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Notes on Some Eocene Foraminifera

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Notes on Some Eocene Foraminifera.

BY

H. YABE.

With 5 Plates.

Contents:—

I.

Four Arenaceous Foraminifera from the Eocene of Haha-jima (Hills-borough Is.), Ogasawara Group. Pl. XVI (I.).

Nummulites are abundant in the calcareous tuff extensively developed along the southwestern coast of Haha-jima (Hillsborough Is.), Ogasawara (Bonin Islands) group, as already reported by Mr. S. TOKUNAGA.[1] Very recently, I obtained a great many samples of this foraminifer from Mr. T. MATSUO, a student of our Geological Institute, Tôhoku Imperial University, who spent last summer vacation in the island in petrological researches and also utilized his time for fossil-collection. By cleaning the surface of the numerous tests of *Nummulites*, four kinds of arenaceous foraminifera have been unexpectedly found adherent to them; of these four, one is represented by a single specimen and assigned, though with some doubt, to the genus *Lituotuba*, while the other three which are more frequent have been determined to be two species of *Sagenina* and one species of *Placopsilina*. Short accounts of these four fossil forms are given below:

Sagenina, CHAPMAN.
(=*Sagenella*, BRADY).

1900. *Sagenina* CHAPMAN: On Some New and Interesting Foraminifera from the Funafuti Atoll, Ellice Islands. Jour. Linn. Soc., London, Zoology, vol. XXVII., No. 176, p. 4.

This genus comprises several living species, with the branching tubular tests always spreading over

1) S. TOKUNAGA: Geological Age of the Ogasawara Group (Bonin Islands) as indicated by the Occurrence of *Nummulites*. Geol. Mag., London, dec. IV., vol. IX., No. 457.

some substrata; the tubes are sandy and calcareous, and provided with a terminal aperture. The genotype is *S. frondescens* BRADY[1] living in the shallow seas of coral regions in the South Pacific[2]; in this species, the tubular branches form a network by anastomosis, and vary between 0.12 and 0.4 mm. in diameter. The second species is *S. divaricans* CUSHMAN[3] from the Philippines, and is distinguished from the former by its seldom anastomosing branches which are considerably narrower, ranging between 0.05 and 0.1 mm. in diameter. The third species, *S. ramulosa* CUSHMAN, from off Guam, 234 fathoms, is characterised by its profusedly branching tubular test, the branches being often massed or confluent; in regard to the diameter of the tube, this species occupies just the intermediate position between the two preceding forms, measuring 0.1–0.2 mm.

S. regularis DOUVILLÉ[4] is only one fossil species hitherto known of the genus and recorded from the Miocene of Java; it is similar to *S. divaricans* in the mode of branching, but the branches are somewhat broader in the fossil species (0.25–0.14 mm. broad, judging from the photographs given by DOUVILLÉ in his paper). One of the two species of *Sagenina* in the present material seems to be identical with DOUVILLÉ's species, whereas the other represents a new type.

Sagenina regularis (DOUVILLÉ).

Pl. XVI.(I.), Figs. 1, 2.

1916. *Sagenella regularis* H. DOUVILLÉ: Les foraminifères des couches de Rembang, p. 33, pl. V., fig. 5; pl. VI., fig. 4.

Tube slender, varying from 0.18 to 0.3 mm. in diameter; bifurcating at regular intervals and in a uniform wide angle, and anastomosing rather rarely. Surface of the tube roughened.

There is no essential difference recognisable between our fossil and *S. regularis;* in spite of the fact that the type specimens of the latter are from a deposit considerably younger than that containing the former, yet I am quite confident about their specific identity.

Abundant.

Sagenina expansa YABE sp. nov.

Pl. XVI.(I.), Figs. 3–5.

More irregularly branching and irregularly anastomosing than the former. Branches provided with a more or less well defined wall only at the tip, and then appearing tubular; elsewhere rather ill defined externally, owing to the irregular thin lateral expansion of the wall. Wall of all the branches often coalescing as to form a thin flat common film spreading over the branching canals inside, except their growing tips. Where the branches exist as a distinct tube, they are 0.45–0.6 mm. or sometimes even slightly broader.

This species matches the living *S. frondescens* in the breadth of the tube; the former, however, does not form a regular network with its branches like the latter. Moreover, the common thin film developed out of the wall of the branches is a characteristic feature of the former, never shown by the latter.

Very common.

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1) BRADY: Foraminifera, 1884, p. 278, Pl. XXVIII., figs. 14, 15. CHAPMAN: On Some New and Interesting Foraminifera from the Funafuti Atoll, Ellice Islands, p. 4, pl. I., figs. 1, 2; pl. II., figs. 1, 2.

2) The northern limit of the distribution of this species is, according to CUSHMAN, Albatross station D 4922 in Vincennes Strait (Yaku-Kaikyo), south of Japan, 60 fathoms. CUSHMAN: Monograph of the Foraminifera of the North Pacific Ocean, pt. I. U. S. Nat. Mus. Bulletin No. LXXI, 1910, p. 72.

3) J. A. CUSHMAN: New Arenaceous Foraminifera from the Philippines. Proc. U. S. Nat. Mus., vol. XXXVIII., No. 1759, p 437, text-fig. 1.

4) J. A. CUSHMAN: l.c., p. 72.

5) H. DOUVILLÉ: Les foraminifères des couches de Rembang. Samm. des Geol. Reichsmuseum in Leiden. I., vol. X., No. 2, 1916, p. 33.

Placopsilina, ORB.

Placopsilina cenomana ORB.

Pl. XVI.(I.), Figs. 6–8.

1850. *Placopsilina cenomana* ORBIGNY: Prodrom de Paleontologie, vol. II., p. 185.

1854. *P. cenomana* REUSS: Beiträge zur Charakteristik der Kreideschichten in den Ostalpen, insbesondere im Gosauthale und am Wolfgangsee. Denksch. K. Akad., Wien, vol. VII., p. 71, pl. XXVIII., figs. 4, 5.

1860. *Lituola cenomana* JONES and PARKER: Rhizopodal Fauna of the Mediterranean compared with that of the Italian and Some Other Tertiary Deposits. Quart. Jour. Geol. Soc., London, vol. XVI., p. 302.

1862. *Lituola* (*Placopsilina*) *cenomana* CARPENTER: Introduction to the Study of Foraminifera, p. 143, pl. XI., figs. 11–14.

1883. *P. cenomana* R. HÄUSLER: Notes on Some Jurassic Astrorhizidae and Lituolidae. Quart. Jour. Geol. Soc., London, vol. XXXIX., p. 27, pl. III., fig. 1.

1883. *P. cenomana* R. HÄUSLER: Die Astrorhiziden und Lituoliden der *Binammatus* Zone. N. Jahrb. M.G.P., I., p. 59, pl. III., figs. 12–14.

1884. *P. cenomana* BRADY: Foraminifera, p. 315, pl. XXXVI., figs. 1–3.

1886. *P. cenomana* HÄUSLER: Die Lituolidenfauna der Aargauischen *Impressa* Schichten. N. Jahrb. M.G.P., BB. IV., p. 8, pl. I, figs. 24–25.

1890. *P. cenomana* HÄUSLER: Monographie der Foraminiferen-Fauna der Schweizerischen *Transversarius*-Zone. Abh. d. Schw. Pal. Gesell., vol. XVII., p. 38, pl. IV., fig. 21; pl. V., figs. 1–17.

1910. *Placopsilina cenomana* CUSHMAN: Monograph of the Foraminifera of the North Pacific Ocean. U. S. Nat. Mus., Bulletin No. 71, p. 119, fig. 186.

Test arenaceous, adherent, consisting of a number of convex chambers in close approximation earlier chambers closely coiled; later ones in a single, irregular linear series. Chamber surrounded by its own wall, except the contact surface with the substratum and the previously formed wall; undivided interiorly. Aperature simple, terminal.

Length 7 mm., breadth 1 mm.

Placopsilina cenomana was first founded on a fossil material from the Cretaceous of France, as its specific name implies; it is now known to occur in the Lower Liassic and later Mesozoic rocks of Europe. HÄUSLER once stated that it is one of the commonest arenaceous foraminifera of the whole Jurassic formation. According to CHAPMAN,[1] it occurs also in certain Tertiary deposits, though rarely. At the present time, it is a common shallow water form of the tropical and subtropical regions, especially among the coral reefs of the Pacific (3–35 fathoms). CUSHMAN recorded it from Albatross station D 4900 in 139 fathoms, off Japan. It is also known from the North Atlantic (west of Ireland) and the Mediterranean.

CUSHMAN, however, says that he is not at all certain about the specific identity of the recent material and the Cretaceous fossils described under the name.

The Eocene specimens now in hand agree with the descriptions and figures of the living examples, given by BRADY and CUSHMAN, in every essential feature, and in this sense, the specific name *cenomana* is here applied to them.

Several specimens examined.

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1) CHAPMAN: Foraminifera, 1902, p. 140. For instance, it occurs in the Eocene formation of Italy.

Lituotuba, RHUMBLER.

Lituotuba? eocenica YABE sp. nov.

Pl. XVI.(I.), Fig. 9.

The genus *Lituotuba* was established by RHUMBLER on *Trochammina lituiformis* BRADY;[1] this species is characterised as follows: Test tubular, closely coiled in plane spiral or irregularly in early portion and subsequently growing linear; irregularly or indistinctly segmented and the sutures externally marked by faint furrows; aperture simple and terminal; surface rather smooth; tube 0.2–0.4 mm. broad and up to 3.7 mm. long; test free.

The present fossil much resembles the early portion of the test of *L. lituiformis*, being irregularly convolute and faintly segmented into numerous chambers of variable sizes; it has the relatively large, oval nucleoconch, and the whole test is adherent to the substratum by its under surface. Thus, in the mode of growth, it is very similar to *Tolypammina vagans* BRADY,[2] the test of which, however, is tubular, simple, uniform in breadth and non-segmented.

The segments of the present fossil varies between 0.3 and 0.6 mm. in breadth.

It is doubtful whether the inclusion of such an adherent foraminifer in the genus *Lituotuba* is correct; here, however, this fossil is assigned to the genus only provisionally, for at present I am not aware of its proper generic position.

ARNOLD HEIM[3] stated that most species of *Nummulites* are inhabitants of the neritic zone (0–200 m deep), so far as he can conclude from his palaeontological and geological study of the nummulitic formations of the Alps of Switzerland. The evidence given by the above mentioned arenaceous foraminifera adherent to the tests of *Nummulites* from Haha-jima accords well with this statement, for most of the allied living species—*Sagenina divaricans, S. frondescens* and *Placopsilina cenomana*—are common forms of shallow water, 3–60 fathoms, although *P. cenomana* was also obtained from the depths 139 fathoms off Japan, 360 fathoms off Crete, and 670 fathoms, west of Ireland, and *Sagenina ramulosa* is known only from 234 fathoms, off Guam. Fossil *S. regularis* from Java attaches to the tests of *Cycloclypeus communis* MARTIN and *C. annulatus* MARTIN, and living *C. carpenteri* BRADY occurs in great abundance at about 50 to 60 fathoms round Funafuti, the limit of its range there being from 30 to 200 fathoms.[4]

II.

Notes on Two Foraminiferal Limestones from E.D. Borneo.[5]

Pl. XVII.(II.) and XVIII.(III.).

This paper contains the descriptions and figures of the foraminifera found in two kinds of limestone from Marah, Bulungan, E.D. Borneo, and belonging to the three genera, *Nummulites, Assilina* and

1) BRADY: l.c., p. 342, pl. XL., figs. 4–7. FLINT: Recent Foraminifera, p. 281, pl. XXVI., fig. 1, 1899. CUSHMAN: Monograph, pt. I., p. 114, fig. 175.

2) BRADY: l.c., p. 260, pl. XXIV., figs. 1–9. FLINT: l.c., p. 270, pl. XI., fig. 2. CUSHMAN: l.c., p. 67, figs. 84–85.

3) A. HEIM: Die Nummuliten- und Flyschbildungen der Schweizeralpen. Abh. d. Schweizerischen Palaeontologischen Gesellschaft, vol. XXXV., 1908, p. 283.

4) CHAPMAN: Foraminifera, p. 248.

5) This is my second paper on the Tertiary foraminiferal rocks of Borneo collected by Mr. S. NODA of the Kuhara Mining Company, the first one being published under the title "Notes on a *Carpenteria*-Limestone from B.N. Borneo" in one of these Science Reports (Geological Series) vol. V., No. 1, 1918.

Orthophragmina. The material was kindly placed in my hand by Mr. S. NODA who collected it at the locality during his geological expedition in 1918 in the island. None of the species of the fossil foraminifera are new; but on account of the geological importance of this occurrence, the present paper is here brought to publication.

The material consists of three fragments of limestone, all of which are compact in texture, dark coloured, argillaceous and sapropelic, and are full of the shells of large foraminifera. Of these three fragments, we can easily distinguish one from the other two by the fact of its being less dark and having a slight brownish tint under the microscope; the former is found to contain

Nummulites subbrongniarti VERBEEK

in abundance, and the latter

Nummulites cfr. *pengaronensis* VERBEEK (rare),
Assilina orientalis DOUVILLÉ (abundant),
A. granulosa ARCH, var. *minor* HEIM (common),
Orthophragmina javana VERBEEK (common),
O. fritschi DOUVILLÉ (common).

As will be seen later on, these two sets of limestone represent two distinct geological stages, the first one being Lower Oligocene and the second Upper Eocene in age.

In an earlier date, VERBEEK[1] already distinguished three divisions in the Eocene formation developed in Riam-Kiwa and Riam-Kanan districts and in the environs of Martapura and Bandjermasin in Southeast Borneo; namely, in descending order:

Stage γ: Nummulitic limestone, 20–90 m. thick, with
Nummulites biarritzensis ARCH.
N. striata ORB. var.
N. subbrongniarti VERBEEK.

Stage β: Soft clay and marl, 250 m. thick, with
Nummulites pengaronensis VERBEEK.
Orthophragmina papyracea BOUBÉE (later called *O. javana* VERBEEK).
O. ephippium SCHLOTH.?
O. dispansa SOW.
O. omphalus FRITSCH.
O. decipiens FRITSCH.

Stage α: Sandstone intercalating some hard shale beds and coal seams; barren of fossils.

H. DOUVILLÉ[2] assigned the stage γ to the Lower Oligocene and the underlying stage β to the Upper Eocene.

N. subbrongniarti VERBEEK is believed by DOUVILLÉ[3] to be almost indistinguishable from *N. sublaevigatus* ARCH. from India; it belongs to the section Reticulatae and is an undoubted ally of European *N. intermedius-fichteli*, hence being an indicator either of Sannoisian stage (if it occurs without *Eulepidina* in association) or the Stampian (if it occurs with *Eulepidina* in association). This species was also found by DOUVILLÉ[4] in BUXTORF's collection of fossils from Southeast Borneo and especially in the material derived from the upper part of BUXTORF's "Lower sandstone and marl" (Sannoisian stage) and

1) R. D. M. VERBEEK: Über die Gliederung der Eocänformation auf der Insel Borneo. Palaeontographica, Suppl. III., 1881. VERBEEK: Die Nummuliten des Borneo Kalksteines. Neues Jahrb. f. M. G. P., 1871, p. 1. K. v. FRITSCH: Einige Eocäne Foraminiferen von Borneo. Palaeontographica, Suppl. III.

2) H. DOUVILLÉ: Les foraminifères dans le Tertiaire de Bornéo. Bull. Soc, Géol. France, ser. IV., vol. V., p. 435, p. 1905.

3) H. DOUVILLÉ: l.c., p. 439.

4) H. DOUVILLÉ: l.c.

in that from the lower part of the "Middle limestone" (Stampian stage). Our limestone which contains *N. subbrongniarti* does not show any trace of the test of *Lepidocyclina*, and it is on this negative evidence that I prefer to assign the limestone to the Lower Oligocene (Sannoisian stage) age rather than to the Upper (Stampian stage).

A foraminifera fauna very similar to that contained in VERBEEK's stage β of Borneo is now also known from Java and the island of Nias through the researches of K. MARTIN and DOUVILLÉ. First, the Nanggoulan beds of Nanggoulan district in the Residency Djokdjokarta, Java, contain the following species of foraminifera:

Nummulites vredenburgi PREVER (=*N. laevigatus* of VERBEEK and *N. douvillei* VREDEBURG).
N. djokdjokartae MARTIN (=*N. lamarcki* of VERBEEK; the megalosphaeric form of the former).[1]
N. pengaronensis VERBEEK (=*N. nanggoulani* VERBEEK)
Orthophragmina javana VERBEEK (=*O. papyracea* var. *javana* VERBEEK)
O. fritschi DOUVILLÉ.
O. omphalus FRITSCH.
O. dispansa SOW.
O. decipiens FRITSCH.

Nearly all the species of *Orthophragmina* and *N. pengaronensis* are common to the Nanggoulan beds of Java and VERBEEK's stage β of Borneo; DOUVILLÉ believes in the Upper Eocene age (Auversian stage) of these deposits, on account of 1) the abundance of *Orthophragmina* and of 2) the occurrence of *N. vredenburgi*, an analogue of *N. brongniarti* ARCH., together with *N. pengaronensis* with radiating alar prolongation of septa.[2]

Second: from the island of Nias, DOUVILLÉ recorded two Eocene foraminifera faunae; one of them, comprising

Nummulites laevigatus BRUG.
N. cfr. *lamarcki* ARCH.
N. baguelensis VERBEEK.
N. kelatensis CARTER.
Assilina granulosa ARCH.
A. orientalis DOUVILLÉ.
Orthophragmina decipiens FRITSCH.
Alveolina javana VERBEEK.

is certainly Middle Lutetian in age, while the other comprising

Nummulites pengaronensis VERBEEK

beside *Assilina*, *Alveolina* and *Orthophragmina*, is slightly younger, being Upper Lutetian in age.[3]

1) SILVESTRI considers *N. djokdjokartae* MARTIN to be specifically identical with *N.* (*Laharpeia*) *lamarckii* ARCH. et HAIME. (SILVESTRI: Nummuliti oligoceniche della Madonna della Catena presso Termini-Imerese (Palermo), Boll. Soc. Geol. Ital., vol. XXVII., 1909, p. 58.
2) H. DOUVILLÉ: Quelques foraminifères de Java. Samm. d. Geol. Reichs-Mus. in Leiden, ser. I., vol. VIII., 1912., p. 279.
3) H. DOUVILLÉ: Les foraminifères de l'île de Nias. Samm. d. Geol. Reichs-Mus. in Leiden, ser. I., vol. VIII., 1912. p. 253.

To tabulate these fossil occurrences:

	Nias I.	Nias II.	Borneo Marah II.	Borneo Stage β	Java Nanggoulan beds.
	M. Lutetian	U. Lutetian		Auversian	
Nummulites					
laevigatus	×	—	—	—	—
cfr. *lamarcki*	×	—	—	—	—
vredenburgi	—	—	—	—	×
djokdjokartae	—	—	—	—	×
baguelensis	×	—	—	—	—
kelatensis	×	—	—	—	—
pengaronensis	—	×	×	×	×
Assilina					
orientalis	×	—	×	—	—
granulosus	×	—	—	—	—
granulosus var. *minor* ...	—	—	×	—	—
Orthophragmina					
javana	—	—	×	×	×
dispansa	—	—	—	×	×
omphalus	—	—	—	×	×
decipiens	×	—	—	×	×
fritschi	—	—	×	—	×
Alveolina					
javana	×	—	—	—	—

It is quite evident that the foraminifera fauna contained in the second group of limestone from Marah, Borneo, now in question, indicates a geological horizon, somewhat intermediate between the Nias I (Middle Lutetian) on one side, and the stage β of Borneo and the Nanggoulan beds of Java (Auversian) on the other, hence the Upper Lutetian.

Description of Fossils.

Nummulites, LAM.

Nummulites subbrongniarti VERBEEK.

Pl. XVII.(II.), Figs. 1–8.

1871. *Nummulites subbrongniarti* VERBEEK: Die Nummuliten des Borneo Kalksteines, p. 6, pl. I., figs 2 a, b; pl. II., figs. 1 a-r.

1896. *N. subbrongniarti* VERBEEK et FENNEMA: Java et Madoura, p. 1154.

1905. *N. subbrongniarti* DOUVILLÉ: Foraminifères du tertiaire de Bornéo, pp. 442, 443, 444.

Microspheric form: Thick lenticular, broadly rounded along the margin; size: 15 mm. in diameter and 6 mm. thick. Young specimens more swollen at the center and thinner along the margin than the adult ones. Surface smooth, without granules; alar prolongation of septa reticulated, meshes being irregularly polygonous and 0.16–0.23 mm. broad in average. Whorls numerous, numbering 23 in a specimen of 15 mm. in diameter; very close, leaving a very narrow interspace between the two consecutive

walls except along the sagittal plane of the shell where the interspace is conspicuously wide. Wall rather thin; in a specimen 6 mm. in its shorter diameter, the wall is thickest when the shell attains a size of 2–3 mm., measuring some 0.16 mm.; from there, the wall becomes gradually thinner as well outwards as inwards. Septa distant; chambers low and considerably elongated spirally.

Megalospheric form: 3 mm. in diameter; considerably swollen, an example 2.72 mm. in diameter being 1.44 mm. thick. Number of whorls 6 in at most. Nucleoconch composed of two chambers, the first one being broad as much as 0.48 mm. Essentially similar in all other features to the microspheric form.

N. subbrongniarti is considered to be the representative of the European *N. intermedius-fichteli* in Eastern Asia,[1] and is believed by H. DOUVILLÉ to be a good zone fossil indicative of the Sannoisian and the Stampian stage; he once recorded the occurrence of *N. subbrongniarti* in the Tertiary of Borneo, and especially in a rock of the Sannoisian stage with *Operculina complanata*, *Heterostegina* aff. *reticulata* and *Sorites martini* in association, and in another of the Stampian stage with *Lepidocyclina mantelli* in association.

Loc.: Marah, Bulungan, E.D. Borneo (NODA Coll. No. 74); Sannoisian. The type specimens of this species first described by VERBEEK are from Riam Kiwa district.

Nummulites cfr. **pengaronensis** VERBEEK.

Pl. XVIII.(III.), Fig. 8.

Compare:

1871. *Nummulites pengaronensis* VERBEEK: Die Nummulites des Borneo Kalksteines, p. 3, pl. I., figs. 1 a–k.

1896. *N. nanggoulani* VERBEEK et FENNEMA: Java et Madoura, p. 1152, pl. VIII., figs. 111–113.

1896. *N. pengaronensis* VERBEEK et FENNEMA: l.c., p. 1152.

1912. *N. pengaronensis* DOUVILLÉ: Quelques foraminifères de Java, p. 384, pl. XXIV., fig. 6.

1912. *N. pengaronensis* DOUVILLÉ: Les foraminifères de l'ile de Nias, p. 263.

The microphotograph here given shows a small *Nummulites* belonging to Radiatae; although this single specimen in section is too fragmental for detailed comparison, yet the numerous, gently curved alar prolongation of its septa indicates its close affinity with *N. pengaronensis* VERBEEK recorded from Borneo, Java and Nias.

As the above species is reported to occur in association with several species of *Orthophragmina* in Borneo and Java, and with a certain species of *Assilina* in Nias, its presence in the present material—which contains *Assilina* and *Orthophragmina*—is highly probable.

N. niasi VERBEEK (*N. niasi* VERBEEK II.,[2]=*N. ramondi* BRADY[3]) is, according to DOUVILLÉ, almost indistinguishable from *N. pengaronensis*.

N. kelatensis CARTER[4] which is also found in association with *Assilina orientalis* and *A. granulosa* in the island of Nias is a species closely allied to *N. pengaronensis*; in the former species, however, the

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1) A. SILVESTRI considers *N. subbrongniarti* VERBEEK and *N. sublaevigatus* ARCH. et HAIME even to be specifically identical with *N.* (*Bruguieria*) *intermedia-fichteli*. A. SILVESTRI: Nummuliti Oligoceniche della Madonna della Catena presso Termini-Imerese (Palermo), Boll. Soc. Geol. Ital., vol. XXVII, 1909, p. 632.

2) *Nummulites niasi* I. of VERBEEK is *Amphistegina*, while *N. niasi* II. is a true *Nummulites*; for the latter the specific name *N. niasi* is retained by DOUVILLÉ. VERBEEK et FENNEMA: l.c., p. 1157, pl. IX., figs. 123–125.

3) BRADY: On Some Fossil Foraminifera from the West Coast District, Sumatra. Geol. Magazine, London, 1875, p. 534, pl. XIII., figs. 4 a, b. *N. ramondi* var. *verbeekiana* BRADY is an *Amphistegina*.

4) DOUVILLÉ: Les foraminifères de l'ile de Nias, p. 262, text-fig. 1. This author considers *N. kelatensis* as the eastern Asiatic representative of *N. atacicus*.

alar prolongation of septa is more strongly curved than in the latter.[1] According to DOUVILLÉ, *N. kelatensis* characterises the Middle Lutetian and *N. pengaronensis* the Upper.

Loc.: Marah, Bulungan, E.D. Borneo (NODA Coll. No. 74); Upper Lutetian.

Assilina, ORBIGNY.

Assilina orientalis DOUVILLÉ.

Pl. XVIII.(III.), Figs. 4 a–b, 4 c?, 5 a–b.

1912. *Assilina orientalis* DOUVILLÉ: Les foraminifères de l'ile de Nias, p. 263, pl. XIX., figs. 6–9.

This is a very characteristic species, being thick lenticular instead of being complanate; the surface shows numerous coarse granules, a few of which on the central part are especially large.

Loc.: Marah, Bulungan, E.D. Borneo (NODA Coll. No. 74); Upper Lutetian.

A. orientalis is previously known from the Middle Lutetian of Nias, the present record being its second occurrence.

Assilina granulosa ARCH. var. **minor** HEIM.

(Megalospheric form—*A. leymeriei* ARCH. et HAIME)

Pl. XVIII.(III.), Figs. 6 a–b, 7 a–b.

1908. *Assilina granulosa* ARCH. var. *minor* HEIM: Nummuliten- und Flyschbildungen der Schweizeralpen, p. 247, pl. VIII., figs. 1–18.

1912. *A. granulosa* DOUVILLÉ: Les foraminifères de l'ile de Nias, p. 263, pl. XIX., figs. 3, 4, 5?; pl. XX., fig. 3?

Another species of *Assilina* which is common in the limestone of the second group from Marah certainly belongs to *A. granulosa* and especially approaches var. *minor* HEIM.

A. granulosa is a species extensively distributed in the nummulitic formations of Europe and Asia; it is easily distinguished from another, likewise a common species; *A. exponens* (megalospheric form—*A. mamillata*) by its lemniscate outline in axial section, and by the possession of less numerous, higher whorls.

Loc.: Marah, Bulungan, E.D. Borneo (NODA Coll. No. 74); Upper Lutetian.

A. granulosa characterises the Upper and Middle Lutetian in Europe; it is found in the Laki division of India and in the Middle Lutetian of the island of Nias.

Orthophragmina, SCHLUMBERGER.

The limestone of the second group from Marah contains two distict species of *Orthophragmina*, both having a somewhat flexuous, circular and discoidal or thin lenticular shell. One of them is distinguished from the other by its relatively large lateral chamberlets and strong pillars; the former belongs certainly to *O. javana* VERBEEK and the latter most probably to *O. fritschi* DOUVILLÉ.

Orthopragmina javana VERBEEK.

Pl. XVIII. (III.), Figs. 2, 3.

1896. *Orbitoides papyracea* var. *javana* VERBEEK et FENNEMA: Java et Madoura, p. 1166, pl. IX., figs. 144–147; pl. X., figs. 150, 151, 155–157.

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1) A. SILVESTRI considers *N. pengaronensis* VERBEEK and *N. nanggoulani* VERBEEK to be specifically identical with *N.* (*Paronaea*) *rotularius* DESH. SILVESTRI: Orbitoidi Cretacee nell'Eocene della Brianza. 1919, p. 48.

1912. *Orthophragmina javana* DOUVILLÉ: Quelques foraminifères de Java, p. 287. pl. XXIII., figs. 1, 2; pl. XXIV., fig. 1.

1915. *Orthophragmina javana* RUTTEN: Studien über Foraminiferen aus Ost-Asien. 8. Vier Eozänvorkommen aus Ost-Borneo. Sam. Geol. Reichs-Mus. Leiden, ser. I., vol. X., p. 7. pl. I., figs. 1–3.

The figured specimen, in tangential section, represents a lenticular shell, attaining more than 10 mm. in diameter; the shell is somewhat flexuous. Lateral chamberlets more or less triangular in tangential section, rather large, being as large as a single chamberlet extending between two adjacent granules. Granules 0.1 mm. thick on an average, their axial distance being 0.23 mm.

Judging from this section, the present form is a swollen variety of *O. javana.*

Loc.: Marah, Bulungan, E.D. Borneo (NODA Coll. No. 74); Upper Lutetian.

O. javana is previously known from Borneo, Java and New Caledonia.[1]

Orthophragmina cfr. **fritschi** DOUVILLÉ.

Pl. XVII.(II.), Fig. 12; Pl. XVIII.(III.), Fig. 1.

1912. *Orthophragmina fritschi* DOUVILLÉ: l.c., p. 288, pl. XXIV., fig. 2.

The figures, here given, represent a species of *Orthophragmina* which differs from the preceding one by being constituted of considerably smaller lateral chamberlets and narrower pillars. Median chamberlets in cyclic order hardly 0.1 mm. long and 0.038 mm. broad; pillars 0.064 mm. broad and at 0.012–0.013 mm. axial distance.

The shell of typical *O. fritschi* is a thin circular disc with a small but prominent boss at its center. The present section are not sufficient for the proper judgment of the general outline of the test; hence there is some uncertainity as to the reference of the fossils in the section to the above-named species, though they agree well with it in all the features recognisable on the sections.

Loc.: Marah, Bulungan, E.D. Borneo (NODA Coll. No. 74); Upper Lutetian.

O. fritschi was previously known from Java.

III.

Notes on *Pellatispira,* BOUSSAC.

Pl. XIX.(IV.) and XX.(V,).

Pellatispira is an interesting and important genus of Foraminifera; it is like an *Assilina* in outline and internal structure; circular, flat discoidal or lenticular; composed of numerous chambers which are more or less distinctly keeled and arranged in a number of volutions in plane spiral. Chambers of a volution embrace but slightly those of the next inner one. Septa radially arranged, being sowewhat convex outwards. Shell-wall and septa similar in texture to those of *Calcarina.*

Genotype: *P. douvillei* BOUSSAC (=*P. madraszi* v. HANTKEN var. *douvillei*). Priabona beds.

BOUSSAC[2] who established this genus on *P. douvillei* and *P. madraszi* from the Priabona beds of Italy and Hungary recognised its affinity to *Assilina.* SCHUBERT[3] soon afterwards declared that the

1) J. DEPRAT: Les Dépôts Éocènes Néo-Calèdoniens. Bull. Soc. Geol. France, ser. IV., vol. V., p. 502, 1905.

2) J. BOUSSAC: Développement et morphologie de quelques foraminifères de Priabona. Bull. Soc. Géol. France, ser. 4, vol. VI. p. 91, 1906.

3) R. SCHUBERT in Neues Jahrb. f. M. G. P., 1908, vol. I., p. 139.

generic distinction of *Pellatispira* and *Assilina* is unnecessary, and more recently PROVALE[1] seemed to take the former as a subgenus of the latter. DOUVILLÉ[2] alone, however, was impressed by the resemblance of *Pellatispira* to *Calcarina* and wrote as follows: "C'est en somme la constitution d'une *Calcarina* dans laquelle les èpines saillantes seraient remplacées par une crête continue."

Thus, *Pellatispira* was regarded by BOUSSAC, SCHUBERT and PROVALE as *Assilina* with a test of considerably coarse texture, and this characteristic texture is exhibited very beautifully in the specimens from Japan. In the specimens from Japan, the shell-wall is invariably composed of two layers, an inner layer which is thin and appears almost compact under low magnification, and an outer layer, thick and very coarsely tubulated. Under high magnification, however, the inner layer also resolves into a finely tubulated one whenever the specimen sliced is preserved favourably for such examination, the tubules attaining 0.01 mm. in diameter, and being one-fourth as narrow as those of the outer layer. In *Pellatispira*, therefore, there are actually two perforated layers taking part in the composition of the shell-wall; thus it differs from *Nummulites* (and *Assilina*) which is provided with the shell-wall single and very finely tubulated according to the prevalent view—or composed of an inner, thin, compact layer and an outer, thick, fibrous one, according to the interpretation of WEDEKIND.[3] At any rate, *Pellatispira* differs entirely from *Nummulites* and *Assilina* in the texture of the shell, and is similar to *Calcarina*.

The texture of the shell-wall of *Calcarina* is excellently illustrated by CARPENTER.[4] As in *Pellatispira*, any thin slices of *Calcarina* show the shell-wall built of two layers; the inner layer which is relatively thin and distinctly perforated,[5] and the outer which is thick and coarsely tubulated. CARPENTER called the inner one "proper wall" and the outer "supplemental skeleton", for the former alone is found to constitute the external wall of newly formed chambers, and the latter is an accumulation of shell-substauce secreted by the organism over the other layer after a time but prior to the formation of the next outer volution.

The septa of *Calcarina* are formed by the infolding of the proper wall; and they are simple and compact. This is also the case in *Pellatispira*.

Another distinction between *Pellatispira* and *Assilina* may perhaps exist in the alar extension of the shell-wall, which is almost unrecognisable in the former, but more or less well developed (though thinner than in *Nummulites* and closely superimposed) in the latter.

Pellatispira is therefore not *Assilina* with coarsely tubulated shell-wall, but is *Calcarina* with chambers arranged in plane spiral; thus it may be placed in Rotaliidae and especially near *Calcarina*. The resemblance of *Pellatispira* and *Assilina* in their external aspect as well as in their internal structure is an interesting instance of convergence.

As cited above, BOUSSAC distinguished two species of *Pellatispira* which are characterised as follows:

P. douvillei BOUSSAC.[6] Diameter 7 mm., thickness 1 mm. Numerous granules in two different sizes distributed all over the surface of the test.

P. madraszi v. HANTKEN.[7] Diam. 4 mm. Granules also in two different sizes, the larger ones being considerably larger than the corresponding ones of the former species and arranged in two regular spiral rows on either side of each volution.

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1) I. PROVALE; Di alcuni nummulitine e orbitoidine dell'isola di Borneo. Riv. Ital. Pal., XIV., 1908, p. 66.

2) H. DOUVILLÉ: Les foraminifères dans le tertiaire de Borneo. Bull. Soc. Géol. France, ser. 4, vol. V., p. 441.

3) H. v. STAFF und R. WEDEKIND: Der Oberkarbone Foraminiferensapropelit Spitzbergens. Bull. Geol. Inst., Upsala, vol. X., 1909, pp. 103–106.

4) W. P. CARPENTER: Introduction to the Study of Foraminifera, p. 220, pl. XIV., figs. 3, 4.

5) The inner layer of the shell-wall of *Calcarina* appears usually also compact under low magnification, even in recent specimens; this fact is important and must always be borne in mind in judging the porosity or non-porosity of a wall with fine texture especially in fossilised materials.

6) BOUSSAC: l.c., p. 91, pl. II., figs. 10–13. PROVALE: l.c., p. 66, pl. IV., figs. 21–24; pl. V, figs. 1–4.

7) v. HANTKEN: Die Fauna der *Clavulina szaboi* Schichten. Mitth. aus dem Jahrb. d. k. ung. geol. Anstalt, vol. IV., p. 86, pl. XVI, fig. 7. 1875. BOUSSAC: l. c., p. 71, pl. II., fig. 14.

LÖRENTHEY,[1] on the other hand, regarded the difference existing between these two forms to be only of varietal and not of specific value; PROVALE who also held the same view distinguished another variety, var. *orbitoidea* PROVALE, which was found in the Eocene of Borneo. The last named variety possesses the following features:

P. madraszi var. *orbitoidea* PROVALE.[2] Diameter 2–5 mm., thickness 1–2 mm. Lenticular, swollen, thinning out towards the thin, sharp margin; surface covered uniformly with numerous granules which become somewhat larger toward the center, and bearing no trace of spiral sulci.

This looks like an *Orbitoides*, though with no trace of reticulation on the surface of the test. Its description is too simple and not accompanied with any illustration of the internal structure; but I believe that a fossil occasionally found in a thin section of a black marl from Tji Peunden near Tjisahan, Tjilangkahan district, Residency Batang, Java,[3] together with numerous *Orthophragmina* and a few *Nummulites*, may safely be assigned to it. I think it is better to raise this variety to a distinct species.

The Bornean form which PROVALE called *P. madraszi* is distinguished from the type of the above-named species and its variety *douvillei* by the more densely pustulated surface of the shell, and may conveniently be distinguished as *P. madraszi* var. *provalei*. Prior to the publication of PROVALE's paper, H. DOUVILLÉ[4] had already reported the occurrence of a species of *Pellatispira* in the Upper Eocene of South Borneo (in a *Orthophragmina* limestone from Temptok near Bintot); more lately, L. RUTTEN[5] figured a "spineless *Calcarina*" from an Eocene limestone of Goenong Kadango on the left side of the Boengaloen river, East Borneo, which is certainly a *Pellatispira*. The same author also stated that he found a "spineless *Calcarina*" in an Eocene limestone from Boentoe Baulo near Kampong Banti in South Celebes; this may be also a *Pellatispira*. At an earlier date, DEPRAT[6] also reported that he had found a similar form in the contemporaneous deposits of New Caledonia.

Pellatispira is also well represented in the nummulitic and orbitoidal limestone of southern Europe, especially of Italy.

So far as we know at present, the genus is confined almost everywhere to the Upper Eocene in the geological range, and its species and varieties, already recorded, are:

P. madraszi v. HANTKEN.
P. madraszi v. HANTKEN var. *douvillei* (BOUSSAC).
P. madraszi v. HANTKEN var. *provalei* YABE.
P. orbitoideus (PROVALE).

As already cited above, this interesting type of foraminifera is now found in certain limestones developed on Haha-jima (Hillsborough Island) in the Ogasawara Group (Bonin Islands) and on Ishigaki-jima in the Riukiu Group, being represented by several forms. However without having isolated specimens at hand, it is difficult to establish distinct species or varieties of the foraminifera, though there are at least such forms among them which may safely be assigned to *P. madraszi* and var. *douvillei*.

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1) J. LÖRENTHEY: Bemerkungen zu der alttertiären Foraminiferenfauna Ungarns (cited after K. ROTH v. TELEGD, Geol. Centralb. vol. XVII., V. 718).

2) PROVALE: l. c., p. 71, pl. V., fig. 5.

3) The specimen was given to me by Prof. K. MARTIN of Leiden, Holland, to whom I wish here to express my thanks for this kindness and for his hospitality and assistance in various ways during my short stay in the city some 10 years ago. See MARTIN: Die Fossilien von Java, Anhang (Die Foraminiferenführenden Gesteine), p. 8. The specimen is marked No. 120 c.

4) H. DOUVILLÉ: l. c., p. 441. BOUSSAC: l. c., p. 91.

5) L. RUTTEN: Studien über Foraminiferen aus Ost-Asien (Fortsetzung). Samm. Geol. Reichsmuseums in Leiden, I., vol. X., No. 1, p. 6, pl. II., 1, 2.

6) J. DEPRAT: Sur la présence de *Pellatispira* dans l'Eocène de Nouvelle-Calédonie. Bull. Soc. Géol. France, ser. 4, vol. IX., 1900, p. 288.

Explanation of Plate XVI.(I.).

Arenaceous Foraminifera adherent to the tests of *Nummulites* from the Eocene of Haha-jima (Hillsborough Island), Ogasawara (Bonin) Group, collected by Mr. T. MATSUO. All magnified nearly 7 times.

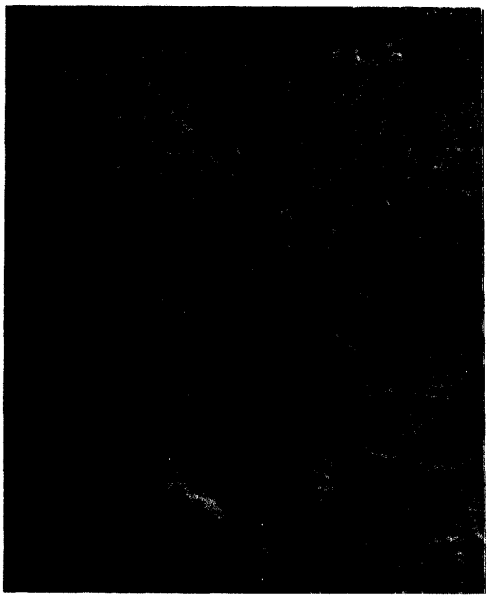
Figs. 1–2. *Sagenina regularis* (DOUVILLÉ).

Figs. 3–5. *Sagenina expansa* YABE.

Figs. 6–8. *Placopsilina cenomana* ORB.

6. A specimen of which some chambers are laid open.
7. A specimen laid open longitudinally, to show the mode of attachment to the substratum Also notice the spiral part.

Fig. 9. *Lituotuba? eocenica* YABE.



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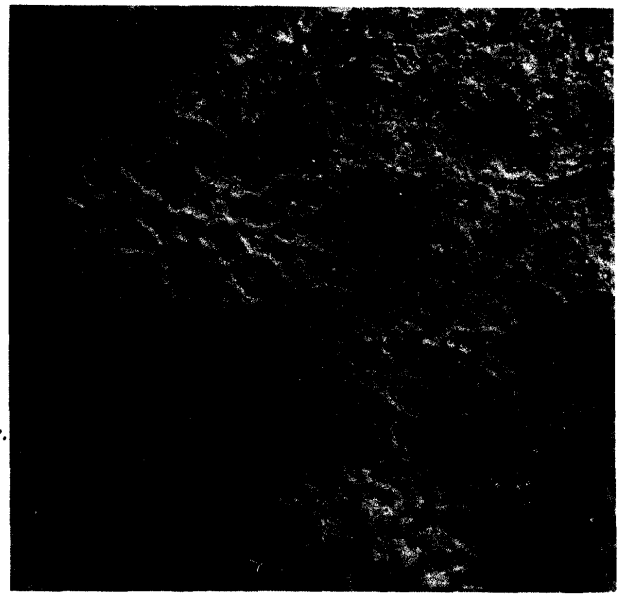

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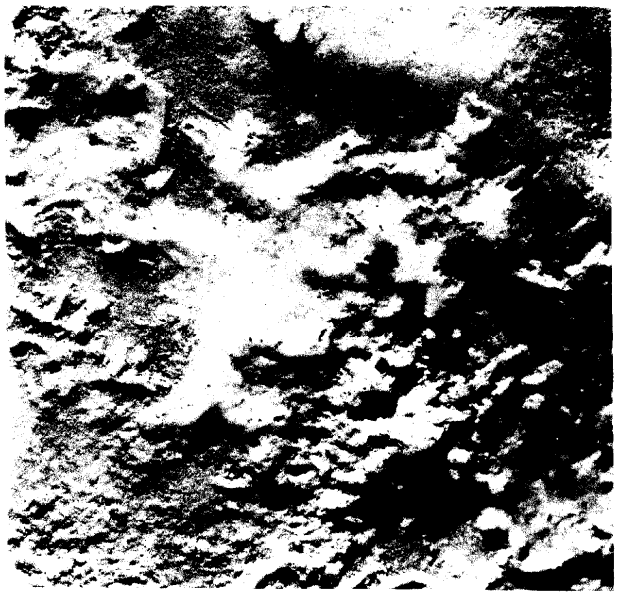

3.

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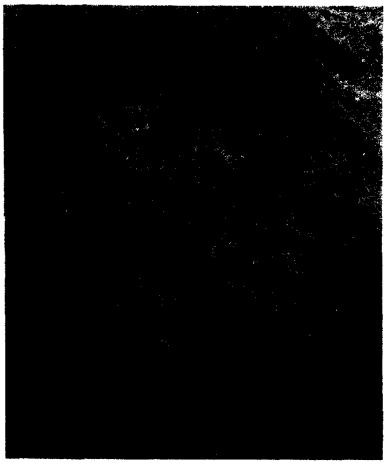

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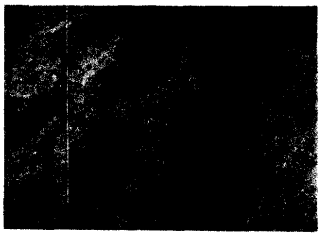
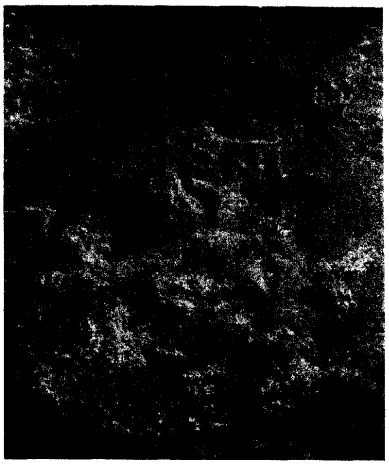


9.

6.



5.

Ebina Photo.

Plate XVII.(II.).

Fossils found in the *Nummulites subbrongniarti*-limestone from Marah, Bulungan, E.D. Borneo, collected by Mr. S. NODA.

Figs. 1–2. *Nummulites subbrongniarti* limestone. × 5.

Fig. 3. *Nummulites subbrongniarti* VERBEEK; microsphaeric form. Showing characteristic reticulation of the septa on the lateral side of the shell. × 20.

Fig. 4. *Nummulites subbrongniarti* VERBEEK; microsphaeric form. Sagittal section, slightly excentric. × 20.

Figs. 5, *a–c*. *Nummulites subbrongniarti* VERBEEK; magalosphaeric form. Axial section through nucleoconch. × 20.

Figs. 6, *a–b*. *Nummulites subbrongniarti* VERBEEK; megalosphaeric form. Sagittal section through nucleoconch. × 20.

Figs. 7, *a–b*. *Nummulites subbrongniarti* VERBEEK; megalosphaeric form with unusually small nucleoconch? Axial section. × 20.

Fig. 8. *Nummulites subbrongniarti* VERBEEK; megalosphaeric form with unusually small nucleoconch? Sagittal section. × 20.

Fig. 9. Gn. et sp. indet.

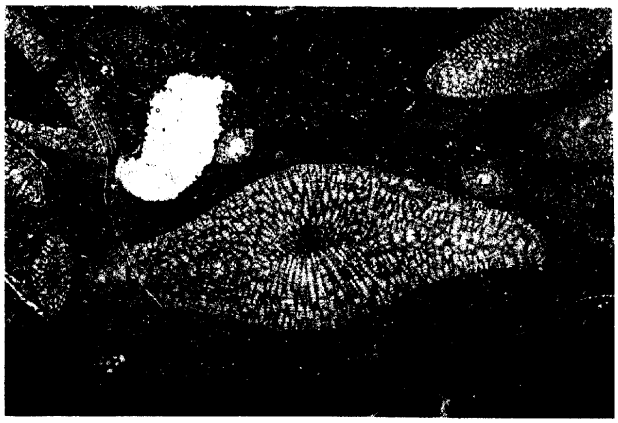
Fossils found in the *Assilina* limestone from Marah, Bulungan, E.D. Borneo, collected by Mr. S. NODA.

Fig. 10. *Assilina* limestone; weathered surface on reflected light. × 1.

Fig. 11. The same in thin section. × 5.

Fig. 12. *Orthophragmina* cfr. *fritschi* DOUVILLÉ. Sagittal section, somewhat excentric. × 15.

12.



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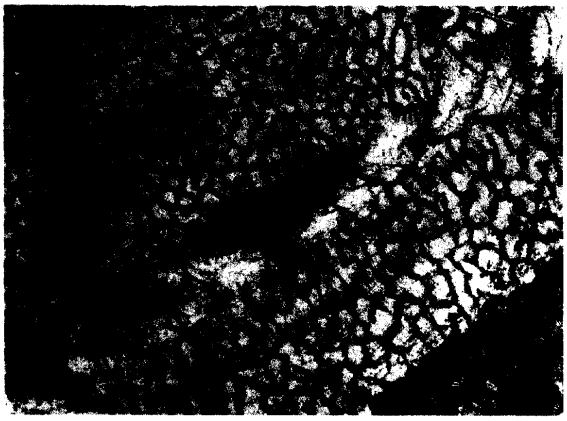

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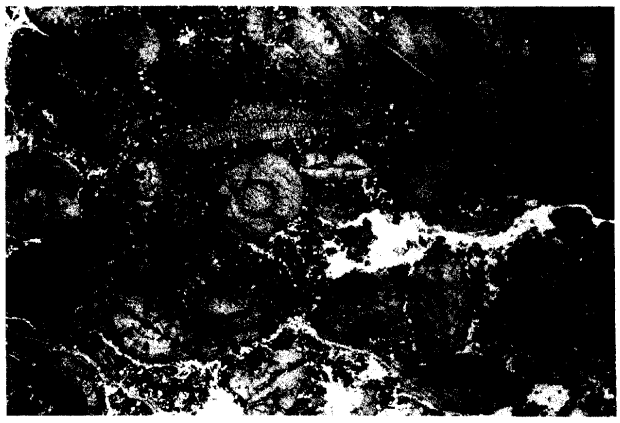
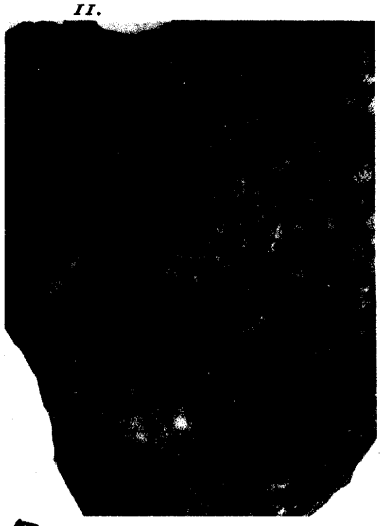


11.

2.

6a.



10.

6b.

5b.

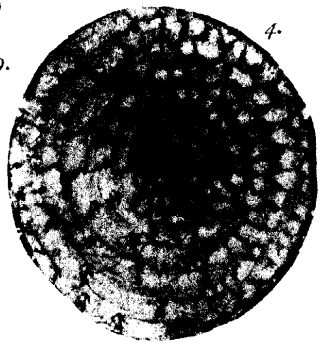
9.

5a.

5c.

7a.

7b.



4.

Otaki Photo.

Plate XVIII.(III.).

Fossils found in the *Assilina* limestome from Marah, Bulungan, E.D. Borneo, collected by Mr. S. NODA.

Fig. 1. *Orthophragmina* cfr. *fritschi* DOUVILLÉ. Sagittal section through nucleoconch. × 15.

Fig. 2. *Orthophragmina javana* VERBEEK. Oblique section. × 15.

Fig. 3. *Orthophragmina javana* VERBEEK. Section perpendicular to the sagittal plane, quite excentric. × 15.

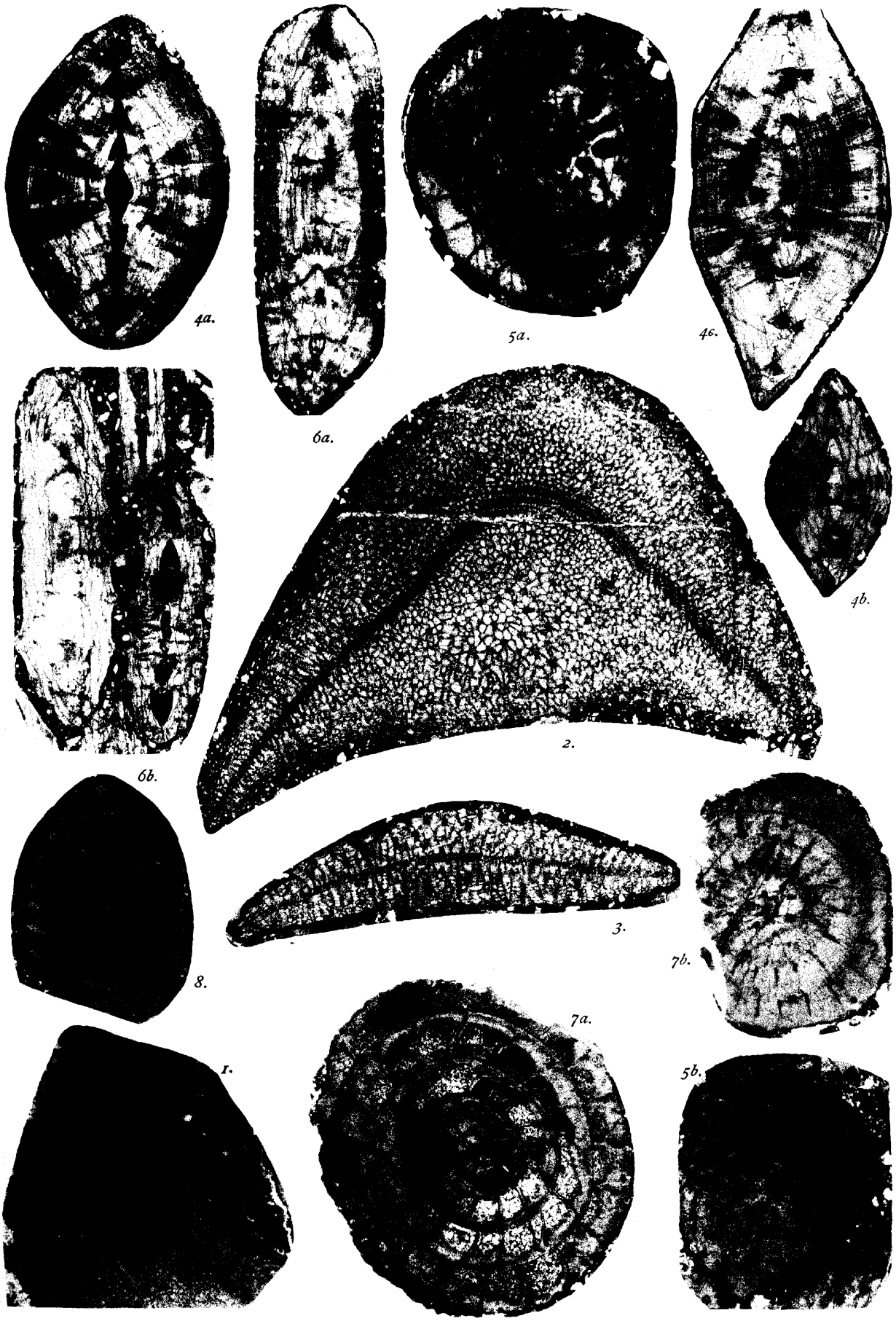
Fig. 4. *Assilina orientalis* DOUVILLÉ. *a* and *b*, two megalosphaeric specimens in axial section through nucleoconch; *c*, a specimen, in axial section somewhat excentric, which is not definitely assigned to either the megalosphaeric or the microspheric form. × 20.

Figs. 5, *a–b*. *Assilina orientalis* DOUVILLÉ; *a*, assigned to this species with some doubt, and *b*, with much confidence. Sections parallel to sagittal plane. × 20.

Figs. 6, *a–b*. *Assilina granulosa* ARCH.; *a*, a specimen with strong granules, and *b*, two with less prominent ones. Section perpendicular to the sagittal plane. × 20.

Figs. 7, *a–b*. *Assilina granulosa* ARCH. Sections parallel to sagittal plane. × 20.

Fig. 8. *Nummulites* cfr. *pengaronensis* VERBEEK. Showing the course of the alar prolongation of septa on the lateral side of the shell. × 20.



Otaki Photo.

Plate XIX.(IV.).

Pellatispira.

Fig. 1. *Pellatispira* limestone from Tôsato, Ishigaki-jima, Riukiu Group. The limestone is essentially composed of the tests of *Pellatispira* and *Lithothamnium*. × 8.

Fig. 2. *P. madraszi* v. HANTKEN from Tôsato, a section slightly oblique and excentric to the sagittal plane. × 20.

Fig. 3. *P. madraszi* var. *douvillei* (BOUSSAC)? from Tôsato; a section almost parallel and slightly excentric to the sagittal plane. × 20.

Figs. 4–6. *P. madraszi* from Tôsato; transverse sections, very excentric. Fig. 6 represents a specimen which may belong to the typical *P. madraszi;* and the other two, those belonging to its more finely pustulated variety.

Fig. 7. *P. madraszi* var. from Oki-mura, Haha-jima, Ogasawara Group; a transverse section, very excentric, showing a strong carina encircling the margin of the shell, which is often entirely worn out as in the specimen represented by the fig. 5. × 20.

Fig. 8. *P. madraszi*, a finely pustulated variety (var. *douvillei?*) from Ibaruma, Ishigaki-jima, Riukiu Group; a transverse section slightly excentric. × 20.

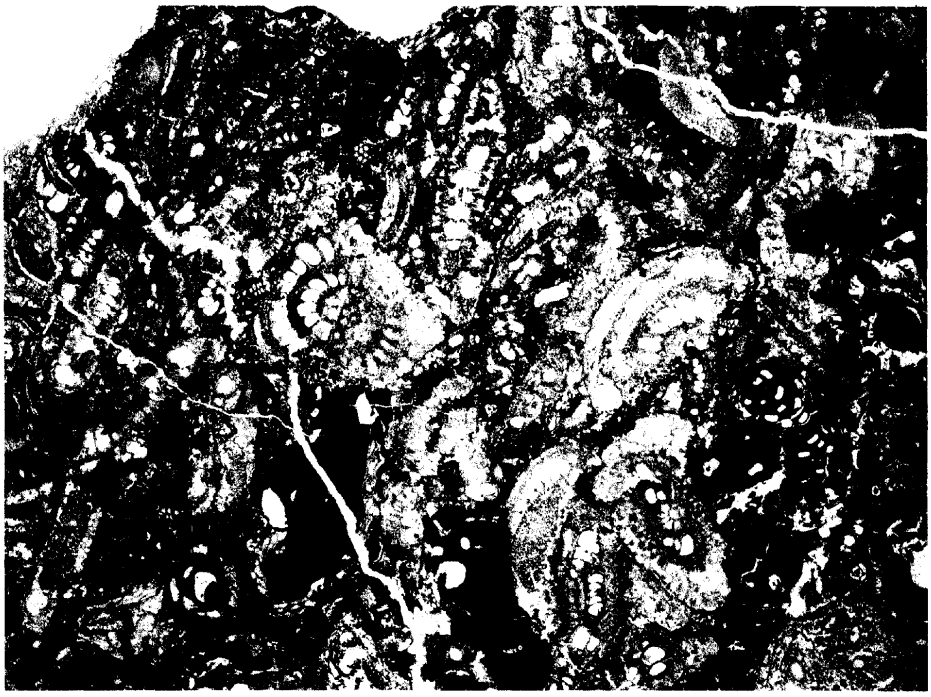


Fig. 1.

Fig. 3.

Fig. 2.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Tamura Photo.

Plate XX.(V.).

Pellatispira and *Calcarina.*

Figs. 1. *P. madraszi* v. HANTKEN, in the *Orthophragmina* limestone from Oki-mura, Haha-jiwa, Ogasawara Group; in transverse section. × 20.

Figs. 2, 2*a*. *P. madraszi* var. *douvillei* BOUSSAC, in the *Pellatispira* limestone from Ibaruma, Ishigaki-jima, Riukiu Group; in transverse section. Fig. 2, × 20; fig. 2*a*, × 94. Fig. 2*a* represents a small part of the shell wall, marked with × on the fig. 2.

Figs. 3, 3*a*. *Calcarina spengleri* P. J. & B.; a thin section of a recent specimen collected from the shore of the atoll Jaluit. Fig. 3, magnified 20 times, shows the coarsely tubulated outer layer and the apparently compact inner thin layer of the shell wall. Fig. 2*a* is a part of it, highly magnified, and shows that the inner shell layer is in reality finely perforated.

Figs. 4 *a–b*. *P. madraszi* v. HANTKEN. *a*, a specimen from the "Ofen marl" of Budapest (after v. HANTKEN); magnification not stated by v. HANTKEN, but certainly 6–8 times magnified. *b*, another one from Priabona (after BOUSSAC); × 7.

Figs. 5 *a–c*. *P. madraszi* var. *douvillei* (BOUSSAC) (after BOUSSAC); *a*, surface view, × 7; *b*, a sagittal section, × 11; *c*, a transverse section, × 11.

Figs. 6 *a–c*. *P. madraszi* var. *douvillei* YABE (after PROVALE); *a* and *b*, surface view, × 4; *c*, a sagittal section, × 5.

Figs. 7 *a–c*. *P. madraszi* PROVALE. *a*, a specimen from Borneo, surface view (after PROVALE), × 7; *b*, a specimen from Tji-Peunden, Java, in sagittal section, × 20; *c*, a specimen from Tji-Peunden, Java, in transverse section, × 20.

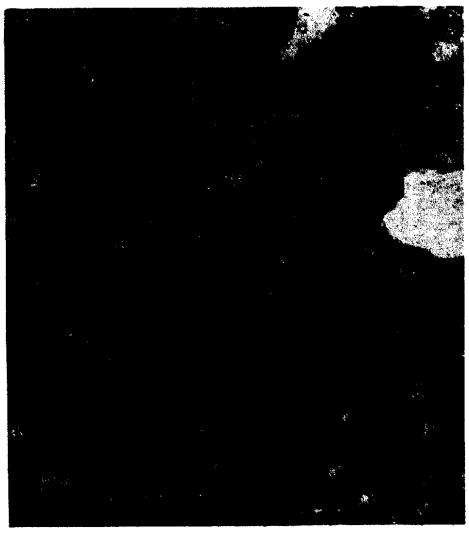


Fig. 2a.

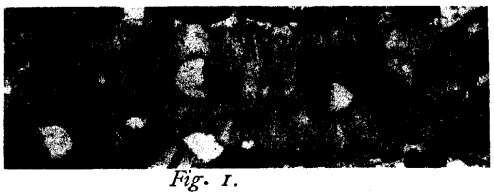


Fig. 1.

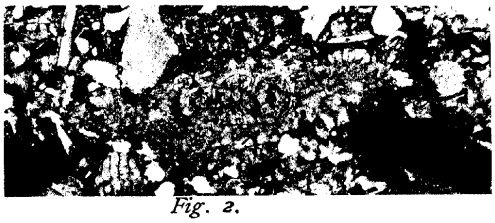


Fig. 2.

Fig. 6a.

Fig. 7b.

Fig. 6b.

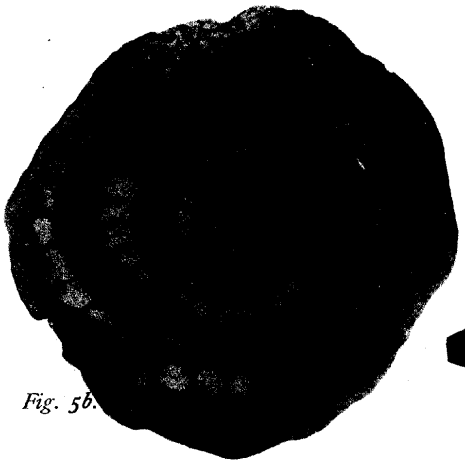


Fig. 5b.

Fig. 7c.

Fig. 5c.

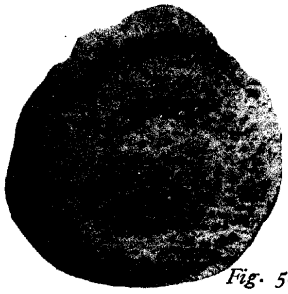


Fig. 5a.

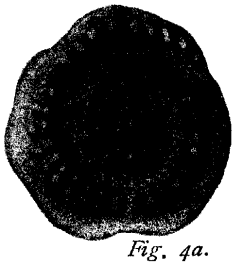


Fig. 4a.

Fig. 6c.

Fig. 4b.

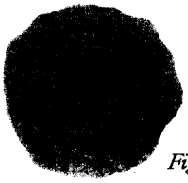


Fig. 7a.

Fig. 3a.

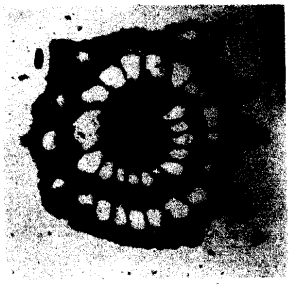


Fig. 3.

Otaki and Ebina Photo.