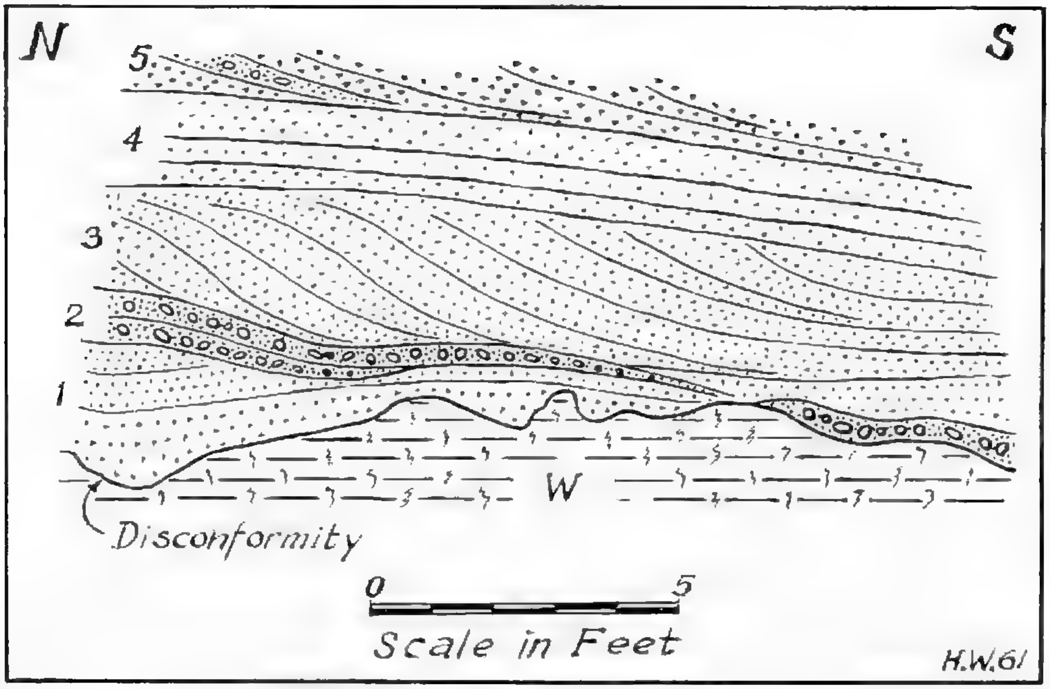

Fig. 1. Sketch showing strong relief of disconformity between Winton Formation (below) and basal portion of Mt. Howie Sandstone (above). W = Winton Formation, shale and siltstone, strongly fractured and limonite stained. (1) to (5) = Mt. Howie Sandstone: (1) Sandstone, white, coarse- to medium-grained, kaolinitic. (2) "Shale conglomerate", shale fragments, ½ to 2 inches diameter, well rounded, with recognisable original bedding, in light grey, sandy, kaolinitic matrix. (3) Sandstone white, medium-grained, current bedded. (4) Sandstone, white, medium-grained, strongly kaolinitic. (5) Sandstone, light grey, coarse-grained, torrentially bedded.

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* New Formation — name.

in between (see Fig. 1 and Plate 1A). The amplitude of the relief of this contact-surface exceeds 20 feet. In one place the contact is vertical to overhanging, suggesting a fossil, undercut, stream embankment (see Plate 1B).

The Winton beds are mainly composed of white and grey shale, siltstone and mudstone with some stringers of fine-grained sandstone. Immediately below the contact (for about 12 to 30 inches) physical disintegration resulted in strong fracturing of the Winton sediments. The fractures, which are generally conchoidal, are commonly filled with limonite. Brown limonite staining is very prominent throughout this zone (see Plate 1B). Both physical disintegration and iron-enrichment are indicative of sub-aerial weathering on an old erosional surface.

The sediments above the disconformity consist of white to light grey, medium- to coarse-grained, quartz sandstones with a kaolinitic matrix. Sorting is poor to fair and grains are subangular to subrounded. Torrential bedding is very prominent, particularly within the lowest member of the sequence. Dips of the foresets vary between 12° and 20°. On a first and by no means conclusive approximation, the direction of current appears to have been south to south-west. Lithology and texture of the sandstone indicate a fluviatile environment.

Approximately 35 feet above the base a shale band 9 feet thick is intercalated. It develops somewhat gradationally from the underlying sandstone, but shows a very sharp upper boundary where it is again succeeded by sandstone.

At or near the disconformity and again above the shale horizon layers and/or lenses of a "shale conglomerate" occur. The "shale conglomerate" consists of rounded to subrounded shale fragments, embedded in a medium-grained, sandy and richly kaolinitic matrix. The average diameter of the shale pebbles ranges from ½ inch to 1 inch, the maximum diameter being about 2½ inches. In numerous cases the original bedding is recognisable within the shale pebbles, now resting at incidental angles to the bedding of the surrounding sediment (see Fig. 1).

The uppermost 30 feet of the section are strongly altered by the formation of siliceous duricrust. The lower portion of this altered sequence is strongly fractured, rubbly and iron stained. It is partly indurated by nodular or irregular bodies of cryptocrystalline silica. The amount of "invaded" secondary silica increases towards the top which consists of a thick cap of grey, very hard, dense and columnar silcrete ("grey billy").

The above description of the sandstone sequence clearly indicates that there is a marked stratigraphic break at its base (disconformity) and that the sandstone sequence was deposited in an environment entirely different from that prevailing during the sedimentation of the Winton Formation.

Therefore the sandstone sequence has to be regarded as a stratigraphic unit in its own right and the author proposes to term it *Mt. Howie Sandstone*.

The type locality for this new formation is Mt. Howie (26°23′50″ S. latitude; 140°54′15″ E. longitude). The outcrops at the deep erosional cut on the north-eastern slope of Mt. Howie are chosen as type section. Stratigraphic succession and lithology of the type section are given in the stratigraphic column. Due to the strong relief of the base of the Mt. Howie Sandstone, the thickness of the lowest member varies up to ± 10 feet and the figure given in the stratigraphic column is an average value.

Stratigraphic Column—Mt. Howie Type Section

Thickness of Stratum	Lithology
5 ft.	duricrust, grey, very hard, dense columnar, siliceous ("grey billy"—silcrete)
25 ft.	duricrust, red, rubbly, sandy and pisolitic, siliceous.
15 ft.	sandstone, white, medium-grained, partly indurated by silica, showing honeycomb weathering.
35 ft.	sandstone, white, medium-grained, medium hard, sub-angular to sub-rounded, kaolinitic, torrential bedded with stringers of coarse sand.
9 ft.	"shale conglomerate", white to pinkish grey. Rounded to sub-rounded shale pebbles (½ in.-2 in.) in fine-grained, sub-angular, strongly kaolinitic sandstone.
18 ft.	sandstone, white, medium- to coarse-grained, porous, slightly kaolinitic, medium hard. Some shale pebbles.
9 ft.	shale, white to creamy grey, silty, kaolinitic, medium hard, massive to poorly bedded, with plant remains and vertical tubes.
35 ft.	sandstone, light grey, medium to coarse-grained, sub-angular, slightly kaolinitic, porous, torrential bedded with lenses of "shale conglomerate" near base.
	Disconformity.
50 ft. +	Winton beds. Shale and siltstone with stringers of sand, flat-lying.

The distribution of the Mt. Howie Sandstone is rather irregular, which, however, might be expected of a sediment of fluviatile origin. Outcrops of Mt. Howie Sandstone occur intermittently from Mt. Howie to the east and south-east, mainly north of the watershed and within the upper drainage area of the Nilpie Creek. The outcrops exhibit all the typical lithological and textural features as described from the type section. Layers and lenses of "shale conglomerate" can be observed commonly, but good exposures of the interface with the underlying Winton Formation are rare. A further characteristic of these outcrops is the development of extensive cave-galleries at the base of the duricrust.

Small remnants of Mt. Howie Sandstone were found also at the headwaters of Jiblie Creek, near the South Australian-Queensland border. There torrentially-bedded sandstones with lenses of "shale conglomerate" form the tops of two isolated hills which situate in the eroded centre of the Nappamilkie Anticline (Wopfner, 1960). The top parts of the sandstone are affected by secondary silicification, demonstrating that both occurrences were capped by duricrust prior to its removal by erosion. However, of particular interest is the disposition of the interface between the Mt. Howie Sandstone and the Winton Formation. The contact between the two formations is again disconformable whereby the respective planes of disconformity dip towards each other. Thus the plane of disconformity on the western outcrop dips 5° ENE., whilst the interface at the eastern exposure dips 10° to 15° NW. Viewed from a distance, this gives the firm impression of a large channel scoured from the flat-lying sediments of the Winton Formation (see Fig. 2). The above observation is further evidence that the Mt. Howie Sandstone is a fluviatile sediment which was deposited in channels cut into the shales and siltstones of the Winton Formation.

The detrital material of the Mt. Howie Sandstone was partly supplied by contemporaneous erosion of the Winton sediments. Large amounts of eroded Winton shale and siltstone were reworked to form the components of the "shale

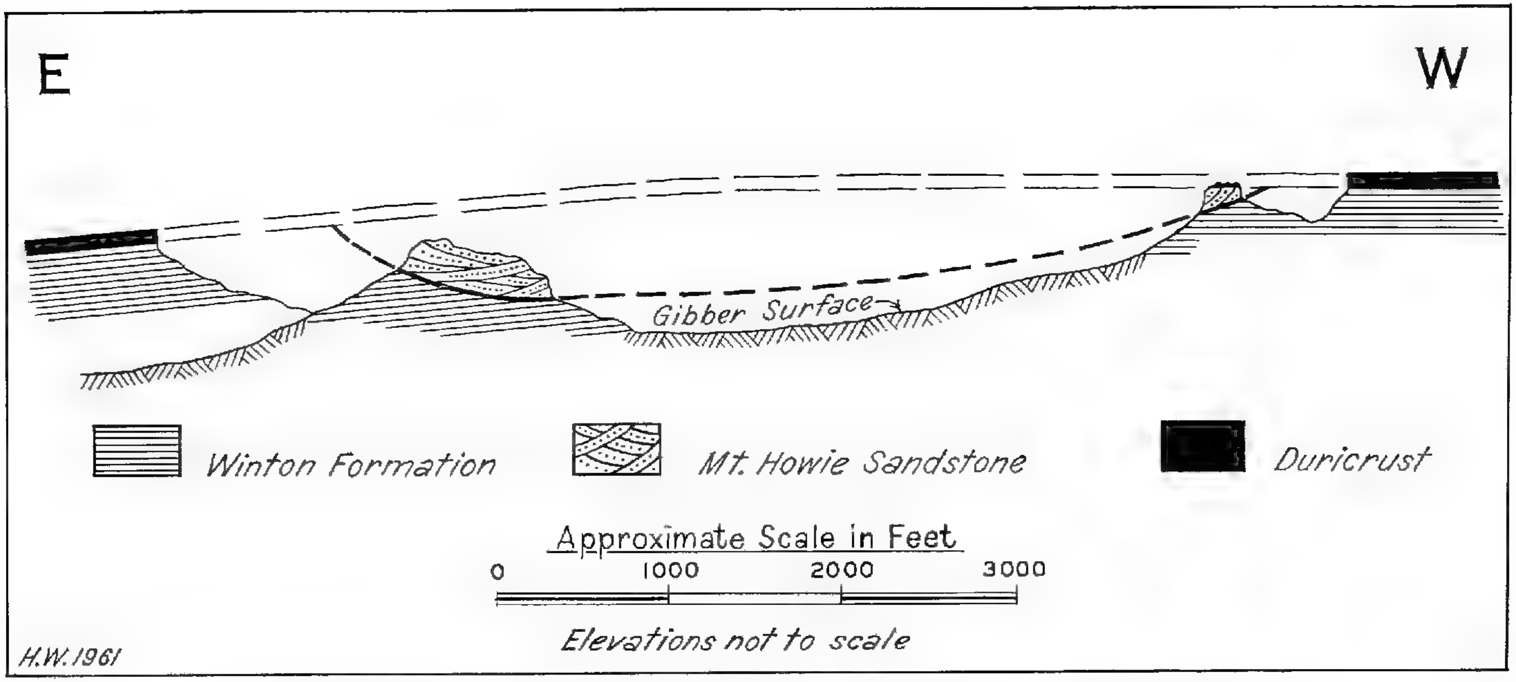

Fig. 2. Sketch showing two remnants of Mt. Howie Sandstone at the headwaters of Jiblie Creek. The Winton sediments dip about 3° E. and 1° W. respectively. The contact at the eastern remnant shows a dip of 10° to 15° NW., whilst the interface at the western hill dips 5° ENE. The probable outline of the fossil stream-channel is marked with heavy, dashed line. The formation and warping of the duricrust postdated the deposition of the Mt. Howie Sandstone.

conglomerate" whilst the clay material and the fine-grained sand-fraction was, at least partially, incorporated in the matrix. For the coarser sand-fraction a more distant source has to be assumed which as yet is unknown. It could have been situated outside the Great Artesian Basin.

Sediments which are very similar in lithology to the Mt. Howie Sandstone were observed on the eastern limb of the Curalle Anticline and within the north-eastern portion of the Morney Dome. Both localities are in south-western Queensland and lie about 55 miles and 95 miles respectively to the north-east of the Mt. Howie type-locality. Further investigation is required before a firm correlation can be made.

A further occurrence of similar sediments was noted on the northern cuesta of Innamincka Dome, about half mile east of the South Australian-Queensland border. The sediment is a white, medium-grained, kaolinitic and strongly current-bedded sandstone, resting disconformably on Winton sediments. The sandstone which is about 60 feet thick, is disconformably overlain by typical Lower Tertiary quartz-agate conglomerate, indicating a pre-Tertiary age of this sandstone. However, additional fossil evidence is needed to reach an indubitable correlation.

Fossil Content and Age

At Mt. Howie type-section, the author and Dr. B. C. Forbes collected several specimens of plant fossils, which occur within the shale band, about 35 feet above the disconformity (see Plate 1A and stratigraphic column, page ?). The fossils consist entirely of casts and moulds, the carbonaceous material which must have been present originally having been completely removed by the intense leaching which took place during the formation of the siliceous duricrust. However, most of the fossil plants are reasonably well preserved and show a surprising amount of detail. The following specimens were identified:

(1) Brachyphyllum sp.

Branchlets, slender, 28 mm. to 34 mm. long, 4 mm. wide, leaves fleshy, spirally arranged, rhomboid lanceolate, keeled, about 3 to 5 mm. long, 1·5 to 2 mm. wide (5 specimens.)

(2) Brachyphyllum sp.

Amentum, ovoid, 8 mm. in diameter at base. Base concave with central stem. Scales rhomboid, longitudinally grooved, spirally disposed, 0·4 mm. long and 0·2 mm. wide, less acute at base. (1 specimen, cast and mould.)

(3) Cycadean Trunk

Impression, parallel striated in 4 mm. intervals. Elliptic nodules, 1·5 to 2 mm. long, 0·9 mm. wide in grooves between and longest diameter parallel with striations. Nodules occur in 12 mm. to 15 mm. intervals along direction of striation and 4 mm. laterally. Total width of specimen 30 mm. (1 specimen.)

(4) (?) Cyad-leaf, median rib.

Cast, two straight singular ridges, 1·5 mm. wide, 23·0 mm. long and 0·6 mm. high and 4 mm. intervals, some auxilliary striations parallel with main ridges. Elongated nodules on crest of ridges in regular intervals of 8 mm. Nodules are 2·0 mm. wide and 0·4 mm. high on top, tapering downwards and developing median groove, before fusing with main ridge, leaflet-scars (?). (2 specimens.)

A Exposure of Mt. Howie Sandstone at the Mt. Howie type-locality (approximately lower half of type-section). The contact between the Winton sediments and the Mt. Howie Sandstone is outlined in lower part of picture. Dr. Forbes standing at base of plant-bearing shale horizon. Torrential bedding is exhibited above (author's photograph).

B Steep, partly overhanging contact between flat-lying Winton shale (right) and torrentially bedded Mt. Howie Sandstone (left and top) at Mt. Howie type-locality. The steep contact-surface is visible below the hammer. The dark portions within the Winton shale are limonite stains (author's photograph).

The author is aware that the definition of the genus Brachyphyllum is rather unsatisfactory (Seward, 1895, p. 214). However, Brachyphyllum is essentially a Mesozoic genus and its occurrence is almost entirely restricted to that era. Furthermore, the flora from Mt. Howie with its complete absence of angiospermae, shows Mesozoic affinities and a strong relationship to the known flora of the Winton Formation (Rowe, 1957; Whitehouse, 1954).

The flora which is characteristic of the Lower Tertiary sediments is mainly composed of angiospermae and is completely different from the one described above.

Furthermore, the lithology of the Mt. Howie Sandstone differs considerably from the lithology of the Lower Tertiary sediments. The Lower Tertiary sandstone is generally clean and well-sorted. The basal conglomerate, composed of highly polished quartz pebbles with large amounts of agate and silicified wood was found to be typically associated with the Lower Tertiary sediments over a very wide area (Tibooburra, Innamincka, Cordillo, Marree). The Mt. Howie Sandstone, in comparison, is ill-sorted and contains a large amount of kaolin and other fine fractions. A basal conglomerate is conspicuously absent and the only psephytic fractions are the reworked shale fragments of the "shale conglomerate".

Concluding, the following points can be stated:

(1) The Mt. Howie Sandstone is younger than the Winton Formation.

(2) The deposition of Mt. Howie Sandstone predates the formation of the duricrust (?Miocene).

(3) There are considerable lithological differences between the Lower Tertiary sediments and the Mt. Howie Sandstone wherefore their equivalence is unlikely.

(4) The Lower Tertiary sediments are the youngest pre-duricrust sediments known.

(5) The flora of the Mt. Howie Sandstone shows Mesozoic affinities.

The evidence outlined above indicates a Mesozoic age and the author suggests the Mt. Howie Sandstone be placed in the Upper Cretaceous, i.e. Turonian or younger.

Thus the Mt. Howie Sandstone documents the youngest Mesozoic sedimentary event recorded so far from the Great Artesian Basin.

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LIST OF LECTURES GIVEN AT MEETINGS DURING THE YEAR 1961-62

Summary

LIST OF LECTURES GIVEN AT MEETINGS DURING THE YEAR 1961-62

July, 1961. Dr. R. V. Southcott: "The Cubomedusae".

Aug., 1961. Mr. R. Cartwright: "Rocket Research in the Upper Atmosphere".

Sept., 1961. Prof. A. R. Alderman: "Trends in Geological Science".

Oct., 1961. Mr. R. V. Woods: "Geology and Forestry: Some Aspects of Their Inter-relations in the Adelaide Hills".

Apr., 1962. Mr. L. W. Parkin: "Minerals for Industry—Current Exploration and Development".

May, 1962. Mr. K. R. Slater: "Reptile Evidence of Zoogeographical Trends in New Guinea".

June, 1962. Dr. H. G. Andrewartha: "How Animals Live in Deserts".

Exhibits

During the year the following members exhibited material at Ordinary Meetings:

Mr. M. J. Tyler—photographs and coloured slides of a leech which is parasitic on the Microhylid frogs.

Mr. F. J. Mitchell—coloured slides of a small python and gecko lizard living symbiotically in termite mounds in the Hammersley Ranges, N.W. Australia.

Mr. T. D. Scott—coloured slides of the University of California's freshwater research station at Sagehen Creek, California, U.S.A.

BALANCE SHEET

Summary

ROYAL SOCIETY OF SOUTH AUSTRALIA (INCORPORATED)

REVENUE ACCOUNT

Receipts and Payments for Year ended 30th June, 1962.

				£	s.	d.
To Balance, 1/7/61				599	13	11
„ Subscriptions				403	16	10
„ Government Grant				1,750	0	0
„ Sale of Publications, etc.				543	6	0
„ Rent of Rooms				35	12	6
„ Interest—						
Endowment Fund	£447	2	9			
Savings Bank	36	7	10			
				483	10	7
				£3,815	19	10

				£	s.
By Printing and Publishing Volume 85, Reprints, etc.				1,931	5
„ Binding				842	19
„ Library Assistants				111	1
„ Clerical Assistance				175	17
„ Printing and Stationery				95	12
„ Postages and Duty Stamps				156	1
„ Cleaning and Polishing				78	0
„ Telephone				33	2
„ Insurance				72	16
„ Packing and Freight				15	0
„ Publications, etc.				7	12
„ Lighting				6	10
„ Balance—					
Bank of Adelaide	£291	9	0		
Less outstanding cheque	1	9	6		
				289	19
				£3,815	19

Audited and found correct.

F. M. ANGEL,
N. S. ANGEL, A.U.A. (Com.) } Hon. Auditors
Adelaide, 6th July, 1962.

F. J. MITCHELL,
Hon. Treasure

ENDOWMENT FUND

				£	s.	d.
To Balance				9,670	0	0
„ Investment Interest—						
Com'wealth Inscribed Stock	428	13	9			
S.A. Inscribed Stock	4	10	0			
S.A. Gas Co. Bonds	13	19	0			
				447	2	9
				£10,117	2	9

				£	s.
By Revenue Transfer				447	2
„ Balance—					
Com'wealth Inscribed Stock	£9,220	0	0		
S.A. Inscribed Stock	150	0	0		
S.A. Gas Co. Bonds	300	0	0		
				9,670	0
				£10,117	2

Audited and found correct. The Commonwealth Stock has been verified by certificate and the S Stock and the Gas Co. Bonds have been inspected in the hands of the Treasurer.

F. M. ANGEL,
N. S. ANGEL, A.U.A. (Com.) } Hon. Auditors
Adelaide, 6th July, 1962.

F. J. MITCHELL,
Hon. Treasurer

AWARDS OF THE SIR JOSEPH VERCO MEDAL AND LIST OF FELLOWS, 1962

Summary

AWARDS OF THE SIR JOSEPH VERCO MEDAL

1929 Prof. Walter Howchin, F.G.S.
1930 John McC. Black, A.L.S.
1931 Prof. Sir Douglas Mawson, O.B.E., D.Sc., B.E., F.R.S.
1933 Prof. J. Burton Cleland, M.D.
1935 Prof. T. Harvey Johnston, M.A., D.Sc.
1938 Prof. J. A. Prescott, D.Sc., F.A.C.I.
1943 Herbert Womersley, A.L.S., F.R.E.S.
1944 Prof. J. G. Wood, D.Sc., Ph.D.
1945 Cecil T. Madigan, M.A., B.E., D.Sc., F.G.S.
1946 Herbert M. Hale, O.B.E.
1955 L. Keith Ward, I.S.O., B.A., B.E., D.Sc.
1956 N. B. Tindale, B.Sc.
1957 C. S. Piper, D.Sc.
1959 C. G. Stephens, D.Sc.
1960 H. H. Finlayson.
1961 R. L. Specht, Ph.D.
1962 H. G. Andrewartha, M.Ag.Sc., D.Sc., F.A.A.

LIST OF FELLOWS

AS AT 30th SEPTEMBER, 1962.

Those marked with an asterisk (*) have contributed papers published in the Society's Transactions. Those marked with a dagger (†) are Life Members.

Any change in address or any other changes should be notified to the Secretary.

Note.—The publications of the Society are not sent to those members whose subscriptions are in arrears.

Date of Election | Date of Honorary Election

HONORARY FELLOWS

1895 1949 *Cleland, Prof. J. B., M.D., Dashwood Road, Beaumont, S.A.—*Verco Medal*, 1933; *Council*, 1921-26, 1932-37; *President*, 1927-28, 1940-41; *Vice-President*, 1926-27, 1941-42.

1913 1955 *Osborn, Prof. T. G. B., D.Sc., 103 Ward Street, North Adelaide—*Council*, 1915-20, 1922-24; *Vice-President*, 1924-25, 1926-27; *President*, 1925-26.

1912 1955 *Ward, L. K., I.S.O., B.A., B.E., D.Sc., 22 Northumberland Street, Heathpool, Marryatville, S.A.—*Council*, 1924-27, 1933-35; *Vice-President*, 1927-28; *President*, 1928-30; *Verco Medal*, 1955.

1922 1962 *Hale, H. M., O.B.E., 12 Bellevue Place, Unley Park, S.A.—*Verco Medal*, 1946; *Council*, 1931-34, 1950-53, 1956-62; *Vice-President*, 1934-36, 1937-38; *President*, 1936-37; *Treasurer*, 1938-50, 1953-56; *Council*, 1957-62.

1933 1962 *Womersley, H., F.R.E.S., A.L.S. (Hon. causa), 43 Carlisle Road, Westbourne Park, S.A.—*Verco Medal*, 1943; *Secretary*, 1936-37; *Editor*, 1937-43, 1945-47; *President*, 1943-44; *Vice-President*, 1944-45; *Treasurer*, 1950-51, 1956-59.

Date of Election

FELLOWS

1946. *Abbie, Prof. A. A., M.D., D.Sc., Ph.D., Department of Anatomy, University of Adelaide, North Terrace, Adelaide, S.A.

1961. Abele, C., B.Sc., 42 Kildonan Road, Warradale Park, S.A.

1959. Aitken, P., B.Sc., South Australian Museum, North Terrace, Adelaide, S.A.

1927. *Alderman, Prof. A. R., Ph.D., D.Sc., F.G.S., Department of Geology, University of Adelaide, North Terrace, Adelaide, S.A.—*Council*, 1937-42, 1954-57; *Vice-President*, 1962-63.

1961. Anders, D. J., B.Sc., Dip.Ed., B.Ed., M.A.C.E., c/o. Adelaide Teachers' College, Kintore Avenue, Adelaide, S.A.

1951. *Anderson, Mrs. S. H., B.Sc., 31 Lakeman Street, North Adelaide, S.A.

1935. *Andrewartha, H. G., M.Ag.Sc., D.Sc., F.A.A., Zoology Dept., University of Adelaide, North Terrace, Adelaide, S.A.—*Council*, 1949-50; *Vice-President*, 1950-51, 1952-53; *President*, 1951-52; *Verco Medal*, 1962.

Date of Election

1935. *Andrewartha, Mrs. H. G., B.Agr.Sc., M.Sc. (nee H. V. Steele), 29 Claremont Avenue, Netherby, S.A.
1929. *Angel, F. M., 34 Fullarton Road, Parkside, S.A.
1939. *Angel, Miss L. M., M.Sc., 2 Moore Street, Toorak, Adelaide, S.A.
1960. Archbold, R. T., South Australian Museum, North Terrace, Adelaide, S.A
1962. Aguaart, Mrs. R. I., c/o. South Australian Museum, North Terrace, Adelaide, S.A.
1962. Bagot, P. H., 62 Hawkers Road, Medindie, S.A.
1945. *Bartlett, H. K., L.Th., 2 Abbotshall Road, Lower Mitcham, S.A.
1958. Bauer, F. H., Department of Geography, University of California, Riverside, California, U.S.A.
1950. Beck, R. G., B.Ag.Sc., R.D.A., Lynewood Park, Mil-Lel, via Mount Gambier, S.A.
1932. Begg, P. R., D.D.Sc., L.D.S., Shell House, 170 North Terrace, Adelaide, S.A.
1928. Best, R. J., D.Sc., F.A.C.I., Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1956. Black, A. B., A.S.A.S.M., M.I.M.M., 36 Woodcroft Avenue, St. Georges, S.A.
1934. Black, E. C., M.B., B.S., Magill Road, Tranmere, S.A.
1962. Blesing, Mrs. N. M., c/o. South Australian Museum, North Terrace, Adelaide, S.A.
1950. Bonnin, N. J., M.B., B.S., F.R.C.S. (Eng.), F.R.A.C.S., 19 Marlborough St., College Park, S.A.
1945. †*Bonython, C. W., B.Sc., A.A.C.I., Romalo House, Romalo Avenue, Magill, S.A.; *Council*, 1961-.
1945. *Boomsma, C. D., M.Sc., B.Sc.For., 6 Celtic Avenue, South Road Park, S.A.
1947. *Bowes, D. R., Ph.D. (Lond.), D.I.C., F.G.S., Department of Geology, University, Glasgow, Scotland.
1957. *Brookes, Miss H. M., Dept. of Entomology, Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1962. Brown, R. G., B.Sc., 3 Jenkins Avenue, Myrtle Bank, S.A.
1961. *Brownell, P. F., Ph.D., c/o. Department of Botany, University of Adelaide, Adelaide, S.A.
1957. Buick, W. G., B.A., c/o Public Library, North Terrace, Adelaide, S.A.
1944. *Burbidge, Miss N. T., M.Sc., C.S.I.R.O., Div. Plant Industry, P.O. Box 109, Canberra, A.C.T.
1958. Buring, I., 51 Richmond Road, Westbourne Park, S.A.
1922. *Campbell, Prof. T. D., D.D.Sc., D.Sc., 24 Lynington Street, Tusmore, S.A.—*Council*, 1928-32, 1935, 1942-45; *Vice-President*, 1932-34; *President*, 1934-35.
1960. Candler, C., 2 Harris St., Glenelg, S.A.
1959. Carrodus, B. B., R.D.Oen., 26 Dequetteville Terrace, Kent Town, S.A.
1953. Carter, A. N., B.Sc., 8 Scott St., Maroubra Bay, N.S.W.
1960. Catley, D. E., 8 Cudmore Terrace, Whyalla, S.A.
1957. *Chippendale, G. M., B.Sc., Lindsay Avenue, Alice Springs, N.T.
1955. Clothier, E. A., Hydroelectric Commission, Hobart, Tas.
1949. Colliver, F. S., Geology Department, University of Queensland, St. Lucia, Brisbane, Q.
1962. Corbett, D. W. P., Ph.D., F.G.S., c/o South Australian Museum, North Terrace, Adelaide, S.A.
1929. *Cotton, B. C., F.R.Z.S., J.P., South Australian Museum, North Terrace, Adelaide, S.A.—*Council*, 1943-46, 1948-49; *Vice-President*, 1949-50, 1951-52; *President*, 1950-51; *Programme Secretary*, 1959-62.
1956. Crawford, A. R., B.Sc., Mines Department, 169 Rundle St., Adelaide, S.A.
1956. Daily, B., Ph.D., Department of Geology, University of Adelaide, North Terrace, Adelaide, S.A.—*Programme Secretary*, 1957-59; *Council*, 1960-.
1962. Dalgarno, C. R., M.Sc., 2 Warrego Crescent, Linden Park, Adelaide, S.A.
1951. Davidson, A. L. C., Ph.D., B.Sc., c/o Messrs. Simpson & Brookman, 35 Grenfell St., Adelaide, S.A.
1950. Deland, C. M., M.B., B.S., D.P.H., D.T.M., 29 Gilbert Street, Goodwood, S.A.—*Council*, 1952-60.
1930. Dix, E. V., Box 12, Aldgate, S.A.
1957. Doull, K. M., M.Ag.Sc., Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1959. Dunlop, P. R. G., B.Sc., 13 Walton Ave., Clearview, S.A.
1944. Dunstone, S. M. L., M.B., B.S., 170 Payneham Road, St. Peters, S.A.
1931. Dwyer, J. M., M.B., B.S., 157 East Terrace, Adelaide, S.A.
1933. *Eardley, Miss C. M., M.Sc., F.L.S., Department of Botany, University of Adelaide, North Terrace, Adelaide, S.A.—*Council*, 1943-46.
1945. *Edmonds, S. J., B.A., Ph.D., Zoology Department, University of Adelaide, North Terrace, Adelaide, S.A.—*Council*, 1954-55; *Programme Secretary*, 1955-56; *Secretary*, 1956-57.

Date of Election	
1902.	*Edquist, A. G., 19 Farrell Street, Glenelg, S.A.—Council, 1949-53.
1962.	*Edwards, R., Marion Road, Marion, S.A.
1956.	*Eichler, H., Dr.rer.nat., State Herbarium, Botanic Garden, North Terrace, Adelaide, S.A.
1959.	Fielder, D. R., B.Sc., Dept. of Zoology, University of Adelaide, North Terrace, Adelaide, S.A.
1927.	*Finlayson, H. H., 305 Ward St., North Adelaide, S.A.—*Verco Medal*, 1960; *Council*, 1937-40.
1951.	Fisher, R. H., 21 Seaview Road, Lynton, S.A.
1960.	Fander, H. W., 15 Auburn Ave., Myrtle Bank, S.A.
1958	*Forbes, B. G., Ph.D., F.G.S., 9 Flinders Road, Hillcrest, S.A.
1958.	Ford, A. W., F.I.C.S., A.C.C.S., 380 South Terrace, Bankstown, N.S.W.
1959.	Forde, N., Dip.For., C.S.I.R.O., Canberra, A.C.T.
1962.	Foster, R. J., B.E., c/o P.E.D., B.S.P., Seria, State of Brunei, Borneo.
1962.	Freytag, I. B., B.Sc., 2 Selway Street, Oaklands Park, S.A.
1954.	Gibson, A. A., A.W.A.S.M., Mines Department, 169 Rundle St., Adelaide, S.A.
1953.	*Glaessner, M. F., D.Sc., F.A.A., Geology Department, University of Adelaide, North Terrace, Adelaide, S.A.—*Council*, 1953-54; *Vice-President*, 1958-59.
1935.	†Goldsack, H., Coromandel Valley, S.A.
1961.	Green, W. J., B.Sc., Delhi Australian Petroleum Ltd., 32 Grenfell St., Adelaide, S.A.
1959.	Green, Miss L. M. A., B.A., M.Sc., Dept. of Anatomy and Histology, University of Adelaide, North Terrace, Adelaide, S.A.
1948.	Gross, G. F., M.Sc., South Australian Museum, Adelaide, S.A.—*Secretary*, 1950-53.
1944.	Guppy, D. J., B.Sc., c/o W.A. Petroleum Co., 251 Adelaide Terrace, Perth, W.A.
1949.	Hall, D. R., Tea Tree Gully, S.A.
1930.	†Hancock, N. L., 3 Bewdley, 66 Beresford Road, Rose Bay, N.S.W.
1962.	Harding, J. H., B.Sc. (W.A.), 92 East Avenue, Clarence Park, S.A.
1946.	*Hardy, Mrs. J. E. (nee A. C. Beckwith), M.Sc., Stewart Ave., Salisbury, S.A.
1914.	Harris, J. R., B.Sc., c/o Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1960.	Harrison, J., 7 McQuillan Ave., Renown Park, S.A.
1958.	Hayball, J. F., B.Sc., 68 Pleasant Avenue, Glandore, S.A.
1960.	Hayman, D. L., Ph.D., Genetics Department, University of Adelaide, North Terrace, Adelaide, S.A.
1944.	Herriot, R. I., B.Agr.Sc., 49 Halsbury Avenue, Kingswood, S.A.
1951.	Hocking, L. J., 46 Kauri Parade, Seacliff, S.A.
1959.	Horwitz, R. G. H., D.Sc., Glenside Road, Woodbury Hill, Stirling West, S.A.
1924.	*Hossfeld, P. S., Ph.D., 132 Fisher Street, Fullarton, S.A.
1944.	Humble, D. S. W., M.P.S., J.P., 238 Payneham Road, Payneham, S.A.
1947.	*Hutton, J. T., B.Sc., A.S.A.S.M., 10 Bellevue Place, Unley Park, S.A. — *Council*, 1957-61; *Vice-President*, 1961-62; *President*, 1962-63.
1928.	Ifould, P., 14 Wyatt Road, Burnside, S.A.
1960.	Ingham, L. J., 34 Lexington Road, Henley South, S.A.
1945.	*Jessup, R. W., M.Sc., 6 North Penno Parade, Belair, S.A.—*Council*, 1961-.
1950.	*Johns, R. K., B.Sc., Department of Mines, 169 Rundle St., Adelaide, S.A.
1957.	Johnson, B., B.Sc.Agr., Ph.D., Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1958.	*Johnson, W., B.Sc. (Hons.), 33 Ryan Avenue, Woodville West, S.A.
1954.	Keats, A. J., B.E., 44 LeFevre Terrace, North Adelaide, S.A.
1962.	Kenny, Mrs. M., c/o South Australian Museum, Adelaide, S.A.
1939.	†Khakhar, H. M., Ph.D., M.B., F.R.G.S., Khakhar Buildings, C.P. Tank Road, Bombay, India.
1962.	King, Miss M. J. E., Mus.Bac., A.U.A., "Mirrabooka", Wilpena St., Eden Hills, S.A.
1949.	*King, D., M.Sc., c/o Utah Development Co., Room 37A, T. & G. Bldg., Brisbane, Q.
1933.	*Kleeman, A. W., Ph.D., Dept. of Geology, University of Adelaide, North Terrace, Adelaide, S.A. *Secretary*, 1945-48; *Vice-President*, 1948-49, 1950-51; *President*, 1949-50.
1960.	Kuchel, R. H., Roseworthy Agricultural College, Roseworthy, S.A.
1941.	*Langford-Smith, T., B.A., M.Sc., Ph.D., Dept. of Geography, University of Sydney, Sydney, N.S.W.
1962.	Laws, D. F., M.A., B.D., Ph.D., Zoology Dept., University of Adelaide, Adelaide, S.A.
1922.	Lendon, G. A., M.D., B.S., F.R.C.P., c/o. Elder's Trustee and Executor Co. Ltd., 37 Currie Street, Adelaide, S.A.
1958.	Lindsay, H. A., 110 Cross Road, Highgate, S.A.

Date of Election

1948. Lothian, T. R. N., N.D.H. (N.Z.), Director, Botanic Garden, Adelaide, S.A.—*Treasurer*, 1952-53; *Council*, 1953-57; *Vice-President*, 1957-58, 1960-61; *President*, 1958-60.
1931. *Ludbrook, Mrs. N. H., M.A., Ph.D., D.I.C., F.G.S., Department of Mines, 169 Rundle St., Adelaide, S.A.—*Council*, 1958-60; *Vice-President*, 1960-61; *President*, 1961-62; *Vice-President*, 1962-63.
1953. Maelzer, D. A., B.Sc. (Hons.), Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1939. Marshall, T. J., M.Agr.Sc., Ph.D., C.S.I.R.O., Division of Soils (Private Mail Bag, No. 1), Adelaide, S.A.—*Council*, 1948-52.
1959. *Martin, Miss H. A., c/o Department of Botany and Biology, University of British Colombia, Vancouver 8, Canada.
1950. Mayo, G. M. E., B.Ag.Sc., Ph.D., 29 Angas Rd., Lower Mitcham, S.A.
1920. Mayo, Sir Herbert, LL.B., Q.C., 90 Northgate St., Unley Park, S.A.
1948. McCulloch, R. N., M.B.E., B.Sc., B.Agr.Sc., Roseworthy Agricultural College, Roseworthy, S.A.
1945. †*Miles, K. R., D.Sc., F.G.S., 11 Church Road, Mitcham, S.A.
1962. Mills, K. J., B.Sc., 17 Denis Street, St. Marys, S.A.
1952. Milne, K. L., F.C.A., 14 Burlington Street, Walkerville, S.A.
1939. Mincham, V. H., 30 Wainhouse Street, Torrensville, S.A.
1958. *Mirams, R. G., B.Sc., 5 Myrtle Rd., Seacliff, S.A.
1951. *Mitchell, F. J., South Australian Museum, North Terrace, Adelaide, S.A.—*Treasurer*, 1959-.
1959. Mitchell, Mrs. F. J., M.Sc., Francis Street, Belair, S.A.
1933. Mitchell, Prof. Sir M. L., M.Sc., c/o Elder's Trustee and Executor Co. Ltd., 37 Currie Street, Adelaide.
1936. *Mountford, C. P., 25 First Avenue, St. Peters, Adelaide, S.A.
1957. *Mumme, Ivan A., B.Sc. (Hons.), c/o Australian Atomic Energy Commission, P.O., Coogee, N.S.W.
1962. Newsome, A., B.Sc., Animal Industry Branch, N.T. Administration, Box 280, Alice Springs, N.T.
1944. Ninnes, A. R., B.A., R.D.A., 62 Sheffield Street, Malvern, S.A.
1962. Nixon, L. G. B., B.Sc., 3 Sweetwater St., Seacombe Gardens, S.A.
1945. *Northcote, K. H., B.Agr.Sc., A.I.A.S., C.S.I.R.O., Division of Soils (Private Mail Bag, No. 1), Adelaide, S.A.
1930. Ockenden, G. P., B.A., 68 Holbrooks Rd., Flinders Park, S.A.
1956. O'Driscoll, E. S., B.Sc., 9 Vinall Street, Dover Gardens, S.A.
1937. *Parkin, L. W., M.Sc., A.S.T.C., Department of Mines, 169 Rundle St., Adelaide, S.A.—*Secretary*, 1953-56; *Vice-President*, 1956-57, 1958-59; *President*, 1957-58.
1949. Parkinson, K. J., B.Sc., 91 Stuart St., Hillcrest, S.A.
1929. Paull, A. G., M.A., B.Sc., 10 Milton Avenue, Fullarton Estate, S.A.
1926. *Piper, C. S., D.Sc., C.S.I.R.O., Division of Soils (Private Mail Bag, No. 1), Adelaide, S.A.—*Verco Medal*, 1957; *Council*, 1941-43; *Vice-President*, 1943-45, 1946-47; *President*, 1945-46.
1948. Powrie, J. K., B.Sc., Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1925. *Prescott, Prof. J. A., C.B.E., D.Sc., F.R.A.C.I., F.R.S., F.A.A., 82 Cross Road, Myrtle Bank, S.A.—*Verco Medal*, 1938, *Council*, 1927-30, 1935-39; *Vice-President*, 1930-32; *President*, 1932-33; *Editor*, 1955-62; *Council*, 1962-63.
1961. Pretty, G. L., B.A., c/o South Australian Museum, Adelaide, S.A.
1957. *Pringle, Miss L. A. B., Box 876c, G.P.O., Adelaide, S.A.
1945. *Pryor, L. D., M.Sc., Dip.For., 32 La Perouse Street, Griffith, Canberra, A.C.T.
1950. *Rattigan, J. H., M.Sc., Newcastle University College, Tigh's Hill, 2N, N.S.W.
1944. Riceman, D. S., D.Sc., B.Agr.Sc., C.S.I.R.O., Division of Biochemistry, Adelaide, S.A.
1947. Riedel, W. R., B.Sc., c/o Scripps Institution of Oceanography, Dept. of Palaeontology, University of California, La Jolla, California, U.S.A.
1953. Rogers, Prof. W. P., D.Sc., Ph.D., F.A.A., M.I.Biol., Zoology Dept., University of Adelaide, North Terrace, Adelaide, S.A.
1951. Rowe, S. A., 22 Shelley Street, Firle, S.A.
1950. Rudd, Prof. E. A., B.Sc., A.M., University of Adelaide, North Terrace, Adelaide, S.A.
1951. Russell, L. D., c/o Adelaide Boys' High School, West Terrace, Adelaide, S.A.
1945. Rymill, J. R., Old Penola Estate, Penola, S.A.
1933. Schneider, M., M.B., B.S., 175 North Terrace, Adelaide, S.A.

Date of Election

1959. Schodde, R., Division of Land Research and Divisional Survey, C.S.I.R.O., Canberra, A.C.T.
1951. *Scott, T. D., M.Sc., South Australian Museum, North Terrace, Adelaide, S.A. *Programme Secretary*, 1953-54, 1956-57; *Secretary*, 1957-.
1925. *Sheard, H., Port Elliot, S.A.
1936. *Sheard, K., D.Sc., C.S.I.R.O., Division of Fisheries and Oceanography, University of W.A., Nedlands, W.A.
1954. Shepherd, R. G., B.Sc., c/o Department of Mines, 169 Rundle St., Adelaide, S.A.
1961. Shepherd, S. A., B.A., LL.B., 5 Rosevear St., Hawthorn, S.A.
1934. Shinkfield, R. C., 57 Canterbury Avenue, Trinity Gardens, S.A.
1962. Smale, D., M.Sc., c/o Department of Mines, Rundle St., Adelaide, S.A.
1925. †Smith, Sir Tom Barr, Kt., B.A., 25 Currie Street, Adelaide, S.A.
1911. *Southcott, R. V., M.D., B.S., D.T.M. & H., 13 Jasper Street, Hyde Park, S.A.—*Council*, 1949-51, 1952-53, 1957-60; *Treasurer*, 1951-52; *Vice-President*, 1953-54, 1955-56, 1961-62; *President*, 1954-55, 1960-61.
1947. *Specht, R. L., Ph.D., Botany Department, University of Melbourne—*Verco Medal*, 1961; *Council*, 1951-52, 1958-60; *Programme Secretary*, 1952-53; *Vice-President*, 1961.
1936. †*Sprigg, R. C., M.Sc., 5 Baker Street, Somerton Park, S.A.
1949. *Spry, A. H., M.Sc., Geology Department, University of Tasmania, Hobart, Tas.
1951. Steadman, Rev. W. R., 8 Blairgowrie Road, St. Georges, S.A.
1938. *Stephens, C. G., D.Sc., C.S.I.R.O., Division of Soils (Private Mail Bag, No. 1), Adelaide, S.A.—*Verco Medal*, 1959; *Council*, 1952-54; *Vice-President*, 1954-55, 1956-57; *President*, 1955-56.
1935. Swaine, C. D., M.B., B.S., 220 Esplanade, Largs North, S.A.
1962. Swinbourne, R. F. G., Box 210, P.O., Alice Springs, N.T.
1951. Swirski, P., M.Ag.Sc., 13 Derwent Ave., Rostrevor, S.A.
1962. *Symon, D. E., B.Ag.Sc., Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1960. Symons, E. F., Uranium Treatment Plant, Port Pirie, S.A.
1934. Symons, I. G., 35 Murray Street, Lower Mitcham, S.A.—*Editor*, 1947-55; *Council*, 1955-58.
1958. Taylor, D. J., Dept. of Entomology, Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.
1959. Taylor, D. J., 23 Westbourne St., Prahran East, Vic.
1929. *Taylor, J. K., B.A., M.Sc., C.S.I.R.O., Division of Soils (Private Mail Bag, No. 1), Adelaide, S.A.—*Council*, 1940-43, 1947-50; *Librarian*, 1951-52; *Vice-President*, 1952-53, 1954-55; *President*, 1953-54; *Editor*, 1962-63.
1961. Teague, F. A., c/o Post Office, Hawker, S.A.
1962. Trusner, R. E., LL.B., c/o. Post Office, Tanunda, S.A.
1948. *Thomas, I. M., M.Sc. (Wales), M.I.Biol., Department of Zoology, University of Adelaide, S.A. *Secretary*, 1948-50; *Council*, 1950-53; *Vice-President*, 1955-56, 1957-58; *President*, 1956-57; *Assistant Editor*, 1958-.
1938. *Thomas, Mrs. I. M. (nee P. M. Mawson), M.Sc., Department of Zoology, University of Adelaide, North Terrace, Adelaide, S.A.
1957. Thomas, J., B.Sc., Woodleigh Road, Blackwood, S.A.
1959. Thomson, B. P., M.Sc., 33 Oaklands Road, Parkholme, S.A.
1940. *Thomson, Capt. J. M., 135 Military Road, Semaphore South, S.A.
1923. *Tindale, N. B., B.Sc., South Australian Museum, North Terrace, Adelaide, S.A. *Verco Medal*, 1956; *Secretary*, 1935-36; *Council*, 1946-47; *Vice-President*, 1947-48, 1949-50; *President*, 1948-49; *Librarian*, 1952-.
1955. *Tucker, B. M., B.Sc., C.S.I.R.O., Division of Soils (Private Mail Bag, No. 1), Adelaide, S.A.
1959. Twidale, C. R., Ph.D., M.Sc., Dept. of Geography, University of Adelaide, North Terrace, Adelaide, S.A.
1959. *Tyler, M. J., Dept. of Physiology, University of Adelaide, North Terrace, Adelaide, S.A.—*Programme Secretary*, 1962-.
1960. Tynan, A. E., c/o Australian Mineral Development Laboratories, Flemington St., Parkside, S.A.
1950. Veitch, J. T., Box 92, Port Lincoln, S.A.
1953. Waterman, R. A., B.A., M.A., Ph.D., Wayne State University, Detroit, Michigan, U.S.A.
1954. *Webb, B. P., M.Sc., Department of Mines, 169 Rundle St., Adelaide, S.A.
1954. Wells, C. B., B.Ag.Sc., Broadlees, Waverley Ridge, Crafers, S.A.
1959. Whelan, Prof. R. F., M.D., Ph.D., D.Sc., Department of Physiology, University of Adelaide, North Terrace, Adelaide, S.A.

Date of Election	
1962.	WHITTEN, G. F., B.Sc., c/o Department of Mines, Rundle Street, Adelaide, S.A.
1946.	*WHITTLE, A. W. G., M.Sc., Department of Economic Geology, University of Adelaide, North Terrace, Adelaide, S.A.
1950.	WILLIAMS, L. D., "Dumosa," Meningie, S.A.
1946.	*WILSON, PROF. A. F., D.Sc., Dept. of Geology, University of Queensland, St. Lucia, Brisbane, Qld.
1961.	*WILSON, P. G., B.Sc., c/o Botanic Garden, North Terrace, Adelaide, S.A.
1954.	*WOMERSLEY, H. B. S., D.Sc., Botany Department, University of Adelaide, North Ter- Adelaide, S.A.—*Council*, 1960-.
1944.	WOMERSLEY, J. S., B.Sc., Dept. of Forests, Lae, New Guinea.
1957.	WOODS, R. V., B.Sc., Mt. Crawford, S.A.
1960.	*WOPFNER, H., Ph.D., 16 Reece Ave., Klemzig, S.A.
1949.	YEATES, J. N., A.M.I.E., A.M.I.M.E., Highways and Local Government Dept., Adelaide, S.A.
1944.	ZIMMER, W. J., Dip.For., F.L.S. (Lond.), 7 Rupert St., Footscray West, W.12, Vic.

AWARDS OF THE SIR JOSEPH VERCO MEDAL AND LIST OF FELLOWS, 1962

Summary

GENERAL INDEX

Names printed in italics as separate entries indicate that the forms are new to science.

CONTENTS