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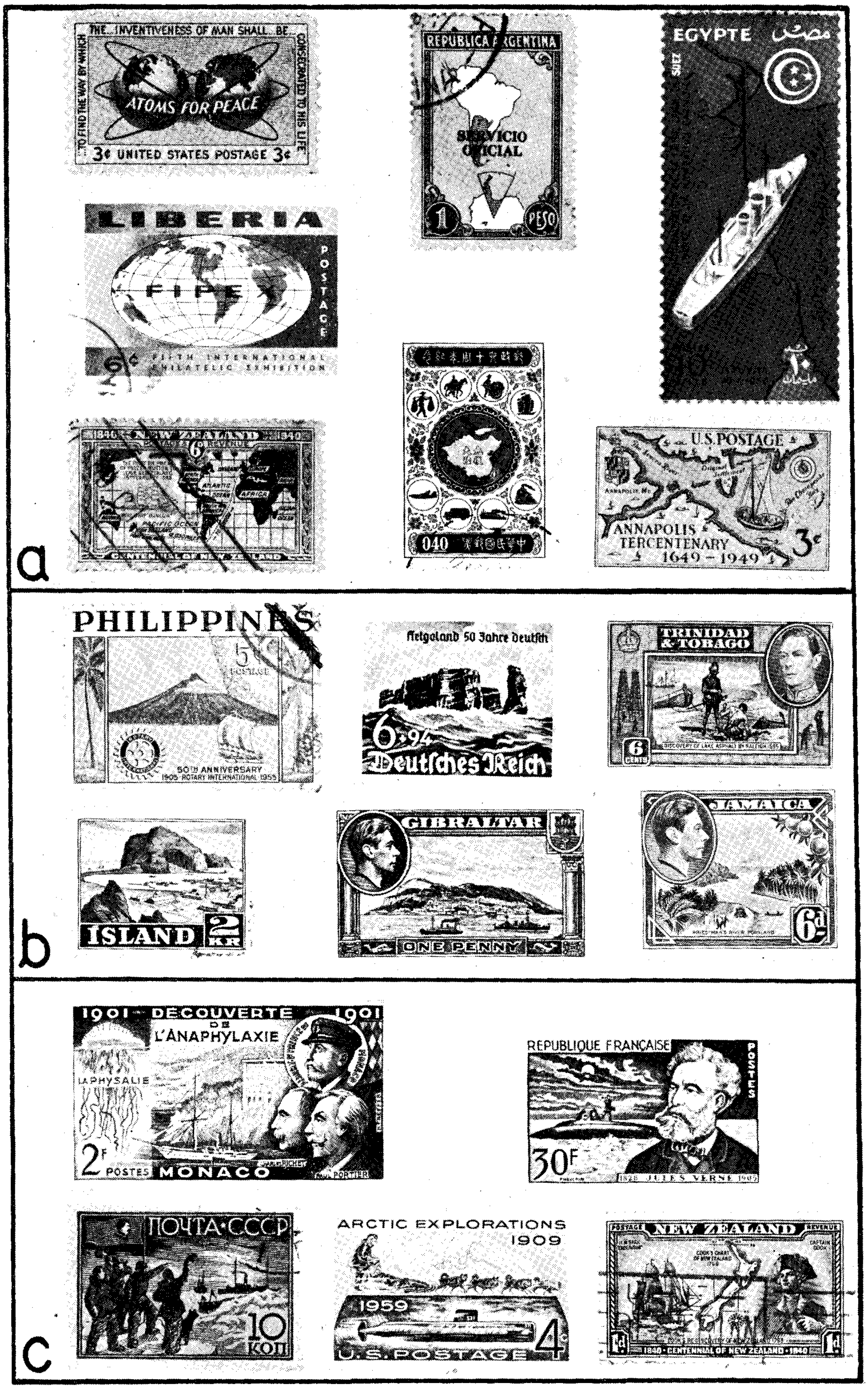
著者	Glaessner M. F.
journal or publication title	Science reports of the Tohoku University. 2nd series, Geology. Special volume = 東北大学理科報告. 地質学
volume	4
page range	37-44
year	1960-05-05
URL	http://hdl.handle.net/10097/28880



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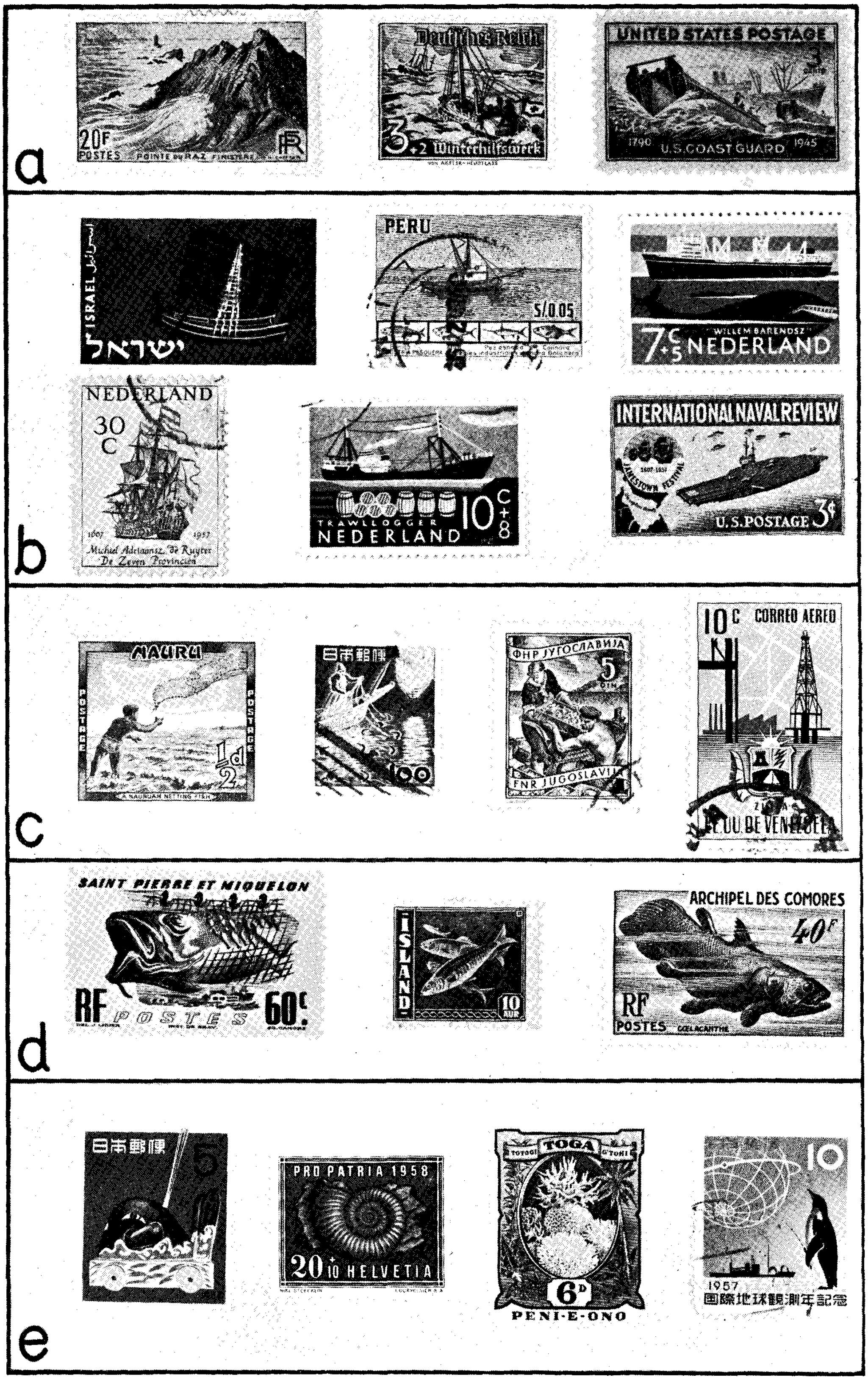

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Science Reports, Tohoku University, Sendai, Japan, 2nd Ser. (Geol.), Spec. Vol., No. 4, pp. 37-44, pl. 6, 1 text-fig., 1960

Upper Cretaceous Larger Foraminifera from New Guinea

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ABSTRACT

An abundant occurrence of the species *Pseudorbitoides israelskii* Vaughan and Cole and *Orbitoides tissoti* Schlumberger in the Upper Senonian (Campanian) of the Port Moresby area (Papua, New Guinea) is described. It is the first occurrence of this distinctive generic assemblage and of the species *P. israelskii* outside the Caribbean-Gulf of Mexico area; a similar assemblage was recently reported from the Austrian Alps, in strata of the same age.

INTRODUCTION

The stratigraphic significance of larger foraminifera in the Tertiary of the Indo-Pacific Region is well known, mostly through the works of van der Vlerk and Umbgrove, Tan Sin Hok, W. Storrs Cole, H. Yabe and S. Hanzawa. In this region, Tertiary rocks predominate greatly over pre-Tertiary sediments which are less well explored. The occurrence of Upper Cretaceous pelagic foraminifera with Mediterranean affinities (*Globotruncana*, *Pseudotextularia*) has led to precise dating of Upper Cretaceous limestones in a number of areas. The discovery of larger foraminifera belonging to European and American species which are here described indicates world-wide distribution of these very valuable stratigraphic markers. The late Klaus Küpper whose untimely death has interrupted a most promising line of research, has drawn attention to phylomorphogenetic sequences in Late Cretaceous orbitoidal foraminifera. Together with A. Papp in Vienna he has produced evidence of a sequence of species or subspecies belonging to *Pseudorbitoides*, *Lepidorbitoides* and *Orbitoides* which is likely to lead to zoning of the Campanian and Maestrichtian, similar to the zoning of the Tertiary by means of evolutionary series in other larger foraminifera. The detailed modern morphological studies of *Pseudorbitoides* and related forms by Brönnimann (1955, 1957) and the recent revision of species of *Orbitoides* by Neumann (1958) were indispensable aids to the identification of the present material.

Acknowledgement. — The writer is indebted to the Australasian Petroleum Company for the use of facilities during his work in the Port Moresby area which led to the discovery of the material here described.

Occurrence. — In 1943 (p. 71) I stated that "The typically Mediterranean Senonian larger foraminifera (*Orbitoides* etc.) are not yet known beyond Northern India and Burma". During geological surveys in the vicinity of Port Moresby, Papua, a previously unknown

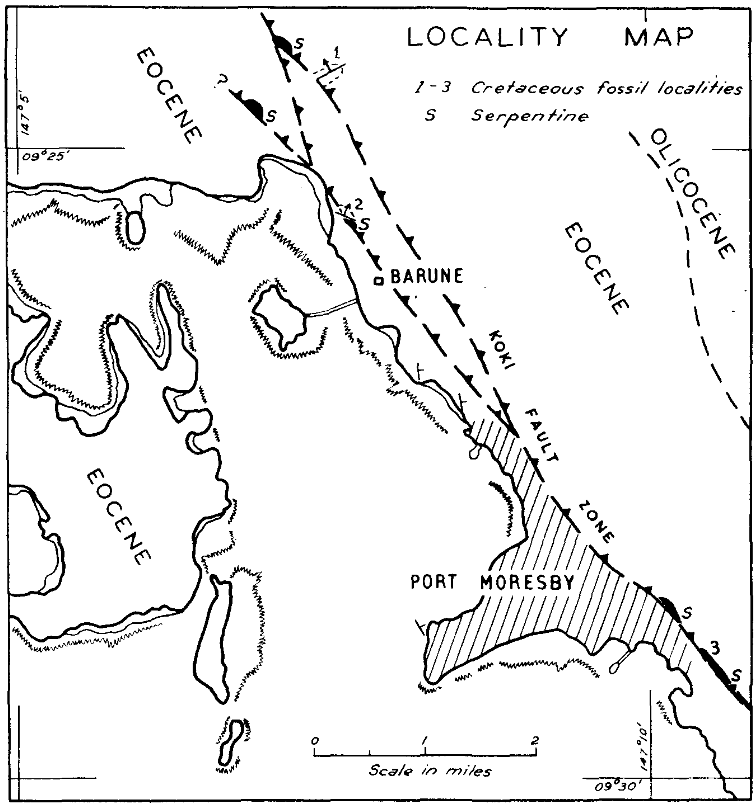

Fig. 1

occurrence of Cretaceous was discovered near Barune Village, about 6 miles north-north-east of Port Moresby, in January 1950 (Fig. 1) and briefly described (Glaessner, 1952, p. 65). The fossiliferous beds are calcareous sandstones which are in places crowded with orbitoidal foraminifera including the genera *Pseudorbitoides* and *Orbitoides*. They are occasionally aligned along the bedding planes. The strike of the Cretaceous Barune Sandstone at this locality is N 65 E and the dip is 40°N. About 100 feet of these beds are exposed between a fault and the Lower Tertiary limestones with abundant *Discocyclina* and *Nummulites* which overlie them probably unconformably as their strike conforms with the regional strike (approximately N 30°W). The contact is, however, not clearly exposed. Serpentine occurs in a number of places along the complex Koki Fault Zone on which thrusting with intense shearing of the serpentine has taken place. In an outcrop on this fault, nearer Barune Village, calcareous sandstones with rare *Globotruncana* but without orbitoids occur between serpentine and Eocene chert and in a small quarry at Koki, in the immediate south-eastern vicinity of Port Moresby, a block of unaltered sandy limestone with *Globotruncana* was found in sheared serpentine. *Pseudorbitoides* was also identified from a limestone band between Goroka and Chimbu in the Eastern Highlands of New Guinea where it is associated with shales containing a rich fauna of smaller foraminifera of Campanian age.

Material. — Six large rock specimens were taken when the Barune Sandstones were first discovered and three more were collected when the locality was re-visited in August 1954. Some 25 thin sections were made of the abundantly fossiliferous harder rock specimens which are crowded with orbitoidal foraminifera. Washing of the softer material produced dozens of free specimens of *Pseudorbitoides.*

Lithology. — The rocks were described in the field as grey calcareous quartz sandstone, bedded, weathering brown, with limonite specks, fine to coarse, hard and platy to soft and crumbling, up to 100 ft. thick. The grain size averages about 1/2 mm in some beds, about 1 mm in others and pebbles of 2 mm diameter and more also occur.

Occurrence of fossils. — The number of fossil remains in some samples is about equal to or exceeds that of the sand grains. The dominant fossils are *Pseudorbitoides* and *Orbitoides* which is rarer. There are also other foraminifera, fragmental mollusca including *Inoceramus*, bryozoa, echinoid remains, and (rarely) calcareous algae (Corallinaceae).

Preservation. — On weathered surfaces the abundant orbitoidal foraminifera are clearly visible but they are softer than most of the mineral grains and some of the cement and are affected and eventually destroyed by weathering. In sections they are seen to be partly recrystallized and in most of the sections at least some of the detail is obscured. The sectioning of loose specimens from friable material has so far proved unrewarding as the external shapes of the fossils are irregular owing to pressure solution so that their orientation is difficult. They remain opaque until very thin so that few well oriented sections are obtained from free specimens. The great abundance of fossils in the hard rock produces a fair number of well-oriented sections from random cuts. The surface features are clearly visible on some naturally stained specimens from friable rocks.

DESCRIPTIONS

Pseudorbitoides israelskii Vaughan and Cole, 1932
Pl. 6, figs. 1–8.

1932 *Pseudorbitoides israelskii* Vaughan and Cole, Nat. Acad. Sci., Proc., vol. 18, p. 614, pl. 2, figs. 1–6. (not fig. 7).

1941 *Pseudorbitoides israelski* Vaughan and Cole, Rutten, Geol. en Mijnbouw, n.s., vol. 3, No. 2, p. 38, pl. 1, figs. 1, 2.

1943 *Pseudorbitoides israelskii* Vaughan and Cole, Jour. Paleont., vol. 17, p. 98, pl. 17, figs. 1, 2.

1944 *Pseudorbitoides israelskii* Vaughan and Cole, Cole, Florida Geol., Bull. 26, pl. 56, pl. 21, figs. 1–5.

1952 *Pseudorbitoides israelskii* Vaughan and Cole, Bermudez, Venezuela Minist. Minas e Hidrocarb., Bol. Geol., vol. 2, No. 4, figs. 5, 6.

1952 *Pseudorbitoides,* Glaessner, Sir Douglas Mawson Anniv. Vol., Adelaide, p. 65.

1952 *Pseudorbitoides,* Glaessner, The Micropalaeontologist, vol. 6, No. 2, p. 25.

1955 *Pseudorbitoides israelskyi* Vaughan and Cole, Brönnimann, Cushman Found. Foram. Res., Contr., vol. 6, pp. 58, 68.

1957 *Pseudorbitoides israelskyi* Vaughan and Cole, Brönnimann, Eclogae Geol. Helvet., vol. 50, p. 592, text-figs. 1–11.

1958 *Pseudorbitoides* sp., Brönnimann, Eclogae Geol. Helvet., vol. 51, p. 422.

This species was recently re-described from topotypes by Brönnimann (1957). The new material agrees in all essential characters and measurements with these descriptions. As it is not well enough preserved to allow any substantial additions to our knowledge of the detailed morphology of the test to be made, only a few significant observations will be mentioned.

The test is lenticular, with a thicker centre and a rounded peripheral outline. A thin flange which is crenulated by the radial plates is visible in specimens preserved on weathered surfaces but breaks off in specimens washed from friable rock. The central part of the surface shows a network of lateral chambers and a number of small pillars, mostly about 0.1 mm in diameter, but occasional individuals have a central cluster of larger pillars or a single central pillar.

The horizontal diameter of the test ranges from 1 to 2.5 mm, and the thickness from 0.5 to 0.8 mm. The maximum diameter was measured on an exceptionally large specimen with a completely preserved thin flange.

In equatorial section embryonic dimorphism was not clearly observed, though a few obscure sections suggest the occurrence of microspheric individuals (which Brönnimann denies). The megalospheric juvenarium appears to be uniserial as a rule; in the many slightly oblique sections the sequence of chambers cannot be established beyond doubt. The spiral is short, comprising about eight chambers in a single whorl. The maximum diameter of the protoconch (including the wall which is about 0.017 to 0.020 mm thick) is about 0.1 mm. The "alternating radial rods" described by Brönnimann (1957, p. 600) as existing between the juvenarium and the radial plates could not be clearly seen. The radial plates are distinct and their number, size and arrangment are as in the typical specimens of the species. They are straight and almost parallel, with transverse connections and with additional plates intercalated towards the periphery. The chambers over- and underlying them (Brönnimann's "primary lateral chambers") are often arranged in more or less radial rows, each covering three–five radial plates.

In vertical section the juvenarium is as figured by Brönnimann (1957, Pl. 2, Fig. 4) in size and shape of chambers. The radial plates as seen in vertical sections near the periphery are regular. The walls of the equatorial layer are distinct and straight, its height increases towards the periphery from about 0.052 to 0.104 mm. No great difference in wall thickness between "primary" and "secondary" lateral chambers has been observed.

The diagnostic features of *P. israelskii* as listed by Vaughan and Cole and by Brönnimann are clearly visible but their significance cannot be fully evaluated on the basis of the available material. If, in fact, further studies confirm the suspected occurrence of microspheric individuals, i.e. of dimorphism, in populations of *P. israelskii*, then the remaining differences between the three species distinguished by Brönnimann (1957, p. 602, Table IV) would appear to be the differences in degree of expression of biocharacters suggesting subspecific rather than specific distinctions. The morphogenetic sequences *israelskii-trechmanni* and *rutteni* suggested by Brönnimann (1955, pp. 74–5) have yet to be confirmed as sequences in time of first appearance. Papp (1954) has suggested that *Pseudorbitoides* evolved into *Lepidorbitoides*. His *P.* cf. *trechmanni* Douvillé (Papp, 1954, p. 163), however, does not belong to this species.

Among the hundreds of normally developed specimens of *Pseudorbitoides israelskii* seen in thin sections and on weathered surfaces, there are a few abnormal ones (Pl. 6, Fig. 7). They are distinguished by a branched median layer arranged in three planes, with the juvenarium near the centre. This is considered an abnormality of growth rather than a distinct genus and species. A corresponding aberrant growth form is known in several species of *Lepidocyclina* (Yabe and Hanzawa, 1928, 1930; Chapman and Crespin, 1932; Crespin, 1936) These forms have been named *L. sumatrensis* (Brady) forma *mirabilis* Yabe and Hanzawa (or var. *mirabilis*) but they are better referred to (informally) as trigonolepidine forms, as suggested by Yabe and Hanzawa. Chapman and Crespin have found the case of the abnormal growth in a duplication of the deuteroconch but the duplication could occur in other embryonic or nepionic chambers. Abnormal branching during growth of a normally uniserial test is known in *Nodosaria*. The trigonolepidine growth form is known in different species of *Lepidocyclina* from Formosa, New Guinea (unpublished observations) and Australia. It is also known in what appears to be a *Discocyclina* (*Orbitoides trigonalis* Checchia Rispoli). It is suggested that Brönnimann's "genus *Ctenorbitoides*" (Brönnimann, 1958, p. 171) from Cuba is a similar abnormality, possibly of *Vaughanina* with which it is associated. The status of the other two associated genera, *Aktinorbitoides* Brönnimann and *Conorbitoides* Brönnimann, as possible individual growth forms should be investigated. Nothing comparable with them has been seen in the present fauna.

Distribution. — Until recently, the genus *Pseudorbitoides* was thought to be confined to Jamaica, Cuba, Louisiana, Texas, Florida and Guatemala (?). According to Brönnimann (1957) *P. israelskii* occurs also in Mexico, British Honduras, Haiti, Puerto Rico and Mississippi. Brönnimann (1958) described *Pseudorbitoides*(?) *chubbi* from Texas, Mexcio, Haiti and Cuba. Papp and Küpper (1953a) described *Pseudorbitoides longispiralis* as a primitive form of the genus from the Campanian of the Austrian Alps and Papp (1954) mentioned *P.* cf. *trechmanni* from slightly younger Campanian strata in the same vicinity. Later, Papp (1956) referred to both forms and to a specifically unidentified one from Upper Austria as "*Pseudorbitoides*", having expressed doubt about their generic identification (Papp, 1955, p. 317).

Age. — Brönnimann (1957) has carefully considered the age of *P. israelskii* in the Caribbean-Gulf Coast region and has concluded (p. 591) : "It seems that this species is restricted to the Campanian". The occurrence here described is apparently in strata of the same age. It will be discussed after consideration of other significant fossils.

Orbitoides tissoti Schlumberger
Pl. 6, figs. 9–11.

1902 *Orbitoides tissoti* Schlumberger, Bull. Soc. Géol. France, sér. 4, vol. 2, p. 259, pl. 8, figs. 21–25, p. 260, fig. 3.
1920 *Orbitella tissoti* (Schlumberger), H. Douvillé, Bull. Soc. Géol. France, sér. 4, vol. 20, p. 214, figs. 1, 10.
1930 *Orbitoides palmeri* Gravell, Journ. Paleont., vol. 4, p. 269, pl. 22, figs. 1–10.
1944 *Orbitoides palmeri* Gravell, Cole, Florida Geol., Bull. 26, p. 55, pl. 21, fig. 13.
1953 *Orbitoides tissoti tissoti* Schlumberger, Papp and Küpper, Sitzungsber. Akad. d. Wiss. Wien, vol. 162, p. 349, pl. 1, figs. 1–2, pl. 2, fig. 2.
1954 *Orbitoides tissoti tissoti* Schlumberger, K. Küpper, Cushm. Found. Foram. Res., Contr., vol. 5, p. 65, pl. 12, figs. 1, 2, text-figs. 2, 12–15.
1955 *Orbitoides tissoti tissoit* Schlumberger, Papp, Verh. Geol. Bundesanst. Wien, pp. 139–141.
1955 *Orbitoides tissoti tissoti* Schlumberger, Papp, Sitzungsber. Akad. d. Wiss. Wien, vol. 164, pp. 320–322.
1956 *Orbitoides tissoti tissoti* Schulmberger, Papp, Paläont. Zeitschr., vol. 30, Sonderheft, p. 46, Abb.

2, Fig. 1, 2.
1958 *Orbitoides tissoti* Schlumberger, Neumann, Mém. Soc. Géol. France, n.s., vol. 37, fasc. 2, 3, Mém. 83, p. 56, pl. 1, figs. 1–9, pl. 2, figs. 1–4, pl. 5, figs. 1, 2, pl. 35,fig. 1, text-fig. 13.

The representatives of the genus *Orbitoides* are less common in the present material than those of *Pseudorbitoides*. No free specimens have been examined. Horizontal sections are not perfect but several centred vertical sections are available. The tests are small. The species is distinguished by the small juvenarium of the megalospheric form. It is typically quadrilocular and this has been observed in several sections. The four auxiliary chambers and the other periembryonic chambers are not clearly visible in the available horizontal sections. The median chambers are arcuate and wider than long. In vertical section the thick walls separating the slit-like lateral chambers are distinctive. The median chambers are high and appear to have only one series of stolons. There are widely spaced thin pillars.

Measurements (from vertical sections). — Diameter of test 2–3 mm, height 1.15–1.30 mm, internal diameter of protoconch 0.165–0.23 mm, length of juvenarium about 0.43–0.52 mm, height of median chambers (including wall near juvenarium about 0.20 mm, thickness of walls of median layer 0.065 mm, approximate number of tiers of lateral chambers 12.

Distribution. — This species was discussed in recent years by K. Küpper (1954), A. Papp and M. Neumann (1958). Küpper recognized the specific identity of *O. palmeri* Gravlell from Cuba with Schlumberger's species from Algeria. This identity is fully confirmed by the present material which agrees in all ascertainable features and measurements with both forms. Papp and Küpper (1953a, p. 349) referred to a small form with occasionally one flat and one more highly conical side as *O. tissoti minima* Vredenburg. This name was based on figures of specimens from the *Nerinea* Beds, south-south-east of Valudayur in the Pondicherry area of south-eastern India. These beds are generally considered as Danian. Early Tertiary with *Discocyclina* has, however, been found in the same area. The figures are too poor to base even a generic identification on them. The name "*minima*" should therefore not be used without further studies of type material and of its stratigraphic position. Papp and Küpper also placed in the synonymy of this subspecies "*minima*" the species *O. vredenburgi* Douvillé from Tibet which is incompletely known. The occurrence of *O. tissoti* in the region of India is still without proof.

The species occurs in Algeria, Spain, the Aquitaine Basin, the Austrian Alps, and Cuba, and probably in other areas from which data are still incomplete or disputed.

Age. — According to Neumann (1958) this species ranges from Santonian to Campanian; according to Papp (1956) it is Campanian.

AGE AND RELATIONS OF THE ORBITOID-BEARING STRATA

The only recognizable species of smaller foraminifera from the Barune Sandstone is *Globotruncana stuarti* (Lapparent) which is rare. A few sections of unidentified benthonic species have also been seen. All other fossils from the Orbitoid-bearing beds are too poorly preserved to be identifiable.

The occurrence of *G. stuarti* is in agreement with Campanian age of *Orbitoides tissoti* and *Pseudorbitoides israelskii* which recent studies appear to have abundantly confirmed.

I suggested in 1952 (p. 65) that "The Barune Sandstone appears to be a near-shore facies of the Upper Senonian Bogoro Limestone". This view is no longer strictly correct as the pink Bogoro limestone contains *Pseudotextularia varians* Rzehak, *P. accrvulinoides* Egger and other elements of what is now considered a fauna of Maestrichtian age. It is thus younger than the Campanian Barune Sandstone. Sandstone is a near-shore facies and the Bogoro Limestone an off-shore facies of the Upper Senonian, but one is slightly older than the other. Maestrichtian faunas of smaller foraminifera of the *Pseudotextularia* zone are widespread in Australian New Guinea. They have been identified from samples collected by H.J. Ward on the Upper Lagaip River (about 6°20′ N and 143°10′E), from the Mango Marls of the Mendi area (Rickwood, 1955, p. 74) and form Kanuivana Creek, 1/2 mile north of Gorugoruna Village, 65 milles east-south-east of Port Moresby (light grey chalky marl, collected by G. J. Wills).

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PLATE 6

Figs. 1–8. *Pseudorbitoides israelskii* Vaughan and Cole

Fig. 1. Slightly oblique equatorial section through centre of test, showing eight spiral chambers of the juvenarium, outlines of chambers and radial plates in upper portion, lateral chambers in lower portion, and pillars. ×30.

Fig. 2. Slightly oblique equatorial section showing part of spiral juvenarium, radial plates at right, and radiating lateral chambers. ×73.

Fig. 3. Portion of centered vertical section showing "sulcoperculinoid" juvenarium, median plates in section, lateral chambers and pillars. ×100.

Fig. 4. Oblique section showing median plane with radial plates above and lateral chambers below. ×34.

Fig. 5. Equatorial section showing megalospheric juvenarium with about eight spiral chambers. ×30.

Fig. 6. Slightly oblique vertical section through centre of test. ×80.

Fig. 7. Section through "trigonolepidine" (twinned) test. ×80.

Fig. 8. Parts of a marginal horizontal section (below) and of a peripheral vertical section (above), showing radial plates. ×50.

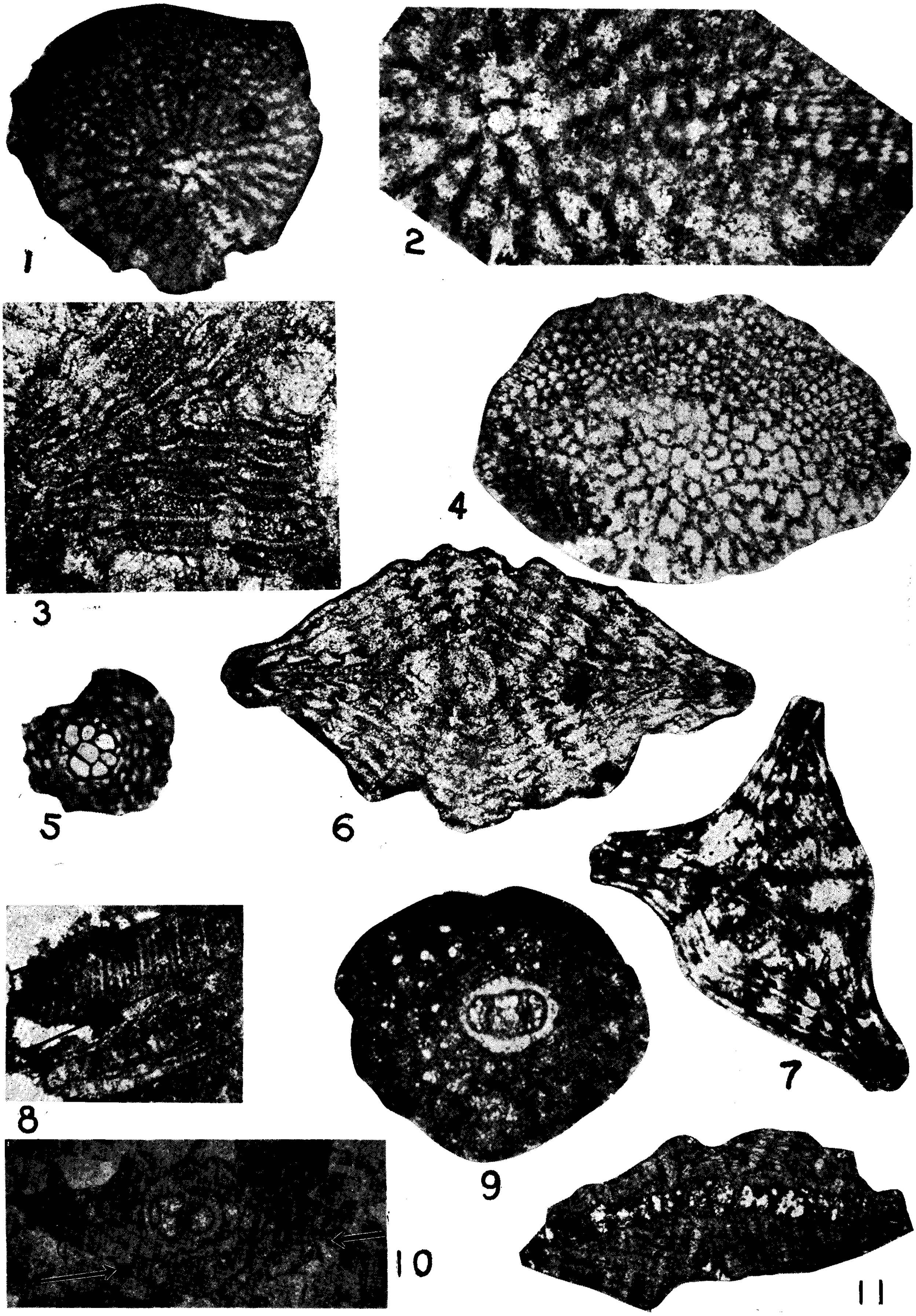
Figs. 9–11. *Orbitoides tissoti* Schlumberger

Fig. 9. Equatorial section of megalospheric test with four-celled thick-walled juvenarium. ×50.

Fig. 10. Vertical section through centre of megalospheric test. A stylolitic suture separates it from a vertical section of *Pseudorbitoides israelskii* (below). ×30.

Fig. 11. Vertical section through centre of megalospheric test. ×30.

All specimens from the Campanian of Barune, near Port Moresby, Papua. Slides in the micropalaeontological collection of the University of Adelaide. Photographs by Dr. Mary Wade and Mr. Tomlinson. Note that the indistinctness of outlines is due to recrystallization of the material.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