Geology.— *On Tertiary Rocks and Foraminifera from North-Western Peru.* By L. RUTTEN.

(Communicated at the meeting of September 29, 1928.)

The Institute of Geology of the University of Utrecht was presented by the Bataafsche Petroleum Maatschappij with a collection of rocks from N. W. Peru made by its geologists in the years 1924 and 1925. These rocks are worthy of notice in that they afford new points of view with reference to the Peruvian Tertiary and contain remarkable fossils.

The literature of the Tertiary of N. W. Peru is not extensive. Geological data are to be found in publications by J. GRZYBOWSKI [1]), V. F. MARSTERS [2]), R. A. DEUSTUA [3]), BEEBY THOMPSON [4]) and J. J. BRAVO [5]). Of much greater importance is the minute description of the region by T. O. BOSWORTH [6]). Palaeontological treatises upon the Tertiary of N.-W. Peru are of much earlier date. To the 19th century belong publications by A. D'ORBIGNY [7]), W. M. GABB [8]), E. T. NELSON [9]), and J. GRZYBOWSKI (l.c.). The fossils collected by BOSWORTH have been examined by H. WOODS, H. L. HAWKINS, T. WAYLAND VAUGHAN and J. CUSHMAN [10]), short memoirs on the eocene fauna of N.-W. Peru have

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[1]) J. GRZYBOWSKI, Die Tertiärabl. d. nördl. Peru etc. N. J. f. Min. B. B. **12**. 1899. p. 610—662.

[2]) V. F. MARSTERS, Informe preliminar sobre la zone petrolifera del Norte del Peru. Bol. Cuerpo Ingenieros de Minas y Aguas. Lima. N⁰. 50. 1907.

V. F. MARSTERS, The Physiography of the Peruvian Andes. Ann. New York Acad. Sc. **22**. 1912. p. 225—228.

[3]) R. A. DEUSTUA, Estado actual y porvenir de la industria petrolifera en el Peru. Lima. 1912.

R. A. DEUSTUA, El petroleo en el Peru. Lima. 1921.

[4]) BEEBY THOMPSON, The geology of Northern Peru. Geological Magazine. 1913. p. 233—234.

[5]) J. J. BRÁVO, Reconocimiento de la región costanera de los departementos Tumbes y Piura. Archiv. Asoc. Peruana para el progreso de las ciencias. I. 1921. p. 15—19.

[6]) T. O. BOSWORTH, Geology of . . . . the Northwest Part of Peru. London, 1922.

[7]) A. D'ORBIGNY, Paléontologie du Voyage dans l'Amérique méridionale. Paris. 1842.

[8]) W. M. GABB, Descr. of new species of South American fossils. Amer. J. of Conchology **5**. 1869. p. 263.

W. M. GABB, Description of a collection of fossils, made by Dr. A. RAIMONDI in Peru. J. Acad. Nat. Sc. Philadelphia. (II). **8**. 1877. p. 264.

[9]) E. T. NELSON, On the molluscan fauna of the later Tertiary of Peru. Transact. Connecticut Acad. of Sc. a. Arts II. 1873. p. 186—206.

[10]) H. WOODS, Eocene and Miocene Mollusca; H. WOODS, Eocene Crustacea; H. L. HAWKINS, An echinoid from the Eocene; T. WAYLAND VAUGHAN, Eocene, Corals; J. CUSHMAN, Eocene foraminifera; in: T. O. BOSWORTH, l.c. p. 51—142.

lately been written by H. DOUVILLÉ [1]), and E. W. BERRY [2]). Tertiary foraminifera (to be discussed lower down) have been made known by J. CUSHMAN (l.c.), C. LISSON [3]), A. TOBLER [4]) and H. DOUVILLÉ [5]), while foraminifera from the adjacent part of Ecuador have been described by T. WAYLAND VAUGHAN [6]). Finally E. W. BERRY [7]) has examined miocene plants.

Several results of the older researches deserve mention here. The tertiary deposits of N. W. Peru are of an enormous thickness. The older inquirers were not quite aware of this: GRZYBOWSKY reports a minimum thickness of 700 m; THOMPSON and MARSTERS mention a minimum thickness of about 1500 m. BOSWORTH, whose observations are no doubt the most numerous and the most detailed of all, reports a thickness of from 4500 to 7500 m:

Zorritos formation more than 1500 m (Miocene?).
Lobitos formation more than 1500 m Eocene.
Negritos formation more than 2100 m Eocene.

Neither did geologists agree in the course of time as to the age of the Tertiary. According to GABB several formations occur near Paita, among which there is certainly the Pliocene. NELSON speaks of "Later Tertiary" near Zorritos. According to GRZYBOWSKI the following subdivisions may be distinguished:

Payta Stufe	Pliocene.
Talara Stufe	Miocene.
Zorritos Stufe	Lower Miocene.
Heath Stufe	Lower Miocene.
Ovibio Stufe	Upper Obliocene.

The results of BOSWORTH's inquiry have already been given higher up. For his age-estimations he relies upon the palaeontological determinations

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1) H. DOUVILLÉ, l'Eocène au Pérou. C. R. Acad. Sc. Paris. **171**. 1920. p. 1345—1347. C.R. somm. Soc. Géol. France. **14**. 1921. p. 193.

2) E. W. BERRY, A new Hercoglossa from the Eocene of Peru. Amer. J. Sc. **6**. 1923. p. 427—431.

3) C. LISSON, Contr. al estudio de algunos foraminiferos terciarios provenientes de la región del Norte del Peru. Arch. Asoc. para el progreso de las Ciencias. Lima I. 1921. p. 52—55.

4) A. TOBLER, Neue Funde von Grossforaminiferen in der Nordperuanischen Küstenregion. Eclogae geologicae Helvetiae. **20**. 1927. p. 415—422.

5) H. DOUVILLÉ, Revision des Lepidocyclines. Mém. Soc. Géol. de France. Nouv. Série. I. **2**. 1924.

6) T. WAYLAND VAUGHAN, Foraminifera from the Upper Eocene deposits of the coast of Ecuador. Proc. Nat. Acad. Sc. Washington. **12**. 1926. p. 533—535.

7) E. W. BERRY, Miocene fossil plants from North Peru. Proc. U.S. Nat. Museum. **55**. 1919. p. 279—294.

of WOODS and others. That the results arrived at by GABB, GRZYBOWSKI and BOSWORTH differ, appears from the fact that according to BOSWORTH only Eocene occurs in the territory of Paita and Talara, while GABB and GRZYBOWSKI report Pliocene. On the other hand BOSWORTH indicates between Punta Sal and Paita (see map on p. 934) only "Zorritos formation", whereas TOBLER also describes eocene foraminifera from this region and points out that BOSWORTH's map is certainly too schematic for this region. On the one hand it, therefore, appears from the older inquiries that the network of observations is certainly not close enough, and on the other hand that it is often difficult to fix the correct age of tertiary deposits.

That the Negritos- and Lobitos-formations must be referred to the eocene, seems to be generally accepted at present, which is to no little degree owing to the occurrence of Venericardia planicosta Lmck. Now it imports us to know that, according to WOODS, the eocene strata of N. W. Peru show palaeontological affinity on the one side with those of California (Medanos and Tejon series) and on the other side to those of the Gulf-region (Clayborne and Wilcox series).

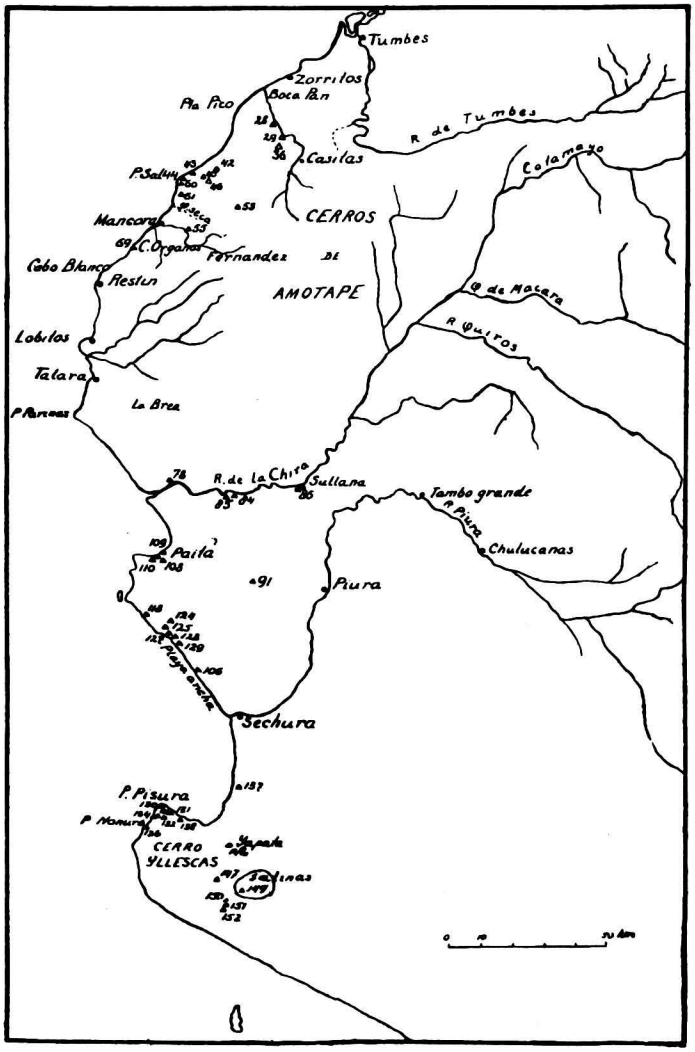
We do not know whether in Peru continuous deposition has taken place from Eocene to Miocene or Pliocene. THOMPSON speaks of an unconformity prior to the Miocene ; BOSWORTH also considers this possible. It is a positive fact, however, that after the Miocene and before the Quaternary a stupendous disturbance has taken place of the enormously thick tertiary deposits. BOSWORTH holds that these disturbances were rather faulting than folding processes. The whole region of N. W. Peru should, according to this author, be considered as a gigantic "crush-breccia". The orogenetic movements have been succeeded by stupendous denudation, followed by quaternary transgression. The quaternary deposits have at various times been lifted up vertically, so that nowadays different littoral terraces are superposed upon each other.

The Tertiary of N. W. Peru consists mainly of shales, sandstones, and littoral gravel ; all of them may contain a certain amount of lime. The boulders of the littoral gravel attain a diameter up to 15 cm. Frequently a coalbearing substance occurs in the shales (especially in the Negritos-formation). The occurrence of true lignite-layers I find recorded only for the upper part of the Zorritos-formation (BOSWORTH, BERRY 1919).

Taking all in all the Tertiary of N. W. Peru displays in many respects affinity with that of California. This affinity is of a palaeontological character (DOUVILLÉ 1920, WOODS), of a petrographic character (DOUVILLÉ 1920, oil occurs in either), of a stratigraphical nature in that in either region the Tertiary is very thick, and of a tectonic character in that in either region the Tertiary has been considerably disturbed.

It will be well to discuss the rocks of the "Bataafsche Petroleum Maatschappij" in geographical order.

The rocks from the northern part of the region, between Boca Pan and Casitas (locality 28, 29, 36) are of slight importance. A number of samples of clay-shale of the first locality originate from the "Heath-formation". Inter se they agree well. These rocks easily turn to silt, their silt-rests contain a few small foraminifera, stratigraphically insignificant. We also



find traces of fish-rests and scarce grains of quartz and plagioclase. The absence of diatoms is remarkable. From this locality was also derived a peculiar, greenish-black rock, composed of granules of glauconite, bound together by a cementing material of siderite (D. 10477) [1]). I had the disposal of two samples of clay-shale from locality 29. They were held

[1]) The D-numbers refer to the collection of slides of the Geol. Institute of Utrecht.

to be eocene; they contain in their scanty silt-rests also traces of insignificant foraminifera and grains of quartz and plagioclase. In one of the samples there are scarce, centric Diatoms. The rock of locality 36 is a quartz-sandstone, built up of grains of "old" quartz with very scarce rutile, zircon, and turmaline and with siliceous cement.

The rocks described are totally unfit for the determination of age. If the glauconite-siderite rock is spread fairly horizontally, it will form an excellent guide-layer for the terrain.

A rather large number of samples were collected in the neighbourhood of Punta Sal. Eocene limestones with Isolepidina R. Douvillei and Orthophragmina found in these localities have been described by TOBLER (l.c.). In different places stratigraphically neutral rocks have been collected here: a gasteropodlime (43), a gray and a brown argillaceous shale with traces of small foraminifera and without diatoms (45) and a calcareous marl concretion, intensely crystalline without clastic material (61). However, from locality 46 a gray strongly recrystallized limestone (D. 10473) is derived, which contains besides numerous Lithothamnia traces of Orthophragmina and is certainly of eocene age. This is the only Orthophragmina-rock that was found in the collection. Furthermore some five samples (45) of a brownish gray limesandstone (D. 10488—10492) were collected, all of which contained Operculina nummulitiformis n.s. The majority of the clastic grains in these rocks are "old" quartz. There are further a limestone (60), consisting almost entirely of shales of Operculina nummulitiformis (D. 10495) and four brown to brownish-red limes (44), all abounding with this fossil (D. 10480—10487, 10493, 10494). In one of these rocks (D. 10483) there occur also very irregular, scarce, small Lepidocyclines apparently stunted in their growth. All these rocks must be of eocene age. From locality 42 originates a fragment of coral-lime, besides two fragments of a sandy, brownish-yellow Lepidocyclina-limestone. The clastic material consists again mainly of dusty quartz, some plagioclase, muscovite and pieces of a quartzitic rock (D. 10591, 10597—10599). The Lepidocyclinae are closely allied to L. R. Douvillei Lisson, but differ from it in possessing numerous columns; they must be referred to a new variety (var. armata). Of locality 44 there is still a calcareous-sandstone, containing Lepidocyclines and a few individuals of Operculina nummulitiformis.

We see, then, that eocene rocks abound in the vicinity of Punta Sal.

Farther into the interior (53) a sandy-marly shale has been collected. It contains many quartz-splinters and traces of small foraminifera. In the terrain it was held to be eocene.

From Quebrada Mancora (55) two rocks have been derived: one eocene(?), a lime-free, fossil-free clay-shale, and a polygene, fossil-free calcareous-sandstone containing much "old" quartz and plagioclase.

LISSON and TOBLER (l.c.) have already recorded rocks from Los Organos (69) with Lepidocyclina R. Douvillei. In the collection of the "Bataafsche Petroleum Maatschappij" there are a calcareous-sandstone with an

uninforming Cristellaria (D. 10478) and three calcareous-sandstones (D. 10600—10602), which contain numerous specimens of Lepidocyclina R. Douvillei var. armata. The clastic material here also is for the greater part dusty quartz, rather many grains of quartzitic rocks and possibly radiolarite.

In the vicinity of Vichayal (78) seven samples of "Pariñas sandstone" have been found (D. 10447, 10496—10507, 10592—10596). They are slightly calcareous sandstones prone to crumble, and coloured yellowish-brown by weathering. The clastic material they contain is composed of old quartz, plagioclase, orthoclase, much green amphibole, a little zircon, ore and traces of garnet. In the silt-residue we found : traces of scales of fish and some lamellibranchs, a few specimens of Operculina nummulitiformis and a good many specimens of a small Lepidocyclina related to Lep. R. Douvillei. The fossils of Vichayal, however, exhibit some constant deviations from this species ; they will be described as Lepidocyclina Vichayalensis n.s.

Whereas the rocks from Vichayal fairly agree with those from the vicinity of Punta Sal and Los Organos, higher up in the Rio Chira some samples of quite a different type have been collected. From Miraflores (83) a "white bed on top of iris shales" is derived (D. 10470). It appears to be a dacite-tuff without organisms with an isotropic matrix, in which there are numerous splinters of lucid quartz, plagioclase, and sparse biotite. It is genetically related to a white sandstone from Sullana (86), whose components are besides very lucid, zonary plagioclase, and bipyramidal quartz with glass-xenoliths, also a few pieces of "old" quartz and quartz-schist. Furthermore the sandstone contains many loosened fragments of effusive matrix. Finally a rock from the Chira-valley is non-typical : (84 Station Nomara). It is a brown shale ("Heath-shale") in whose scarce washing-residues some small foraminifera are recognized.

Another quite new type of rock has been collected between Chira-, and Piura-river. It easily turns to silt, is very light and is clayey to the touch. In its minimal ooze-residues only quartz can be identified. In a preparation made of the scrapings of the rock numberless marine, centric diatoms occur. The rock is a yellow diatomite.

A very large number of rocks, chiefly of no importance, have been collected in the close vicinity of Paita. Sixteen samples of "Heath-shales" from locality 108 are fairly alike inter se. They readily turn to silt, are brownish-gray to yellowish-gray and finely argillaceous to sandy ; often with many small particles of coal ; gypsum occurs in narrow veins and on fault-planes. Of minerals we observe in the washing-residues especially splinters and dust of old quartz and plagioclase. The marly shales always have a small content of stratigraphically insignificant foraminifera : Textularidae, Nodosaridae, Rotalidae, and Globigerinidae. Rarely do we find rests of Lamellibranchs and Gastropods ; there are nearly always small scales and toothlets of fish. Diatoms are ever absent. The rocks collected in the localities 109 and 110 are completely alike.

Various other rocks from this region adjoin the "Heath-shales". A yellow, calcareous-marl from 110 (D. 10446) with small Rotalidae and Textularidae is only a somewhat more calcareous variety of the marls. In the shales concretions occur collected in all localities mentioned (108, 109, 110) (D. 10443, 10444, 10445, 10459, 10468). They are all yellow, dolomitic, porous limestones, almost without clastic material, and consisting of small loosely adhering rhomboheders of calcite and dolomite. Occasionally they contain small foraminifera. Lastly to the group of the preceding rocks belongs a yellow lime from 110, with numberless small Textularidae (D. 10469).

The rocks of the "Heath-formation" that have been described, are not fit for the determination of age, but the shales and their concretions are easily discernible rocks. In the field they were considered to be oligocene. Only one rock in the vicinity of Paita was considered eocene ; a calcareous-sandstone of the "Disco-formation" (locality 110). It contains Operculina nummulitiformis and Lepidocyclinae ; the clastic material it contains is old quartz, muscovite and ?porphyrite : so it bears a great resemblance to the eocene rocks found more towards the north.

Another group of shales with concretions found more towards the south, have been referred to the eocene by the geologists of the "Bataafsche Petroleum Maatschappij", and classed under the "Playa ancha series". The direct relation between "Heath" and "Playa ancha" could not be established. Microscopical examination has made out that the two formations can indeed be distinguished the one from the other, but cannot afford a positive confirmation as to the age of the "Playa ancha series". The shales (128, 129) are grayish-brown, porous, lime-free, very easily silting rocks ; in the scanty residues are found quartz, plagioclase, and a few radiolaria, but foraminifera are lacking. It may be that volcanic glass occurs in the residue. Diatoms are not scarce. The concretions from the Playa ancha shales (125, 128, 129) also differ from those from the "Heath": they contain namely many more mineral splinters and lack the rhomboheder-structure. Small, irrelevant foraminifera and calcified radiolaria may occur in them. It is very striking that in the Playa ancha concretions the mineral fragments (old quartz, plagioclase and muscovite) are very sharp splinters without a trace of rounding (D. 10461—10466). In this they forcibly remind us of the "splinter-sand" from the recent-desert of N.W. Peru, described by BOSWORTH, for comparison we refer to Fig. 83 of BOSWORTH and the annexed figure. However the mineral splinters in the Playa ancha-concretions are very much smaller than those from the recent splinter-sand. It seems to me that the sharp-edged mineral-splinters in the Playa-ancha concretions imply, *that a desert-climate prevailed already during their deposition in N.W. Peru.*

The difference between "Heath"-, and "Palya-ancha"-rocks may be briefly summarized here.

Heath : marly shales with not infrequent foraminifera, without radiolaria or diatoms ;
dolomitic calcareous concretions with rhomboheder-structure, almost without clastic material.

Playa-ancha : calcium-free, porous shales, well-nigh without foraminifera, with radiolaria and diatoms ;
calcareous concretions without rhomboheder-structure with much micro-splintersand.

Locality 106 still furnished two samples of "Playa-ancha shales", which however are different rocks. The one is a yellowish-white diatomite with many centric diatoms and a few radiolaria, the second is a yellowish-white, crumbling marl with many isolated carbonate-rhomboheders, with pieces of quartz, plagioclase and garnet and with traces of diatoms.

Of locality 118 (Tortugas-Pta Perico) a crumbling sandstone with "old" minerals is present ; of 124 (close to Silla de Paita) an irrelevant, yellowish-brown calcareous-sandstone.

The last district where rocks have been collected, is the surroundings of the Cerro Illescas. From locality 142 (Yapate) three very typical rocks are derived : the first two white, very soft rocks, which appear to consist almost entirely of intact specimens and fragments of centric diatoms, the third is a much more compact rock, whose scrapings contain besides diatoms also isotropic or faintly aggregate-polarizing flakes and grains. The former rocks are typical samples of diatomite, the latter is a siliceous diatom-bearing tuff (D. 10448, 10449). Completely comparable rocks have been taken from locality 149 : white, gray, and green varietal forms of marine diatomite ; in one sample occasional Textularidae and Cristallaria also occur. Also slightly differing rocks have been collected at the last-named locality : a yellowish-white, crumbling limestone, still containing many diatoms, and a greenish white, siliceous marl (10450), with very scarce diatoms. A white diatomite also originates from 150. In the environment of the named localities the following rocks have been collected. Near 147 (D. 10457) a lime sandstone with splinters of quartz (?young-effusive) as clear as water, plagioclase, biotite and muscovite ; near 151 a porous, sandy limestone (D. 10460) with rounded granules of old quartz, biotite, muscovite and plagioclase and with undeterminable remains of organisms ; near 152 a very peculiar white, oölithic-like rock. It appears to consist of white globules of silicified diatomite, kept together by siliceous cement (D. 10459). It is on this account a "silicified sand of diatomite".

A good many rocks, differing from the preceding ones, have been found near the coast. An opalized, chalcedonized sandstone (D. 10452) with hyaline quartsz-splinters, was derived from 137 (Cerro El Viejo). There are several rocks from 138; two peculiar calcified andesite-tuffs, and a mari with a marl-lime. The first-named (D. 10455, 10456) are white rocks with much fresh plagioclase of zonary structure and with splinters and hooks

of volcanic glass and pumice-stone: all kept together by a limy cement, which is beautifully crystalline and is orientated over large distances. Part of the marl easily turns to silt: it contains besides effusiva, fresh plagioclase, numerous small uninforming foraminifera and a rare small Lepidocyclina (D. 10453). The yellowish-white limestone (D. 10454) is rich in stratigraphically unimportant foraminifera. Locality 131 and 132 (D. 10479) furnished sandy marls, which contain clastic material, as glass-bearing, fresh plagioclase and volcanic glass, besides old quartz and muscovite; of remains of organisms we find rests of fish, small foraminifera, radiolaria and diatoms. In 133 and 136 isolated specimens of a new Lepidocycline have been collected, which will be described as Polylepidina variabilis n.s. From 134 two limestones have originated (D. 10522). The only clastic material contained in one of them is quartz, in the other also rolled-down pieces of greywacke. They contain numerous, small Lepidocyclines probably belonging to Isolepidina R. Douvillei var. armata.

Finally three limestones originate from locality 130 (D. 10604, 10605). They are quartz-bearing limestones with many specimens of Operculina nummulitiformis; one sample also contains small undeterminable Lepidocyclines.

The following remarks are suggested by the rocks described.

In part they open up a new vista into the Tertiary of N. W. Peru. This refers least to the composition of the "old" material in the tertiary formation. The minerals found (quartz, felspars, amphibole, mica, zircon, turmaline, ore and garnet) are such as are always concentrated in the decomposition of an "old" mountain-range; moreover their presence could be safely anticipated. The *presence of rolled-down radiolarite* alone would be striking (locality 69); but its presence could not be demonstrated with certainty.

The occurrence of much tuffogene material is new (dacitetuff in 83, dacitesandstone in 86, effusive quartz in 137, 147, andesite tuff in 138, marl with andesite material in 138, and limestones with andesite material in 131, 132). They suggest volcanic eruptions with dacitic-andesitic material at none too great a distance. The rocks, in which the effusive material occurs, are all considered to be Eocene; of some this view could be corroborated by palaeontological data. In the "Heath formation" (considered to be Oligocene), however, no effusive material could be detected. In this respect there is a contrast between N. W. Peru and S. Ecuador. SHEPPARD has just described a tuffogene material from the lower-oligocene "Ancon white sandstone" of Ecuador, while the Eocene is free from volcanic material there [1]). It should be observed, however, that SHEPPARD's publication does not give us decisive arguments for referring the white Ancon-sandstone to the oligocene.

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[1]) G. SHEPPARD, The geology of Ancon point, Ecuador. J. of Geol. **36**. 1928. p. 113—138.

It is remarkable, that the shape of the clastic material in the concretions of the "Playa ancha shales" probably indicates the pre-existence of *a desert-climate in N. W. Peru during their deposition.* In this connection it should be observed that for part of the Californian Eocene (the Medanos, Series) BRUCE L. CLARK has also suspected on other ground the existence of a very dry hinterland [1]).

The most remarkable result no doubt is *the finding of depositions with marine diatoms on a large scale* [2]). Similar rocks were not known either from the Tertiary of N. W. Peru or from Ecuador or Chile. Sometimes they are siliceous diatomaceous-earths (localities 91, 106, 142, 149, 150, 152) ; sometimes they are shales, which contain marine diatoms (locality 29, the Playa-ancha shales); sometimes the diatoms occur in calcareous rocks (locality 131, 132). By the finding of these diatomaceous deposits the geological relationship between the Tertiary of N. W. Peru and California is once more substantiated. Whereas, however, in California the diatomaceous deposits are best developed in the Miocene (Monterey shales — although they are not absent in the Eocene (e.g. in the Coalinga Oil field) — the diatomaceous-deposits of N. W. Peru seem to be exclusively of eocene age. Anyhow, in the ?oligocene "Heath-formation" no further trace of diatoms was recognized.

The occurrence of marine diatomaceous-deposits in N. W. Peru is of twofold geological importance, viz. regionally and generally. Until recently North-American geologists were of the opinion that for an understanding of the genesis of the tertiary diatomaceous deposits of California — which have been formed in a temperate climate — it is required to assume that arctic currents supplied the diatoms from the northern part of the Pacific, where they are known to abound and that these diatoms succumbed in warm, more or less closed lagoons [3]). So a complete apparatus of hypotheses was laid under contribution to make the genesis of the Monterey-shales and facially similar deposits harmonize with the actually-geologic data. It is evident that the occurrence of similar Diatom-depositions at less than 10° from the aequator cannot be explained in this way. But at the same time also the data of "actual geology" have altered. Whereas CLARK could still write in 1921 that "diatomaceous oozes in any considerable quantity are now only found in Arctic and Antarctic waters" (l.c.), we know, that even now enormous invasions of diatoms occur from time to time on the Californian coast, as Prof. BAAS BECKING of Stanford University informed me.

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[1]) BRUCE L. CLARK, The marine tertiary of the West coast of the United States, etc. J. of Geol. **29**. 1921. p. 583—614.

[2]) When this article was already under the press I was informed by my friend Dr. W. HOTZ of Basle that diatomaceous deposits have already been described from NW- Peru by A. WERENFELS (Eclogae geologicae Helvetiae **19**, 1926, 630—631 and **20**, 1927, 473—486). I am very sorry that I have not had under the eyes these essays, the „Eclogae" not being present in any library in Utrecht.

[3]) BRUCE L. CLARK, l.c., J. C. BRANNER, Bull. Geol. Soc. of America, **24**. 1913. p. 94.

When considering how quickly our views of the genesis of the marine diatomaceous depositions had to be reconsidered in consequence of new geological and biological facts, we have to ask ourselves whether perhaps in the future also our conception of the genesis of other sediments, notably of the radiolarian deposits, will have to be revised.

Palaeontology.

Operculina nummulitiformis n.s. (Fig. 1—10 and Pl. I, Fig. 11, 12).

Occurrence: Locality 130, South of Punta Pisura, D. 10604.
Locality 110, Paita, D. 10523.
Locality 78, N. W. of Vichayal, D. 10496, 10497.
Locality 60, Quebrada Punta brava, D. 10495.
Locality 45, Quebrada negra and Quebrada N. W. of Conchudo, D. 10488—10492.
Locality 44, Quebrada seca, D. 10480—10488, 10493, 10494.

Probably everywhere in eocene rocks.

Small, flat, nummulinids, entirely or for the greatest part involute, of which it is difficult to say to which genus they belong, to Operculina or to Nummulites. They possess 4—5 convolutions; in a few cases there is a beginning of a sixth convolution. The horizontal diameter is mostly less than 3 mm; in some ten specimens it amounted to 1.9—3.7 mm. The thickness (height) is 0.35—0.45 mm. The initial chamber has a diameter of from 45—100 μ; it is impossible to distinguish micro- and megalospherical forms. In the last whorl there are 26—32 chamberlets. The horizontal-section is rather nummulitiform than operculiniform: the vertical section is just the reverse.

It is well known that the large Nummulites, so typical of the European and the Asiatic Eogene have not yet been described from America. However, in the course of years a number of old-tertiary forms from this part of the world have become known, that are to be referred to the genus Operculina or to Nummulites. TH. WAYLAND VAUGHAN [1]) has given us a review of what we know of them. According to him by far most Nummulites, described by earlier authors from America, are in reality Operculinae, and only few, very small true Nummulites are known (?Middle Eocene to Oligocene), of which only N. parvula Cushman has received a proper description. Representatives of the genus Operculina are much more numerous: of fossil forms VAUGHAN (l.c.) and CUSHMAN [2]) report about ten, mostly well-described species. The Peruvian form differs from all these species in that it is small and exhibits many convolutions. As late as 1910 CUSHMAN [3]) insisted on it that Operculinae should have at most 4 whorls. Afterwards (l.c., 1921), however, he described a fossil form from the eocene Ocala-lime of Florida (Operculina Willcoxi Heilprin) that has about 5 whorls, which completely invest each other. This species has no doubt strong affinities with the

[1]) T. WAYLAND VAUGHAN, American and European larger Foraminifera. Bull. Geol. Soc. America. **35**. 1924. p. 785—822.

[2]) J. A. CUSHMAN, American Species of Operculina and Heterostegina. U. States Geol. Survey. Prof. Paper 128E. 1921.

[3]) J. A. CUSHMAN, A monograph of the foraminifera of the N. Pacific. U. States Nat. Museum. Bulletin **71**. IV. 1910. p. 36.

Peruvian species, but it is larger (according to the pictures up to 8 mm), and has in the last whorl more chambers (35—45). With Op. Willcoxi as well as with Op. nummulitiformis we have to do with an intermediate form between the genera Operculina and

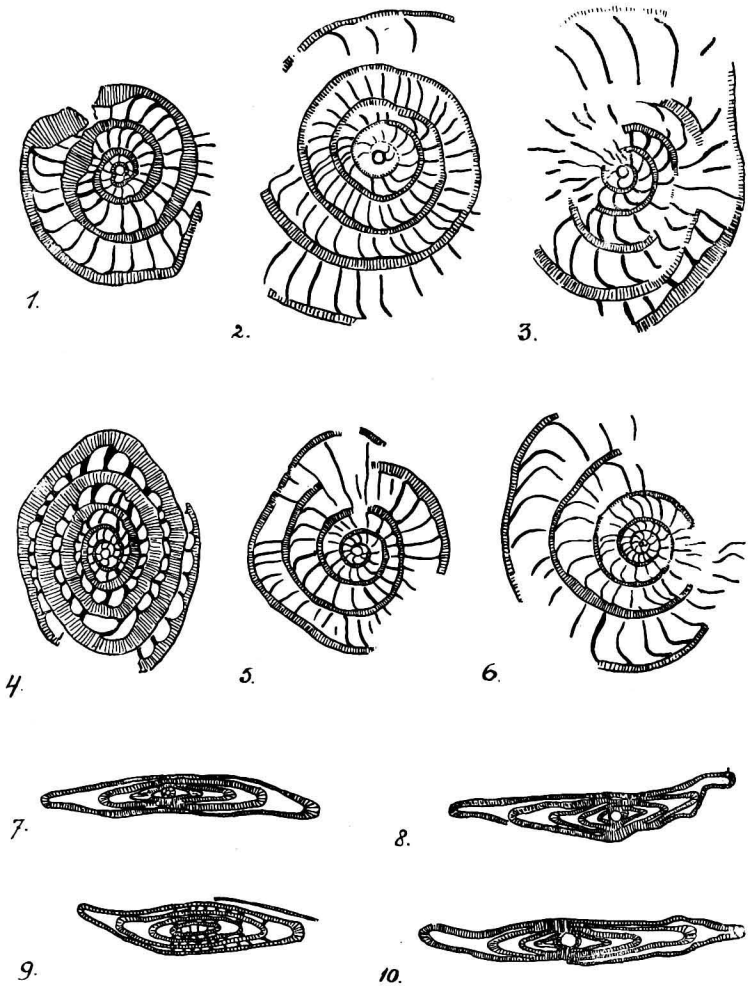


Fig. 1—5, 7—10. Magn. × 15; Fig. 6. Magn. × 10.
Fig. 1, 5 from D 10480; 8, 9, from D 10481; 6 from D 10484; 3, 4, from D 10487; 7, 10 from D 10493; 2 from D 10494.

Nummulites. Also CUSHMAN hesitated whether he should class Op. Willcoxi as an Operculina or a Nummulite (l.c. 1921).

It is probable, but not quite certain, that all specimens of Op. nummulitiformis have originated from eocene strata. The fossil is well typified and easy to recognize; it will possibly serve as an excellent guiding fossil.

Lepidocyclina (Polylepidina) variabilis n.s. (Pl. I, Fig. 13—22; further Fig. 23*a*—*h* and Fig. 24*a*—*e*).

Occurrence: Locality 133, East of Quitir, D. 10508—10521.
Locality 136, Punta Nonura.

Probably in eocene strata.

Very well-defined form. There are large, microspherical individuals, with a diameter of from 15—18 mm and a thickness of 2½ mm, and smaller megalospherical individuals from 5—8 mm in diameter. When full-grown they display both a very typical, swollen outer-edge, where the number of layers of median chambers is enlarged, and the lateral chambers are lacking (Fig. 16 and 17 on Pl. I). The fossils are most often circular with a more or less distinct tubercle in the centre ; in normal condition they are developed in one plane (Pl. I, Fig. 19, 20 and 17). A few, however, are irregularly saddle-shaped (Pl. I, Fig. 18), no doubt in consequence of accommodation to abnormal conditions of growth. The surface exhibits numberless, very fine columns (Pl. I, Fig. 19, 20), arranged more or less concentrically. The embryonic chamber in the microspherical forms must be very small ; I have not succeeded in visualizing it in a preparation (Fig. 21, 22 on Pl. I). The median chambers are very different as to size and shape (Fig. 24*a*—*e*). The microspherical forms have in their fullgrown stage in the central part 15—20 layers of lateral rooms on either side of the median-chamber-layer. The embryonic apparatus is very remarkable (Fig. 23*a*—*h* ; Pl. I, Fig. 13, 14, 15). Its exceeding variability in shape

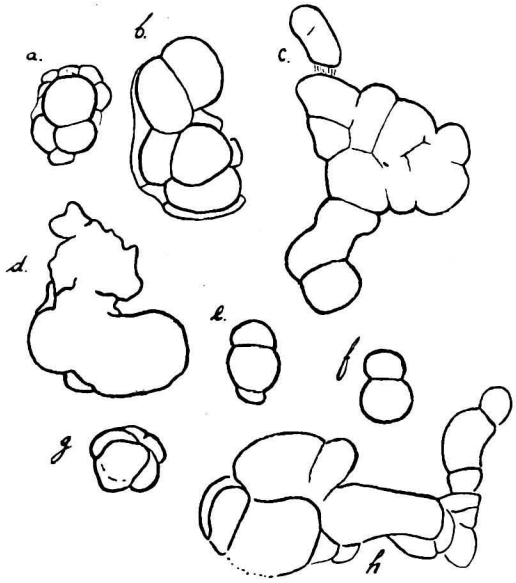


Fig. 23 *a*—*h*. Magn. × 20. Embryonal chambers of Polylepidina variabilis. *a* from D 10514; *b* from D 10510; *c* from D 10513; *d* from D 10515; *e* from D 10512; *f* from D 10520; *g* from D 10511; *h* from D 10521.

and in size has given origin to the name of the species. A single individual (Fig. 23*f*) displayed an Isolepidina-like embr. app. ; in all the others the embr. app. consisted of more than 2 chambers, while the number may rise to 11, and no regularity whatsoever can be distinguished in the arrangement of the chambers.

VAUGHAN (l.c.) has devised the term Polylepidina for Lepidocyclines with an embr. app., that consists of several chambers not differing much in size, and has observed that the number of embryonal chambers can rise to 5. We may refer the fossils of Peru to this subgenus, provided that the definition includes also such cases in which the number of embr. chambers amounts to more than 5. The Peruvian forms differ from the three Polylepidines described by VAUGHAN by the larger dimensions, by the very typical rim and by the incredible variability of the embryonic apparatus.

It is almost certain that the forms of Pol. variabilis have been found in eocene strata; if they occur more frequently in Peru, they will form excellent guides, as a large vertical distribution of such a specialized form is not imaginable. The Polylepidines described by VAUGHAN are also eocene.

Lepidocyclina (Isolepidina) R. Douvillei Lisson, var. armata nov. var. (Fig. 24, 1, m; Pl. II, Fig. 27, 28; Fig. 29*a*—*d*).

Occurrence: Locality 42, W. of Cerro Pinal, D. 10591, 10597—10599.
Locality 44, Quebrada seca.
Locality 69, Los Organos, D. 10600—10602.
At all localities in eocene rocks.

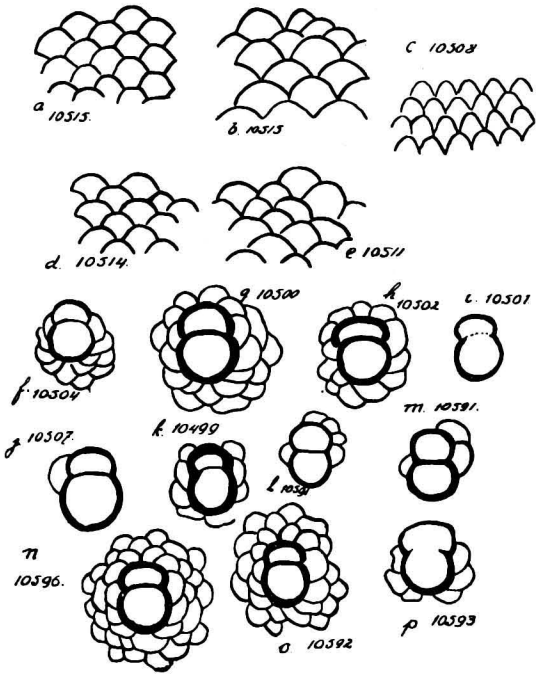


Fig. 24 *a*—*e* Polylepidina variabilis; *l*, *m*, Isolepidina R. Douvillei var. armata; *f*—*k*, *n*—*p*, Lepidocyclina (?Isolepidina) Vichayalensis. Magnif. circa × 32. *f* from D 10504; *g* from D 10500; *h* from D 10502; *i* from D 10501; *j* from D 10507; *k* from D 10499; *l* from D 10591; *m* from D 10591; *n* from D 10596; *o* from D 10592; *p* from D 10593.

To this variety a number of small Lepidocyclines have been referred, which, as to their main characteristics, agree with the species L. (Isolepidina) R. Douvillei, as described by LISSON [1]). The diameter of the megalospherical individuals is about 1½—2½ mm; their thickness about 0.7—1 mm. The embryonal apparatus is typically isolepidine; its largest width is about 250 μ (Fig. 24 *l, m*). The forms differ, however, from Lep. R. Douvillei in the fact that they always possess distinct and numerous columns (Fig. 27, 29*a—d*), which are largest and most numerous in the centre. This is why I have had to class them under a new variety. A few microspherical individuals have a diameter of up to 4 mm (Pl. II, Fig. 28).

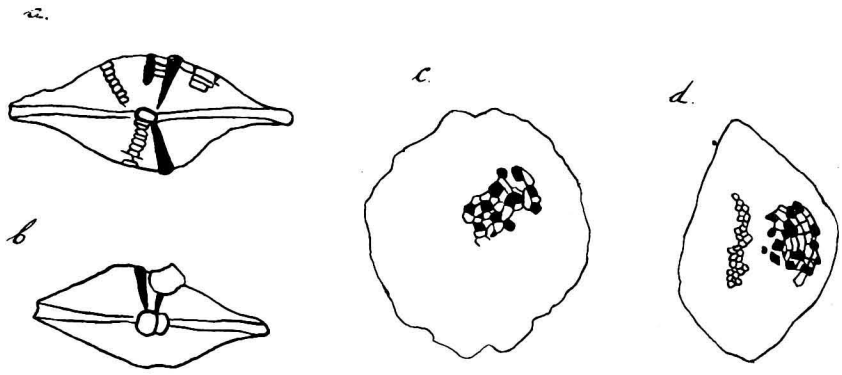


Fig. 29. Lepidocyclina R. Douvillei var. armata. *a, b* from D 10598, *c* from D 10597, *d* from D 10591.

H. DOUVILLÉ [2]) maintains that Lepidocyclina R. Douvillei is perhaps equivalent to Lep Trinitatis. A. TOBLER has already pointed out that this cannot be right, since Lep. Trinitatis has numerous strong columns, which are wanting in Lep. R. Douvillei. Now the conception would be admissible that the "columned" variety of Lep. R. Douvillei is, in strictness, nothing but Lep. Trinitatis. But this is not the case: according to the dimensions given by H. DOUVILLÉ the megalospherical form of Lep. Trinitatis is much larger, and the embryonal apparatus is also very much larger. The diameter of the individuals is recorded 3—4 mm the largest diameter of the embryonal apparatus 0.5 mm.

Lepidocyclina (?Isolepidina) Vichayalensis n.s. (Fig. 24, *f—k, n—p*, Pl. II, Fig. 25, 26).

Occurrence: Locality 79, N. W. of Vichayal, (D. 10498—10507, 10592—10596).

The fossils were found in eocene Pariñas-sandstone.

These fossils are also allied to Lepidocyclina R. Douvillei, with which they agree especially in the lack of columns (Plate II, Fig. 26). But they differ from the species in question first of all by decidedly larger dimensions (the microspherical individuals have a diameter of 3—5 mm) and secondly by the structure of the embryonal apparatus.

[1]) C. LISSON, l.c.

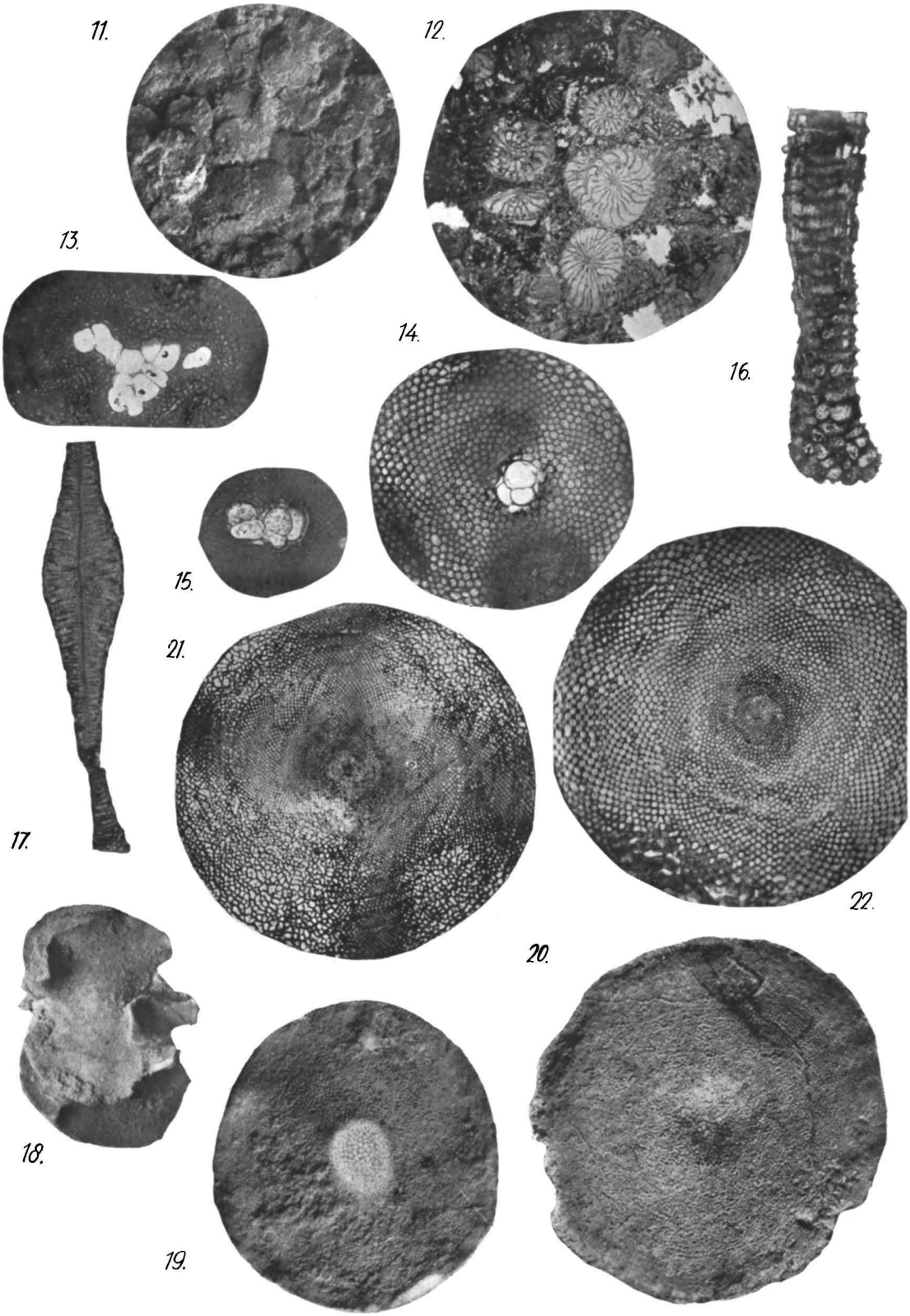
[2]) H. DOUVILLÉ, Mém. Soc. Géol. de France. Nouvelle série. I. 2, 1924. p. 34—36

Whereas in Lep. R. Douvillei this is strictly "isolepidine", in the fossils of Vichayal it regularly occurs that the septum, separating the first and the second chamber, is not straight but distinctly bent (Fig. 24 and 25). The embryonal apparatus — although resembling that of Isolepidina — deviates a little from it in the direction of Nephrolepidina. It was necessary, therefore, to devise a new species for these fossils, which I assigned to the subgenus Isolepidina, though I query its accuracy. The arrangement of the median chambers, in some individuals reminds us of Helicolepidina TOBLER.

EXPLANATION OF THE PLATES.

Pl. I, Fig. 11, 12 Operculina nummulitiformis. Fig. 11 magn. × 4, Fig. 12 magn. × 6.
Fig. 13—22 Lepidocyclina (Polylepidina) variabilis n.s.
Fig. 13, magn. × 10 from D 10513.
Fig. 14, magn. × 14 from D 10514.
Fig. 15, magn. × 11 from D 10510.
Fig. 16, magn. × 19 from D 10517.
Fig. 17, magn. × 6 from D 10518.
Fig. 18, magn. × 3½.
Fig. 19, magn. × 3½.
Fig. 20, magn. × 3½.
Fig. 21, magn. × 9 from D 10508.
Fig. 22, magn. × 9 from D 10515.

Pl. II, Fig. 25, 26, Lepidocyclina Vichayalensis n.s.
Fig. 25, magn. × 45 from D 10496.
Fig. 26, magn. × 45 from D 10494.
Fig. 27, 28 Lepidocyclina (Isolepidina) R. Douvillei Lisson, var. armata nov. var.
Fig. 27, magn. × 20.
Fig. 28, magn. × 25 from D 10599.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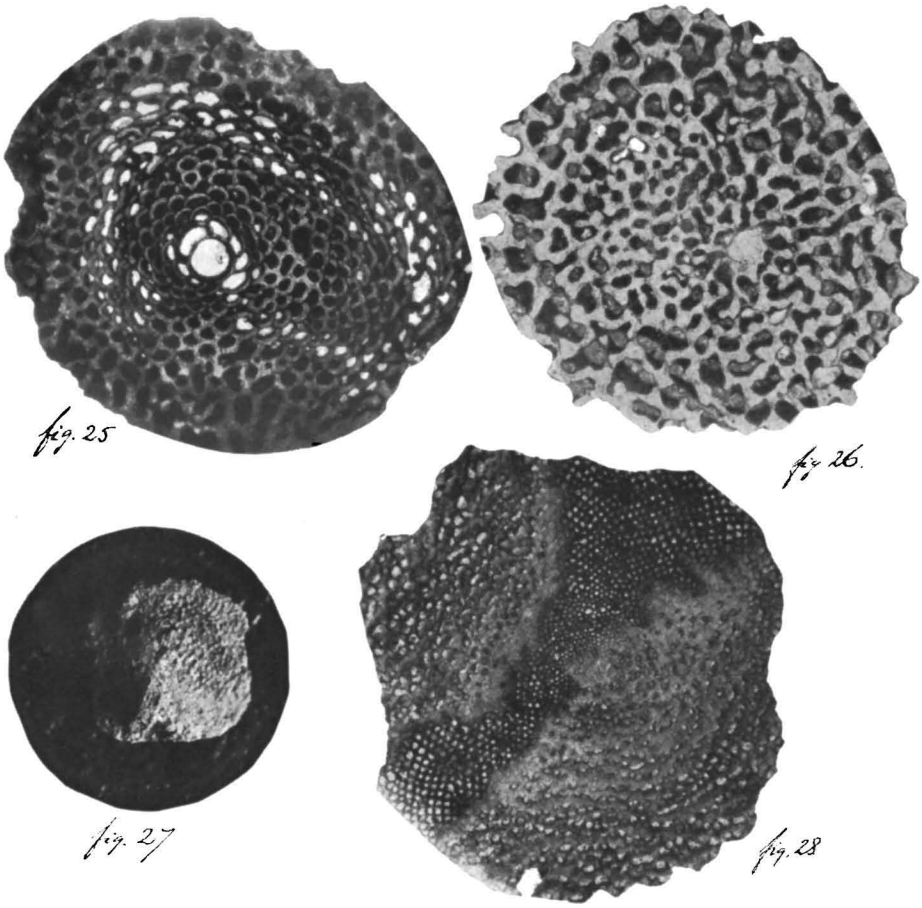
fig. 25
fig. 26.
fig. 27
fig. 28