DESCRIPTION OF A LIMESTONE OF LOWER MIOCENE AGE FROM BOOTLESS INLET, PAPUA.

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With Plates VII, VIII, and IX.

(Communicated by W. S. DUN.)

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1. Introduction.

THE rock specimens from the above locality, for the examination of which I am indebted to my friend Mr. W. S. Dun, of Sydney, have an important bearing on the geology of Papua. The limestone is in fact, a very fine example of a foraminiferal rock denoting a definite horizon in the Cainozoic system. The specimens were collected at Bootless Inlet, Papua, by Mr. J. E. Carne, F.G.S., during his recent geological explorations in search of petroleum-bearing beds.

The present occasion seems to be the second on which Cainozoic fossils belonging to a definite horizon have been obtained from Papua, the first being the determinations made by C. S. Wilkinson in 1876.[1] That author then recorded *Voluta macroptera*, *Volutilithes anticingulatus* and several other genera of mollusca from the blue clays of Hall's Sound, Papua, and which he regarded as common

[1] Proc. Linn. Soc. N. S. Wales, Vol. 1, pt. 2, 1876, pp. 114, 115.

also to the Victorian Cainozoics.[1] He further remarks that "The Miocene clay beds of New Guinea, judging from the specimens collected by Mr. Macleay, are exactly similar in lithological character to the Lower Miocene beds near Geelong, and on the Cape Otway coast in Victoria." Wilkinson accepted McCoy's conclusions as to the Miocene age of the Victorian beds, when he compared them with the clays of Hall's Sound. Since that time, however, some authors have relegated the Victorian beds above named to the lower series, the Eocene. Latterly the writer, having obtained what he regards as conclusive evidence of the sequence and relative ages of the Victorian beds, finds it supports the original idea of McCoy's, that the Geelong and Torquay series are comparable with the Miocene beds of the northern hemisphere. It will, therefore, be of great interest if we can obtain further evidence from Papua as to the relationship of the blue clays to the *Lepidocyclina* limestone herein described.

Wilkinson also referred to an oolitic limestone occurring at Bramble Bay,[2] which he thought to be an upper bed of the Miocene formation. It is here suggested that this and the brecciated rock composed of corals, shells and echinoids, from Yule Island, may have some age affinity with the present brecciated limestone. So far as we can judge from the palæontological evidence, both the *Voluta* clays and the *Lepidocyclina* limestone occur on or about the same horizon; the latter by its characteristic species denoting an Upper Aquitanian stage, whilst the Cape Otway series probably comprises that and the succeeding Burdigalian stages, as seen in the shell marls of Bird Rock and the polyzoal rock of Spring Creek and Batesford[3] respectively.

[1] Wilkinson rightly refers the two species named as common to the Otway series, now called Janjukian, and not, as would be gathered from Mr. Etheridge's note (Pal. Queensland and New Guinea, 1892, p. 697), denoting the fauna of Schnapper Point, Mornington and Muddy Creek.

[2] *Loc. supra. cit.*, p. 115.

[3] The *Lepidocyclinæ* of Batesford denote a higher stage than those of Papua.

In his paper on the echinoids of New Guinea, Tenison Woods[1] referring to the limestone of Yule Island mentioned by Wilkinson, states that he could not "detect any Foraminifera on subjecting different portions to microscopic examination." He also notes its resemblance both lithologically and palæontologically (in the presence of well preserved *Pectens*) to the Mount Gambier limestone, although the Yule Island rock showed an absence of polyzoa.

Besides the Cainozoic fossiliferous rocks above mentioned, Jurassic,[2] doubtful Cretaceous,[3] and numerous Pleistocene fossils[4] have been recorded from Papua.

2. Note on the Bearing of the Foraminiferal Limestones upon the occurrence of Petroleum Fields.

The Cainozoic geology of the petroleum area of the Gulf division of Papua indicates that there are in this district enormous deposits of sandstone, marls and hard limestones. Mr. E. R. Stanley remarks of these beds "All carry fossil remains in parts."[5] The limestones and marls, as shown by this present work and previous papers already quoted,

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[1] Proc. Linn. Soc.. N. S. Wales, Vol. II, pt. 2, 1877, p. 126.

[2] Etheridge, R. jnr., "Our Present Knowledge of the Palæontology of New Guinea." Rec. Geol, Surv. N. S. Wales, Vol. I, pt. 3, 1889, pp. 175, 176. Also Etheridge and Jack, Geol. and Pal. Queensland and New Guinea, 1892, p. 696.

[3] Etheridge, R. jnr., in Pal. Queensland, etc., p. 696. Also Maitland, A. G., "The Salient Features of British New Guinea (Papua)." Journ. W.A. Nat. Hist. Soc., Vol. II, No. 2, May, 1905, p. 52.

[4] Etheridge, R. jnr., Rec. Geol. Surv., N. S. Wales, Vol. I, pt. 3, 1889, p. 174.

[5] See Report by J. E. Carne, F.G.S., on the Petroleum Oil Field, Vailala River, *ibid.*, p. 174. In this report Mr. Carne states that the blue mudstone and sandstone of the Mura Group and at Orokolo Spring contain indications of petroleum ; and that the petroleum-bearing strata of Vailala and the coal-seams at Purari and Curnick Rivers are identical in age. Mr. Carne further draws attention to the probable westerly extension of the oil belt across Dutch New Guinea and thence to Timor and Java. Also "Report on the Geology of the Vailala Petroleum Area, Gulf Division, Papua." Stanley, E. R., Commonwealth Government Report on Papua, for the year ending June 30th, 1912, p. 176.

are of true Cainozoic age, and this opinion as regards the mudstones is further confirmed by Stanley's determination of the fossils from the petroleum-bearing mudstones as consisting largely of *Pleurotomiidæ* and *Dentaliidæ*. Bearing in mind the fact that both the mudstone and the limestone form part of a nearly synchronous series, it is most necessary to follow up this discovery of a Lower Miocene limestone by further collecting in other areas of the country.

The close relationship of these *Lepidocyclina* limestones with oil-bearing strata is not confined to Papua, but is a prominent feature in Borneo, Sumatra and Java, with which fields the present locality is undoubtedly stratigraphically connected. Verbeek and Fennema, in their exhaustive geological treatise on Java and Madoura[1] refer to the probability of the vast number of foraminifera found having been the source of the petroleum in those islands. Thus these authors observe[2] that "il est très probable que l'on doit chercher l'origine du pétrole dans la masse sarcodaire de ces foraminifères, très petits il est vrai, mais existant à des millions d' examplaires; en effet, cette masse contient des matières grasses, et déjà l'on a réussi à fabriquer artificiellement du pétrole par distillation des graisses."

As a corollary to this theory of a foraminiferal origin of the petroleum in certain areas, one may mention that many of the foraminiferal limestones of Carboniferous age in England and Scotland, as the *Endothyra* and *Saccammina* limestones, are often highly bituminous; and there is also a limestone rich in bitumen found in the Carboniferous of Russia, which is crowded with the remains of the foraminifer, *Schwagerina*. Whilst pointing out the economic value of the foraminiferal remains as a source of hydrocarbon, it is also noted that the fish remains found in these

[1] Description géologique de Java et Madoura, Vols. I and II, Amsterdam, 1896. [2] *Op. cit.*, Vol. II, p. 1043.

Papuan rocks, may in some strata as yet undiscovered, be found to occur in greater abundance than in the present limestone sample, and consequently yield a further supply of oily material, as they have been known to do elsewhere.

3. Detailed Description of the Limestone.

General Structure.

The limestone of Bootless Inlet is a fairly compact rock, but shows a sub-brecciated structure in which the fragmentary character was induced prior to the final cementation of the constituents.

A microscopical examination shows that in its initial stages of formation, this rock was a shallow-water shelly and coral sand, the particles being intermingled with fragments of a now partially or wholly decomposed volcanic rock of diabasic and andesitic nature, some fragments being quite glassy in structure as if derived from submarine ejections. The component organisms forming the rock are foraminiferal tests, among which are some gigantic species of *Lepidocyclina*, fragments of fish-teeth and bone, echinoid remains, polyzoa and calcareous algæ. The separate organisms show signs of severe treatment, being not so much water-worn as angularly chipped and fractured, especially in the case of the larger foraminiferal tests. In most examples the peripheral edges of the large, peltate forms, as *Heterostegina* and *Lepidocyclina*, have been chipped and broken, and some of the organic material has been finely comminuted. Tidal and current action would scarcely account for this subangular, and even angular, condition of the shells, and many of the fragments are so sharply fractured as to lead one to conclude that fishes with crushing teeth, as the *Labridæ* and *Sparidæ*, as well as other predatory animals, such as the echinoids and star-fishes, may be partly or wholly responsible for the peculiar condition of the material composing this limestone.

Towards this conclusion strong support is rendered by the relative abundance of fish remains, as teeth and bone fragments, occurring scattered throughout the limestone. The writer had already drawn attention[1] to the possibility of such reef-forming foraminifera as *Carpenteria* which occur in coral islands, having been broken up by predatory fishes which would find a nutritious pabulum in the protoplasmic tests of the larger rhizopods.

Description of Fossil Remains in the Limestone.

PLANTÆ.

Genus LITHOTHAMNION, Philippi, 1837, emend. Foslie, 1900.

LITHOTHAMNION RAMOSISSIMUM, Reuss sp.

Nullipora ramosissima, Reuss, 1848, Haidinger's Naturw. Abhandl., Vol. II, pt. ii, p. 29, pl. iii, figs. 10, 11.

Lithothamnion ramosissium, Rss. sp., Gümbel, 1871, Abhandl. k. bayer. Akad. Wiss., Vol. XI, pt. i, p. 34, pl. i, figs. 1a - d. Smith, W. W., 1907, Phil. Journ. Sci., Vol. II, No. 6, p. 396, pl. III ? IV. Chapman, 1913, Proc. Roy. Soc. Vict., Vol. XXVI, (N.S.) pt. i, p. 166, pl. xvi, figs. 1 a—c, 2, 3.

Fragments of this branching type of calcareous alga are quite common in the limestone. It often materially helps to build up limestones of Cainozoic, and especially of Miocene age; as for example the "Leitha Kalk" of the Vienna Basin. It generally accompanies the *Lepidocyclina* limestone of the Indo-Pacific area, as at Christmas Island, Borneo, Japan, the New Hebrides and the Philippines. In Australia, *Lithothamnion* is of frequent occurrence in the Janjukian series of Victoria and South Australia.

[1] "Foraminifera collected round the Funafuti Atoll from Shallow and Moderately Deep Water." Journ. Linn. Soc. Lond., Zool. Vol. XXVIII, 1902, p. 394 (in note on *Carpenteria balaniformis);* and on p. 395 (in note on *C. raphidodendron*).

Lithothamnion sp.

A laminate or encrusting species also occurs in the limestone. It has numerous conceptacles immersed below the surface of the thallus, and therefore belongs to the above genus. The specimen is probably the encrusting condition of the foregoing species, which, being attached to a free particle, is prevented by its motion from taking on the dendroid habit of the normal form.

FORAMINIFERA.

Fam. Miliolidæ.

Genus MILIOLINA, Williamson.

Miliolina sp.

A section across the test of a milioline occurs in one of the limestone sections. It resembles *M. circularis*, Bornemann sp. in general contour. It belongs, moreover, to a group which is at home in shallow-water deposits in all parts of the world.

Fam. Textulariidæ.

Genus TEXTULARIA, Defrance.

Textularia rugosa, Reuss sp.

Plecanium rugosum, Reuss, 1869, Sitzungsb. d. k. Ak. Wiss. Wien, Vol. LIX, p. 433, pl. i, figs. 3a, b.

Textularia rugosa, Rss. sp., Brady, H. B., 1884, Rep. Chall. Vol. IX, p. 363, pl. xlii, figs. 23, 24. Chapman, 1907, Journ. Linn. Soc. Lond., Zool. Vol. XXX, p. 27, pl. iii, fig. 57.

A vertical section showing the characteristic features of the test of the above species occurs in one of the thin slices of limestone. It is a peculiarly restricted coral reef species, although very rarely found under other and more argillaceous conditions in warm temperate seas. Especially was this so in past times, as in the Oligocene of Gaas,

south of France, and the Oligocene of Grice's Creek, Victoria.

T. rugosa is of frequent occurrence in the limestone containing *Lithothamnion* and *Lepidocyclina* of Christmas Island,[1] belonging to the same geological horizon as the present sample. In the living condition it has been frequently recorded from the South Pacific and East Indian areas, as round Funafuti, Honolulu, Sandwich Islands, Admiralty Islands, Friendly Islands, as well as in the Gulf of Suez.

Fam. Globigerinidæ.

Genus GLOBIGERINA, d'Orbigny.

GLOBIGERINA BULLOIDES, d'Orbigny.

Globigerina bulloides, d'Orbigny, 1826, Ann. Sci. Nat., Vol. VII, p. 277, No. 1, Modèles, No. 17 and No. 76. Brady, H. B., 1884, Rep. Chall. Vol. IX, p. 593, pls. lxxvii, lxxix, figs. 3–7.

Occasional small-sized tests of the above species occur in the present sample of limestone from Papua. It is a pelagic form, but by no means confined to the open sea, although there most abundant.

GLOBIGERINA TRILOBA, Reuss.

Globigerina triloba, Reuss, 1849, Denkschr. Akad. Wiss. Wien., Vol. I, p. 374, pl. xlvii, fig. 11. *G. bulloides*, d'Orb., var. *triloba*, Rss., Brady, H. B., 1884, Rep. Chall., Vol. IX, p. 595, pl. lxxix, figs. 1, 2; pl. lxxxi, figs. 2, 3. *G. triloba*, Rss., Chapman, 1910, Proc. Roy. Soc. Vict. Vol. XXII, (N.S.) pt. ii, p. 281.

[1] Jones and Chapman, "On the Foraminifera of the Orbitoidal Limestone and Reef Rock of Christmas Island." Mon. Christmas Island (Brit. Mus.) by C. W. Andrews, 1900, p. 231.

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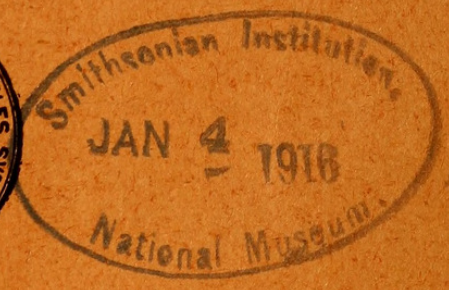
(Plates vii, viii, ix, x, xi, xii.)



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Some small, rather thick-shelled examples of this pelagic species occur in the limestone from Papua. It is one of the species accompanying *Lepidocyclina* in the Miocene limestone at Batesford near Geelong.

GLOBIGERINA CONGLOBATA, Brady.

Globigera conglobata, Brady, 1879, Quart. Journ. Micr. Sci., Vol. XIX, N.S., p. 72. Idem, 1884, Rep. Chall. Vol. IX, p. 603, pl. lxxx, figs. 1 – 5 ; pl. lxxxii, fig. 5.

A few typical examples of this stoutly-built, pelagic foraminifer, so frequently met with in tropical coral-reef deposits, both fossil and recent, occur here. The closely adpressed outer chambers and their excessively thick walls distinguish the form from others of this genus.

Fam. Rotaliidæ.

Genus TRUNCATULINA, d'Orbigny.

TRUNCATULINA cf. LOBATULA, Walker and Jacob sp.

Nautilus lobatulus, Walker and Jacob, 1798, Adams' Essays, Kanmacher's ed., p. 642, pl. xiv, fig. 36.

Truncatulina lobatula, W. and J. sp., Brady, 1884, Rep. Chall., Vol. IX, p. 660, pl. xcii, fig. 10; pl. xciii, figs. 1, 4, 5; pl. cxv, figs. 4, 5.

A partial section of a thin-walled *Truncatulina*, probably nearest to the above species, occurs in the Papuan *Lepidocyclina* rock. It is a common shallow-water form in almost all existing seas.

Genus CARPENTERIA, Gray.

CARPENTERIA CAPITATA, Jones and Chapman. Pl. VII, fig. 1.

Carpenteria capitata, Jones and Chapman, 1900, Mon. Christmas Island (Brit. Mus.), p. 246, pl. xx, fig. 7.

The test in this species is thicker than in *C. monticularis*,[1] and, unlike *C. utricularis*,[2] has a smooth exterior. From *C. raphidodrendon*[3] it is separated by its non-rambling habit, showing a tendency rather to connect *Rupertia stabilis*[4] with *Carpenteria proteiformis*.[5]

Sections of *Lepidocyclina* limestone from Triomoté Island, Loo Choo Islands, show the rock to contain numerous remains of *Carpenteria* which Messrs. Newton and Holland[6] have compared in one instance with the above species, *C. capitata*.

The Christmas Island specimen measures 6 mm. in height, whilst the largest specimen in the present limestone sample is 2·5 mm. Several specimens occur in the limestone sections examined.

Genus ROTALIA, Lamarck.

ROTALIA CALCAR, d'Orbigny sp.

Calcarina calcar, d'Orbigny, 1826, Ann. Sci. Nat., Vol. VII, p. 276, No. 1; Modèle, No. 34. Idem, 1839, Foram. Cuba, p. 93, pl. v, figs. 22 – 24.

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[1] *C. monticularis*, Carter, Ann. Mag. Nat. Hist., Ser. 4, Vol. XIX, 1877, p. 211, pl. xiii. Brady, Rep. Chall. Vol. IX, 1884, p. 677, pl. xcix, figs. 1 – 5. Chapman, Journ. Linn. Soc. Lond., Zool., Vol. XXVIII, 1900, p. 14, pl. ii, fig. 5; pl. iv, figs. 5, 6.

[2] *Polytrema utricularis*, Carter, Ann. Mag. Nat. Hist., Ser. 4, Vol, XVII, 1876, p. 210, pl. xiii, figs. 11 – 16. *Carpenteria utricularis*, Carter sp., Brady, Rep. Chall. Vol. IX, 1884, p. 678, pl. xcix, figs. 6, 7; pl. c, figs. 1 – 4. Chapman, Journ. Linn. Soc. Lond., Zool., Vol. XXVIII, 1900, p. 12, pl. ii, fig. 4; pl. iv, figs. 3, 4.

[3] *C. rhapidodendron*, Moebius, Tageblatt der 49 Versammlung deutscher Naturforscher und Aerzte in Hamburg, 1876, p. 115. Chapman, Journ. Linn. Soc Lond., Zool., Vol. XXVIII, 1900, p. 395, pl. xxv. fig. 2.

[4] *Rupertia stabilis*, Wallich, Ann. Mag. Nat. Hist., Ser. 4, Vol. XIX, 1877, p. 501, pl. xx. Jones and Chapman, Mon. Christmas Island, 1900, p. 254, pl. xxi, fig. 11.

[5] *Carpenteria balaniformis* var. *proteiformis*, Goës, Retic. Rhizop. Carib. Sea, 1882, p. 94, pl. vi, figs. 208 – 214; pl. vii, figs. 215 – 219. *C. proteiformis*, Goës, Brady, Rep. Chall., Vol. IX, 1884, p. 679, pl. xcvii, figs. 8 – 14.

[6] Journ. Coll. Sci. Imp. Univ., Tokyo, Vol. XVII, Art. 6, 1902, p. 15, pl. ii, fig. 3.

Rotalia calcar, d'Orb. sp., Brady, 1884, Rep. Chall., Vol. IX, p. 709, pl. cviii, fig. 3. Chapman, 1910, Proc. Roy. Soc. Vict., Vol. XXII (N.S.), pt. ii, p. 289, pl. iii, fig. 2.

This is a typical coral-reef species at the present day. As a fossil it occurs in the older Muddy Creek beds (Oligocene); and in the Batesford limestone series (Miocene).

One or two specimens with the salient features well-defined, occur in the limestone. They show the strong papillæ and vestiges of the spurs of secondary shell-growth of this species.

Fam. Nummulinidæ.

Genus AMPHISTEGINA, d'Orbigny.

AMPHISTEGINA LESSONII, d'Orbigny. Plate VII, fig. 2; Plate IX, fig. 8.

Amphistegina lessonii, d'Orbigny, 1826, Ann. Sci. Nat., Vol. VII, p. 304, No. 3, pl. xvii, figs. 1–4; Modèle, No. 98. Brady, 1884, Rep. Chall. Vol. IX, p. 740, pl. cxi, figs. 1–7. Flint, 1899, Rep. U.S. Nat. Mus. (Rep. for 1897), p. 338, pl. lxxx, fig. 4.

The lenticular tests of the above species are very abundant in portions of the Papuan limestone. The majority of the shells are of the thick, inæquilateral type, typical of the warmer areas of the coral seas at moderately shallow depths. The post-Miocene limestone of Port Stanley, New Hebrides, contains similar varietal forms with thickened tests, associated with the encrusting *Polytrema planum*, Carter.[1]

Genus OPERCULINA, d'Orbigny.

OPERCULINA COMPLANATA, Defrance sp. Plate VII, fig. 2.

Lenticulites complanata, Defrance, 1822, Dict. Sci. Nat., Vol. XXV, p. 453.

[1] As at Funafuti and elsewhere, see Chapman, Journ. Linn. Soc. Lond., Zool., Vol. XVIII, 1901, p. 205.

Operculina complanata, Defrance sp., Newton and Holland, 1902, Journ. Coll. Sci., Imp. Univ. Tokyo, Vol. xvii, Art. 6, p. 13, pl. i, figs. 3, 5; pl. iii, fig. 3. Chapman, 1908, Proc. Linn. Soc. N. S. Wales, Vol. xxxii, pt. iv, p. 749, pl. xxxvii, figs. 1, 2; pl. xxxviii, fig. 3.

Several tests of the above species occur in the limestone sections; but the form is not so common as that of *Heterostegina depressa* in the same rock, and which it much resembles in section. In *Heterostegina* the area around the umbilical axis in vertical section is correspondingly thicker than in *Operculina*, and a few fragments in horizontal section bear out this determination.

O. complanata is a typical and common form in almost all Cainozoic deposits laid down in warm temperate seas. Amongst other places it occurs at Muddy Creek, Victoria (Oliogocene), and the New Hebrides (Miocene); as well as in the Raised Coral Reefs of the Loo Choo Islands, Japan (? Pleistocene).

Genus HETEROSTEGINA, d'Orbigny.

HETEROSTEGINA DEPRESSA, d'Orbigny. Plate IX, fig. 9.

Heterostegina depressa, d'Orbigny, 1826, Ann. Sci. Nat., Vol. vii, p. 305, pl. xvii, figs. 5–7; Modèle, No. 99. Brady, 1884, Rep. Chall., Vol. ix, p. 746, pl. cxii, figs. 14–20. Chapman, 1900, Journ. Linn. Soc. Lond. Zool., Vol. xxviii, p. 18, pl. iii, figs. 6, 7.

Unlike the structure of the living forms of this species, which show in the majority of cases that they belong to the megalospheric stage (propagation by budding), the Papuan fossil examples are nearly always microspheric (adapted for sexual generation).

H. depressa is very common in thin slices of the Papuan limestone. The species is widely distributed, generally in coral seas and warm temperate areas, and is found fossil from Eocene times.

HETEROSTEGINA MARGARITATA, Schlumberger.

Plate IX, fig. 11.

Heterostegina margaritata, Schlumberger, 1902, Samml. Geol. Reichs. Mus. Leiden, Ser. 1, Vol. VI, pt. iii, p. 252, pl. vii, fig. 4.

One or two well marked examples of this species are found in the limestone sections. They are easily distinguished from *H. depressa* not only by the pustulate ornament of the surface, but from the internal structure seen in section, in which the cones of non-tubulate shell are distinctly marked off from the rest of the test.

The species probably occurs also in the Middle Miocene (Janjukian) of Batesford, as previously remarked by the writer.[1]

Schlumberger's specimens came from Teweh, Borneo, and his figured example shows the megalospheric stage.

Genus CYCLOCLYPEUS, Carpenter.

CYCLOCLYPEUS COMMUNIS, Martin. Plate IX, fig. 8.

Cycloclypeus communis, Martin, 1880, Niederländische Archiv fur Zool., Leyden, Vol. v, p. 191, pl. xiii, figs. 1, 2.

Fragments of the tests of this generic type are distributed throughout the Papuan limestone. No isolated test-fragments could be seen, however, on the small portion of the weathered surface of the rock examined, so that a definite determination of the species was impossible.

Two species of this genus have already been recorded from Miocene *Lepidocyclina* limestone; one of these is the above species from Java (Martin) and Borneo (H. Douvillé), the other being *C. pustulosus*, Chapman, from the New Hebrides[2] and Batesford near Geelong.[3]

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[1] Proc. Roy. Soc. Vict., Vol. XXII, (N.S.), pt. ii, 1910, p. 295.

[2] Journ. Linn. Soc. N. S. Wales, Vol. XXX, 1905, p. 271, pl. v, fig. 1; pl. vi, fig. 2; pl. vii, fig. 2.

[3] Proc. Roy. Soc. Vict., Vol. XXII, (N.S.), pt. ii, 1910, p. 295, pl. ii, fig. 6; pl. v, fig. 4.

The lengths of the chamberlets near the centre of the disc in *C. communis*, as given by Martin, measure $\frac{1}{10}$ mm., whilst that of *C. pustulosus* is much smaller, being only about $\frac{1}{42}$ mm. In the present example the chamberlets of about the third annulus from the primordial chambers have a mean length of $\frac{1}{14}$ mm., so that the evidence in this respect is in favour of a reference to the above species, *C. communis*.

Genus LEPIDOCYCLINA, Gümbel.

LEPIDOCYCLINA SUMATRENSIS, Brady sp. Plate VII, fig. 3.

Orbitoides sumatrensis, Brady, 1875, Geol. Mag., Dec. II, Vol. II, p. 536, pl. xiv, fig. 8.

Orbitoides (Lepidocyclina) sumatrensis, Brady, Newton and Holland, 1899, Ann. Mag. Nat. Hist., Ser. 7, Vol. III, p. 259, pl. x, figs. 7, 8, 10, 11 (fig. 12 = *L. tournoueri*, Lem. and Douv.). Jones and Chapman, 1900, Mon. Christmas Island (Brit. Mus.), p. 244, pl. xx, fig. 6.

Lepidocyclina sumatrensis, Brady sp., Silvestri, A., 1906, Atti della Pontificia Accad. Rom. d. Nuovi Lincei, Anno LIX, p. 150.

Some typical and beautifully preserved specimens of *L. sumatrensis* occur in the limestone sections. They are of average dimensions, having a diameter of about 3 mm. The Borneo specimens also have a diameter of 3 mm., whilst those from the Loo Choo Islands are only 1·5 mm.

Lemoine and Douvillé have recorded *L.* cf. *sumatrensis* from France and Spain,[1] but that particular form is herein referred to *L. Andrewsiana*, Jones and Chapman for reasons subsequently mentioned. *L. sumatrensis* has been cited, with some reservation by the present writer, from the New Hebrides Miocene.[2] Other localities for this species are,

[1] Mem. Soc. Geol. France, Vol. XII, pt. ii, 1904, p. 18, pl. i, fig. 14; pl. ii, fig. 15; pl. iii, fig. 6.

[2] Chapman, Journ. Linn. Soc. N. S. Wales, Vol. xxx, 1905, p. 267, and ibid., Vol. XXXII, pt. 4, 1908, p. 753.

Borneo, Sumatra, Christmas Island and the Loo Choo Islands, Japan.

LEPIDOCYCLINA ANDREWSIANA, Jones and Chapman sp.
Plate IX, fig. 8.

Orbitoides (Lepidocyclina) Andrewsiana, Jones and Chapman, 1900, Mon. Christmas Island (Brit. Mus.), p. 255, pl. xxi, fig. 14.

Lepidocyclina sumatrensis, Newton and Holland (non Brady), 1902, Journ. Coll. Sci. Imp. Univ., Tokyo, Vol. XVII, Art. 6, p. 11, pl. i, fig. 7.

L. cf. *sumatrensis*, Brady, Lemoine and Douvillé, R., 1904, Mem Soc. Geol. France, Vol. XII, pt. ii, p. 18, pl. i, fig. 14; pl. ii, fig. 15; pl. iii, fig. 6.

L. Andrewsiana, J. and C., Chapman, 1908, Journ. Linn. Soc. N.S. Wales, Vol. XXXII, p. 757, pl. xxxix, fig. 10.

This species is distinguished from *L. sumatrensis*, Brady sp., by its lenticular rather than subglobular shape, the circumferential disc as a rule being pronounced. It is a larger species than *L. sumatrensis*, averaging about six milimetres in diameter. The megalospheric condition seems to obtain in all the specimens examined or described. Lemoine and Douvillé figure interesting examples from Spain, France and Italy under the name of *L.* cf. *sumatrensis*, Brady, but marked differences from that species are evident in the more numerously pustulate central area of the disc, and the tendency to develop a depressed border. These differences have already been noticed by Dr. A. Silvestri,[1] who refers to this form under a separate heading from the species identified with Brady's true *L. sumatrensis*. From *L. tournoueri*, *L. Andrewsiana* is chiefly distinguishable by the compact structure of the latter as regards the peripheral layers. The examples from the Loo Choo Islands

[1] Atti della Pontificia Accad. Rom. d. Nuovi Lincei, Anno LIX, p. 150.

described and figured by Newton and Holland also belong to this species.

Distribution.—Spain, France, Italy, New Hebrides, Loo Choo Islands, and Christmas Island.

LEPIDOCYCLINA MURRAYANA, Jones and Chapman sp.
Plate VIII, fig. 7.

Orbitoides (Lepidocyclina) Murrayana, Jones and Chapman, 1900, Mon. Christmas Island (Brit. Mus.), p. 252, 253, pl. xxi, fig. 10.

Lepidocyclina formosa, Schlumberger, 1902, Samml. des Geol. Reichs-Mus. Leyden, Ser. 1, Vol. VI, pt. 3, p. 251, pl. vii, figs. 1–3. Douvillé, R., 1909, Ann. Soc. Roy. Zool. et Malac. de Belgique, Vol. XLIV, p. 135, pl. vi, figs. 1, 2. Provale, 1909, Rivista Ital Pal., Anno XV, p. 5, pl. ii, figs. 1–3.

The test of this striking species, which belongs to the group of *L. dilatata*, Michelotti and *L. insulae-natalis*, Jones and Chapman, has an undulating disc, which, when cut equatorially, gives the appearance of a central disc with four or more rays. Schlumberger described his *L. formosa* as a new species, on the supposition that our *L. Murrayana* had rectangular chambers. This was evidently due to a misreading of our original description, where, speaking of *Orbitoides stellata*, we state[1] of that species that it "has rectangular chambers in the median plane and consequently belongs to the *Discocycline* series." However, we proceed to say "the earlier known species (*O. stellata*) having rectangular chambers in the median plane, we have named this form, which has the rounded imbricated chambers, distinctively as *Orbitoides (Lepidocyclina) Murrayana*." It follows therefore that *L. formosa* drops into the synonymy of the above species.

[1] Mon. Christmas Island (Brit. Mus.), 1900, p. 253.

Distribution.—Christmas Island, Indian Ocean (Chapman); Borneo (Schlumberger); German East Africa and Madagascar (R. Douvillé).

LEPIDOCYCLINA VERBEEKI, Newton and Holland sp.

Plate VIII, figs. 5, 6; Plate IX, fig. 10.

Orbitoides papyracea, Brady (non Boubée), 1875, Geol. Mag. Dec. II, Vol. II, p. 535, pl. xiv, fig. 1.

Lepidocyclina sp. *g* and *k*, Verbeek and Fennema, 1896, Descr. Geol. de Java et Madoura, Vol. I, pl. xi, figs. 173–175, 177–180; Vol. II, p. 1178.

Orbitoides (Lepidocyclina) Verbeeki, Newton and Holland, 1899, Ann. Mag. Nat. Hist., Ser. 7, Vol. III, p. 257, pl. ix, figs. 7–11; pl. x, fig. 1. Jones and Chapman, 1900, Mon. Christmas Island (Brit. Mus.), p. 245. Newton and Holland, 1902, Journ. Coll. Sci. Imp. Univ. Tokyo, Vol. XVII, Art. 6, p. 12.

Orbitoides? Verbeeki, M. and H., Smith, W. D., 1906, Phil. Journ. Sci., Vol. I, No. 2, p. 206, pl. ii, fig. 1.

This modification of the species, represented by form *A*, is abundant in the Papuan limestone. It is distinguished from *L. Andrewsiana* by its more lenticular shape and absence of large, well-marked pillars; the superficial papillæ, representing the terminations of these pillars, being very small, and imparting a granulate appearance to the exterior. As a rule the tests are regular, but occasionally the disc tends to become slightly flexuose, but not to so marked a degree as in *L. Murrayana*.

Form *A*.—This is very common. The diameter of the test averages about 7 mm. Verbeek's figured specimen measures 4·6 mm. The megaspheres in the Papuan examples have a larger diameter of 690μ–1170μ; whilst Verbeek's specimen is only 360μ.

Form *B*.—This form is rare and of large dimensions, one specimen when complete measuring 23 mm. in diameter.

The enormous development of the form *A* and its extraordinarily large megasphere make it necessary to refer this form, the most abundant in the Papuan limestone, to a new variety of *L. Verbeeki*, viz., var. *papuaensis*.

Distribution.—*L. Verbeeki*, which in all previously figured specimens are of the megalospheric form, excepting perhaps the occurrence in the Philippines recorded by W. D. Smith, occurs in Sumatra, Borneo, Christmas Island, Formosa, the Loo Choo Islands, and probably the Philippines.

The present Papuan occurrence appears to be the first undoubted record of the species in the microspheric stage. (Form B.)

ECHINODERMATA.

Echinoid spines and plates.

The radioles of several types, probably belonging to more than one species of sea-urchin are present in this limestone. Remains of the plates of the test in addition show this group to be well represented in the sub-littoral fauna at the time. None of the remains are determinable, although in all probability both diadematoids and spatangoids are present.

POLYZOA.

Fragmental remains of indeterminate remains of polyzoa are occasionally seen in this limestone.

PISCES.

Tooth of fish, allied to ? *Chrysophrys*, Plate VII, fig. 4.

An oblique section of a fish tooth occurs, amongst other obscure fish remains, in one of the limestone sections. On comparing it with a section of the tooth of the living *Chrysophrys* (Sea Bream), the structure is seen to be almost identical, and different from the tooth structure of the *Labridæ* (Wrasses), both of which groups, however, are characteristic feeders on shell-fish and similar food.

4. Summary.

The following organic remains have herein been determined as from the *Lepidocyclina* limestone at creek head, one and a half miles inland from Bootless Inlet, Papua:—

Lithothamnion ramosissimum, Reuss sp.
Miliolina sp.
Textularia rugosa, Rss. sp.
Globigerina bulloides, d'Orbigny.
,, *triloba*, Rss.
,, *conglobata*, Brady
Truncatulina cf. *lobatula*, W. and J. sp.
Carpenteria capitata, J. and C.
Amphistegina lessonii, d'Orb.
Operculina complanata, Defr. sp.
Heterostegina depressa, d'Orb.
,, *margaritata*, Schlumberger.
Cycloclpeus cf. *communis*, Martin.
Lepidocyclina sumatrensis, Brady sp.
,, *Andrewsiana*, J. and C. sp.
,, *Murrayana*, J. and C. sp.
,, *Verbeeki*, Newton and Holland sp. var. *papuaensis*, nov.
Echinoderm remains, indet.
Polyzoa, indet.
Fish tooth, cf. *Chrysophrys*.

Amongst these organisms the important factors in the determination of the Lower Miocene age of the limestone are the genera and species of *Carpenteria*, *Heterostegina*, *Cycloclypeus* and *Lepidocyclina*.

A comparison of the Papuan series of fossils may be profitably made with those given in the table of stages in the Cainozoic series of Borneo by H. Douvllé.[1] This was

[1] "Les Foraminifères dans le Tertiaire de Bornéo." Bull. Soc. Geol. France, Ser. 4, Vol. v, 1905, p. 454.

based on a collection of rocks made in Borneo by Dr. Buxtorf. It shows the Papuan series to be nearest related to Douvillé's stage 10 or Upper Aquitanian, with a slight leaning towards the Lower Aquitanian indicated by the presence of *L. Murrayana*, J. and C. (= *L. formosa*, Schl.). The Upper Aquitanian, however, contains the majority of genera and species found in the present series, as *Heterostegina margaritata*, *Cycloclypeus communis* and *L. Verbeeki*, the latter belonging to the *L. insulæ-natalis* group, with large or medium sized tests, small or undeveloped pillars and closely-set and widely-expanded chamberlets in the peripheral zone. The range of *L. Murrayana* (= *L. formosa*) moreover, is really of higher range in the geological scale than H. Douvillé sets forth in his table, for, as already remarked, this species belongs to the *L. dilatata* group, which is characteristic of the Upper Aquitanian in Italy. In that country Dr. A. Silvestri has shown[1] that *L. dilatata* occurs in company with *L. marginata*, a species which is found in the Miocene of the Geelong District at Batesford, Victoria.

In conclusion it may be noted that this occurrence of a Lower Miocene horizon in Papua is of exceptional interest as showing the existence of another link in the chain of localities where the beds of the old shore-line of the ancient Tethyan sea were laid down. It thus helps to connect with the Victorian occurrence at Batesford, in all probability by way of a portion of the lost shore-line indicated by the subsiding area now occupied in part by the Great Barrier Reef off the north-eastern coast of Australia: whilst a divergent arm extended as far as New Zealand, as shown by the occurrence of *Lepidocyclinæ* at Orakei Bay.

[1] "Distribuzione geographica e geologica di Due Lepidocicline comuni nel Terziario Italiano." Mem. del Pont. Acc. Rom. d. Nuovi Lincei, vol. xxix, 1911, p. 52.

Explanation of Plates.

Plate VII.

Fig. 1. *Carpenteria capitata*, Jones and Chapman. Section nearly vertical to the plane of growth. × 26.

„ 2. *Operculina complanata*, Defrance, and *Amphistegina lessonii*, d'Orb. Several vertical sections. × 26.

„ 3. *Lepidocyclina sumatrensis*, Brady sp. Vertical section. × 13.

„ 4. Vertical section of fish tooth *(? Chrysophrys)*, showing vasodentinal structure.

Plate VIII.

Fig. 5. *Lepidocyclina Verbeeki*, Newton and Holland sp., var. *papuaensis*, nov. Form *B*. Vertical section. × 8.

„ 6. *L. Verbeeki* var. *papuaensis*, nov. Form *A*. Vertical section. × 13.

„ 7. *L. Murrayana*, Jones and Chapman sp. Form *A*. Vertical section. × 16.

Plate IX.

Fig. 8. *Lepidocyclina Andrewsiana*, Jones and Chapman sp. Form *A*. Vertical section: *Amphistegina lessonii*, d'Orb., and *Cycloclypeus* cf. *communis*, Martin.

„ 9. *Heterostegina depressa*, d'Orbigny sp. Vertical section. × 26.

„ 10. *Lepidocyclina Verbeeki*, var. *papuaensis*, nov. Form *A*. Vertical section. × 17.

„ 11. *Heterostegina margaritata*, Schlumberger. Vertical section. × 19.