Petrology. — “On a Young-Tertiary Limestone of the Isle of Rotti with Coccoliths, Calci- and Manganese-peroxide-Spherulites”.
By Tan Sin Hok. (Communicated by Prof. H. A. Brouwer).

(Communicated at the meeting of June 26, 1926)

Introduction. The in many respects remarkable collection of young-tertiary limestones, collected by Professor Dr. H. A. Brouwer on the occasion of the Dutch Timor-Expedition, was kindly placed at my disposal for sedimentary-petrographical research.

In preparing this paper the author has been put under special obligation to Professor Brouwer for his extremely valuable directions and stimulative interest.

These limestones which are believed to be of pliocene age, are very frequent in the South of Rotti; they are found with reefs 1). The groups diagenetically not much altered, were examined, all being white and soft.

The following division could be made:
1. Radiolarian-limestones.
2. Foraminifera-limestones.

The groundmass of these limestones is very fine-grained; in group 2 aragonite-asterisks occur very numerously, whereas they are not yet met with in group 1. This paper is confined to an abnormal type out of the group of the foraminifera-limestones.

Method of Examination. Thin slices as well as preparations made of the disintegrated limestone, magnified about 375—750, were examined in monochromatic yellow light.

The monochromatic light was used to simplify the recognition of spherulitic and fibro-radiate forms. As is known fibro-radiate aggregates of optically uni-axial crystals exhibit in parallel-polarized light the interferencefigure of homogeneous uni-axial crystals in convergent-polarized light 2). Monochromatic light makes the interference-cross more conspicuous, so that those aggregates cannot be overlooked so easily.

Making of the preparations. A fragment of the stone is boiled in distilled water. By this treatment it was completely disintegrated without any damage to its components.

1) H. A. Brouwer 3. p. 72.
Agregates of rhombic crystals of analogous structure form interference-figures of little difference.
A drop of the resulting milk of lime was evaporated on a slide, and on the residue some diluted canada-balsam was brought (as a solvent xylol was used).

Professor S. Squinabol of Turin recommended this diluted balsam for the mounting of preparations of Radiolaria. In this soft medium they can be brought to rotation by a gentle pressure on the cover-slip, so that now they may be studied in every position.

This diluted balsam can be generally recommended for sedimentary-petrographical researches.

For the concentration of heavier or coarser ingredients the method which is already known, was followed: the beaker with the milk of lime was brought in a rotatory motion, the desired concentrate accumulates in the least agitated parts of the fluid and can be transferred by a pipette.

Description of specimen: 168 x, from Bebalain. Rotti.
Macroscopically a gray, dirty-white rock, soft; coming-off, with many spots of MnO₂, often surrounded by a brown envelope.

Microscopically a compact limestone, fine-grained;

A. the coarsest constituents of which are:
   a. Foraminifera which reach a maximum dimension of 100 μ.
   Globigerinidae and fragments of larger globigerina.
   Textularidae.
   The planctonic foraminifera predominate, very curious is that larger individuals are absent.
   b. Terrigenous fragments of lime: they are of the same order of size as the foraminifera, usually with sharp edges, therefore not distinctly marked off against the groundmass, many of them do not extinct homogeneously.
   Mineralogically they consist of aragonite or calcite, (discernment by means of Mohr's salt: FeSO₄ (NH₄)₂ SO₄ 6 H₂O ¹).
   c. volcanic glass, subordinate, occurring in transparent pieces with many opaque spots; between crossed nicols, minerals with gray polarization-colours, probable feldspars, are visible.
   d. concretions of manganese-peroxide, menerous, as little spots or cloudy accumulations of irregular shape. The largest accumulation in the sections is 240 × 135 μ. Where the grains are not closely accumulated a brown colour is often visible. The manganese-peroxide encloses the ground-mass and fills also the chambers of the globigerina.
   Qualitatively the manganese was analysed by dissolving the grains in a bead of salt of phosphorus and then performing the colourreaction by oxidation with KNO₃.

¹) K. Keilhack, 7. p. 397. For the examination of preparations it is easier to apply this reaction than Meigen's, and moreover, it produces still distinct colours with objects of minute dimensions.
The reactions from which the conclusion was drawn that the manganese occurs as superoxide were:
1. evolution of Cl₂ from concentrated HCl.
2. evolution of O₂ from H₂O₂.
These reactions were performed in the laboratory of microbiology by Ir. C. B. Van Niel t. to whom the author feels greatly obliged.

B. The finer components of the ground-mass are:
e. Coccoliths;
f. Asterisks ("Disco-asters");
g. Calci-spherulites;
h. Grains of calcite;
i. Grains of aragonite.

e. Coccolithophoridae Lohmann ¹)
circular, oval to elliptical disks, diameter 2—20 μ, most of them are about 10 μ and less. Thickness 3 μ and less.

¹) H. LOHMANN 10, p. 147; J. SCHILLER 17, p. 282.
**Discoliths** fig. 2, 6.
not perforated, diameter till 4 μ, thickness about 1 μ, margin thickened.
Sometimes with a button in the center fig. 2.
They are easily to be brought to the system of LOHMANN 1).
The most frequent of these have been pictured:
Pontosphaera huxleyi Lohmann fig. 6.
Pontosphaera pellucida Lohmann fig. 2.

**Placoliths** (Lohmann).
with singular perforation, fig. 1, 4.
with double perforation, fig. 5.
with irregular perforation, fig. 10.
The surface is striated radially 2). LOHMANN’s conception (loc. cit. page 114) that the margin of the placoliths is thinner than the center, was confirmed.
By rotating of the placoliths, the differentiation in basal and distal disk could be observed, these disks appear to differ in size, the plane of the disks is convex-concave.
The figures given in the sketch belong to the Coccolithophora Lohmann and are identified as:
Coccolithophora leptophora Murray and Blackman fig. 1.
Coccolithophora pelagica (Wallich) Lohmann fig. 4, 5, 10.

**Rhabdoliths**: It is remarkable that they occur in a very subordinate way.
Fig. 7: Discosphaera Thomisonii Ostenfeld with a distinct axial perforation.

**Structure of the Coccoliths**: They consist of radially placed needles which diverge in the placoliths from the perforation or perforations; these fibres cause the radial striations on the disk, an adoption of radiating channels within the disk for their explication is superfluous 3).
The optical orientation of the fibres is negative. Which of the other axes of elasticity lies in the disk-plane could not be determined. In the disk-plane the fibres are not placed perfectly radially, eventually caused by ramification of the fibres. This appears from the behaviour of the interference-figure when revolving the microscopic stage. Then the arms of the cross do not keep the same orientation. Fig. 11 is a Coccolithophora leptophora Murr. and Blackm., fig. 8 is a C. pelagica (Wallich) Lohm. between crossed nicols. In consequence of the structure of 2 disks the interference-figure of the disk-center often differs from that of the margin.
It is very probable that in space the aragonite-fibres do not diverge from one single center, as the spherulites, but from various centers of the disk-axis. In vertical section the extinction is not homogeneous 4). By

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1) H. LOHMANN 10, p. 147; J. SCHILLER 17, p. 282.
2) These striations are only visible on the largest disks.
3) A. VOELTZKOW 21, p. 483.
4) This observation could only be made on the bigger placoliths.
optical way with the method of Schröder van der Kolk the mineralogical modification of CaCO₃ which form the coccoliths, could not be determined. The colouring with Mohr’s salt, however, was positive for aragonite.

Nor do the rhaboliths extinct homogeneously in profile, so that probably they too are built up of fibres which in space are arranged analogically as in the coccoliths.

f. Asterisks. ("Disco-asters") fig. 3, 9.

These too consist of aragonite; to which organisms they belonged, cannot yet be decided. They will be treated in another paper.

g. Calci-spherulites.
Radiated in structure, irregular in external form, size 2–5 μ. First they were thought to be coccoliths, but they differ from these in:

1. compared with coccoliths of the same size they exhibit a higher interference-colour;

2. when rotated round an axis in a plane parallel to the stage, they appear to be no disks at all, the interference-cross remains visible in all positions;

3. in structure they are perfectly spherulitic, the interference-figure persist with the same orientation of the cross-arms as well during the revolution of the stage as on being revolved on an axis in the plane of the stage.

In general one can expect that the structure of crystalline products of chemical or biochemical extraplasmatic origin, especially, in the beginning of their formation, follows as accurately as possible the laws of crystallography, whereas the products of physiological-intraplasmatic origin in the first place aims at reaching a definite morphological ultimate shape.

The discernment between spherulites and coccoliths does not always run easily, they also consist of aragonite-needles, with negative orientation; perhaps here we have to do with the modification Vaterite 1).

h. Grains of calcite.
By means of colouring with Mohr’s salt they could be recognised and distinguished from:

i. Grains of aragonite,
also occurring in irregular forms, which often do not extinct homogeneously.

Remark: After dissolving the rock in respectively HNO₃, HCl, acetic acid a residue was obtained, which absorbs organic colouring matters, obviously the lime contains some clay.

1) F. Klockmann 8, p. 455 and p. 457. Below 29° C., from solutions of calcium-carbonate, calcite will always precipitate. Above this temperature aragonite, and in the presence of free bases as ammonia the spherulitic Vaterite. Aragonite, however, may also be formed below 29° C. especially in the presence of Magnesia-salts, e.g. in seawater.
Views on the various components of the rock.

To avoid repetition in the following statements the premise is made that in this rock diagenetic alteration, if it has taken place, must be very subordinate.

Phenomena of solution were not observed on the aragonite-components, whereas their minute dimensions and the porosity of the rock had made them highly accessible for chemical attack; if solutions had circulated in this rock those particles certainly would have acted as crystallization-centers, and so would have furthered a precipitation, but the fact that the disintegration of the sample was so easily done, as was previously stated, makes it evident that any posterior impregnation by solutions, saturated with calcium- or maganese-carbonates must be excluded.

While the tropical climate favours the chemical weathering the elevation of this rock must be of very recent date.

The occurrence with coralreefs points at a sedimentation in a shallow sea, notwithstanding the pelagic habit of the rock.

Concretions of manganese: MOLENGRAAFF 1) in 1915 came to the following conclusion: "Nodules and concretions of manganese in general (therefore) are not characteristic of abysmal deposits in this way that from the occurrence of such concretions in a certain deposit, one would be justified in concluding that the deposit could be nothing else than an abysmal deposit . . . ."

The chemical process of their growth is a very slow one, and the chance of finding them is inversely proportional to the rate of accumulation. About the velocity of the sedimentation of our rock, no data can be obtained of course, but it is certain that it was greater than of abysmal sediments.

In the discussion following the communication of his paper, MOLENGRAAFF on WICHMANN's remark, admits the possibility of the formation of manganese-nodules by biochemical processes, but at the same time he points out that until now the existence of bacterial life in abysmal depths has not been proved (pag. 428).

At this moment manganese-bacteria from the sea or from sea-mud, not to mention those from abysmal depths have not been described.

BEIJERINCK 2) demonstrated them in garden-mould, VON WOLZOGEN KÜHR 3) found them as hydrobios in dune-water and it is not improbable that they are represented in the halobios, a supposition which Prof. Dr. A. J. KLUYVER thinks very probable (verbal communication).

In this connection the attention is drawn to the following quotation:

1) G. A. F. MOLENGRAAFF 12, p. 418.
2) M. W. BEIJERINCK 2, p. 123.
3) C. A. H. VON WOLZOGEN KÜHR 21, No. 3, 4, 5.
"Vielleicht wird man aber annehmen, dass die Manganknollen ähnlich wie das Sumpferz durch Vermittlung von Bakterien ausgeschieden wurden, und dass sie sich dort in grösseren Mengen anhaufen konnten, wo die Lebensbedingungen für diese besonders günstig waren".  

Without further commentary BEIJERINCK (on page 128) calls the grains of manganese-superoxide formed by bacteria spherulites, they are perfectly round and have a rough surface, and, besides, they should include organic matter. They reach sizes to 350 μ.  

Another possible way of formations is chemical oxidation of the manganese-ion dissolved in the seawater, especially as it is known that seawater reacts alkaline and that the oxidation of manganese-ions depends on the concentration of the hydrogen-ions in the medium.  

But, if this process had taken place, the Mn-spherulites would have been arranged more or less in layers, and would not occur as dispersed spots. Post-genetical formation must be excluded for reasons mentioned above. The only possible origin of the accumulations in this rock is that they are a product of bacteria, which lived in the superior parts of the sedimentated mud.  

Then the accumulations ("star-accumulations") might be considered as the products of secretion of the former colonies.  

MOLENGRAAFF's pronouncement: "Consequently concretions of manganese are in this manner characteristic of abysmal deposits that they may form an important percentage in proportion to other constituents exclusively in such deposits", now can be stated precisely in this manner that the manganese-superoxide as: "important percentage in proportion to the other constituents" is only in this case an indication of an abysmal sediment, when it occurs in big grains: non numerus granulorum sed magnitudo grani. For, the quantity is as well a function of the favourable-ness of biological factors, whereas the magnitude, it being of no consequence whether the precipitation was caused by chemical or biochemical processes, in the first place, is ruled by the time available for undisturbed growth, thus is connected with the velocity of sedimentation of the other constituents of the rock; circumstances which, without any doubt, are as favourable as possible in abysmal depths.  

Calci-spherulites. STEINMANN 3) asserts that the coccoliths occurring in biancone, lay in a ground-mass consisting of grains which should have a fibrous-crystalline structure. He asserts them to be "Verwesungsfällungskalk". Besides from the decay of organic matter, calci-spherulites can be obtained in the laboratory in a purely anorganic way. (HARTING 4)
and see quotation on page 1099) Physical-chemical precipitations of lime are not impossible in nature 1).

It cannot be decided in which of these ways the calci-spherulites in this rock have been formed. A sure indication of the biochemical formation is the occurrence of organisms, whereas there are no terms to consider a co-existing physical-chemical “planktogeneous” formation as impossible. 

ANDREE 2) makes a difference between “Verwesungsfällungskalk” viz. lime issued from precipitation in sea-water by the action of “decay”-products and “physiologische Fällungskalk” viz. lime, which is formed in direct connection with the physiology of living organism, in the first place of bacteria.

Other geologists too, accept on DREW’s authority that there exist bacteria which may be brought to a physiological group of: “Calcium-carbonate-bacteria”, on the ground of the fact that the production of calcium-carbonate is to be reckoned among the direct physiological processes of those bacteria.

However, it ought to be mentioned, that evidently this conception is not agreed with in biological cercles. So the well known bacteriologist MOLISCH gives the following definition of “calcium-carbonate-bacteria”: “Die Bacterien erzeugen entweder aus Eiweisz, ihren Derivaten oder Nitraten Ammoniak, dieses verbindet sich mit der im Wasser gelösten Kalksalzen . . . . zu Kohlensauren Kalk, der entweder für sich allein oder mit Phosphorsäure zusammen in Form der Sphärite erscheint 3).

It is evident that the difference between: “Verwesungsfällungskalk” and “physiologische Fällungskalk” mentioned above, has no reason to be kept, a conclusion backed by Professor Dr. A. J. KLUYVER.

Bacteria which produce lime were met with by DREW in great numbers in the surface-water and in the mud of the sea of Florida, they only prosper in warm seas and in the most florid way in depths less than 100—200 fathoms 4).

In the mud in loco VAUGHAN 5) found calci-spherulites of 4—6 μ. HARTING’S and STEINMANN’S 6) experiments might cause the supposition that the formation of spherulites, is only possible in a viscous medium. Professor Dr. A. J. KLUYVER kindly communicated to me: “A viscous medium is certainly not necessary for the formation of calci-spherulites, perhaps not for the manganese-spherulites.

A further indication of the conditions during the sedimentation of this rock gives the following quotation from MOLISCH’S paper (loc. cit. page 135): “Die Menge des Ammoniaks muss eine gewisse Höhe erreichen.
wenn die Fällung des CO$_3$Ca erfolgen soll". Strong oceanic currents are consequently not to be expected.

HARTING, STEINMANN 1) and BEIJERINCK (loc. cit.) found in the spherulites from their experiments an organic matter with properties of conchyloline. It is possible that part of the residue, obtained by dissolving the rock, and which was considered as clay, may be conchyloline.

Coccolithophoridae 2) are uni-cellular Flagellata which belong to the nanno-phyto-plankton. They avoid sweetened sea-water and are met with in tropical and temperates seas. According to MURRAY and RENARD Rhabdosphaera and Discosphaera Lohm. would have their greatest development in aequatorial seas. Coccolithophora Lohm. in the seas of the temperate zones.

Curious is that in this sediment, though certainly formed in the tropics Rhabdosphaera and Discosphaera occur very subordinately.

The origin of the rock: 3) About the young-tertiary Globigerina-rocks of Rotti, BROUWER (loc. cit. page 76) writes: . . . "achten wij het waarschijnlijk dat ze — hoewel in samenstelling veel overeenkomst vertoonend met sommige afzettingen van recent globigerinenslib in diepzee — niet op zeer groote diepte, maar in een zee, waarin misschien koraaleilanden aanwezig waren, zijn afgezet. Wij kunnen b.v. denken aan soortgelijke afzettingen als de kalkslibvormingen in lagunen van koraalriffen en die welke ontstaan uit met koraalmelk beladen, „witte water”, dat na stormen tot verscheidene kilometers afstand van koraalriffen voorkomt, waaruit het kalkslib gelijkvrij met de globigerinenschalen is bezonken.

Of, de globigerinengesteenten kunnen zijn afgezet op een dicht onder de zeeoppervlakte gelegen rug, die door diepere zeeën met gunstige levensvoorwaarden voor planktonische foraminiferen was omgeven" 4)

In literature a recent mud of the composition of this rock is not known. Of the fossil limestones the limes of Albrada, a raised atoll in the Indian Ocean 5) are to be compared with this rock. But VOELTZKOW

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1) G. STEINMANN 19, p. 40—45.
2) H. LOHMANN loc. cit. J. SCHILLER loc. cit.
3) In the microbiological parts the author's thanks are due to Prof. Dr. A. J. KLUYVER and Ir. C. B. VAN NIEL, to whose better judgment the questions were submitted.
4) " . . . we think it probable that — in spite of the great resemblance of their composition with some sediments of recent globerina-ooze in the deepsea — they were not sedimentated in very great depth, but in a sea, where perhaps coral-islands were present.

For instance, we can think of analogous sediments as the formations of calcareous-mud in lagoons of coral-reefs and those which issue from “white-water” loaded with coral-milk that after storms occurs up to several kilometers' distance from coral-reefs, from which the calcareous-mud simultaneously with the shells of the globerina were sedimentated.

Either, the globigerina-rocks were formed on a ridge situated close to the sea-surface and surrounded by deeper seas with favourable conditions of life for planktonic foraminifera”.
5) A. VOELTZKOW 21.
still owes an explanation for the occurrence of the coccoliths in "pure culture".

Brouwer's first explication is most probable for this rock, but under very circumstances.

The geological occurrence in connection with coral-reefs is an indication of a formation in shallow water: the fine-granularity, the occurrence of calci-spherulites for a quiet medium, circumstances which are to be found in the most quiet parts of the lagoon of an atoll, far from the entrances to the open ocean and which in this special case were met with far from the shores of the lagoon. So the rock represents the finest "washings" of coral-mud, brought by weak currents, stronger sea-currents which could transport coarser material do not occur or are very scarce. The accumulated coral-mud consisted of fine detrital lime issued from the atoll, of coccospores and little foraminifera. They could settle in this part of the lagoon, the organisms died, the dead albumen-matter were putrefied by bacteria, the issuing ammonia reached a concentration necessary for the precipitation of calcium-carbonate, besides, the manganese-compounds in the volcanic ash were transformed in manganous-carbonate. In this part of the lagoon probably only bacterial life was possible, all organisms occurring in this rock must be originated from individuals not living in situ, a conclusion drawn from the absence of greater foraminifera. ¹)

The organisms, bearers of the "Disco-asters" must not be considered as a form adapted to these special conditions, they are common in the group of the soft globigerina-rocks, which represent more normal coral-mud: (e.g. 178 × from Bebalain).

This rock-abnormity can be nothing but a local facies.

**Literature.**


¹) For the "azoism" the denitifying bacteria could be hold responsible (Brandt’s hypothesis). The flora and consequently the fauna too, due to the resulting scanty percentage, eventually, the total absence of nitrates.

The circumstance that the waterrefreshment is very defective makes comprehensible that the bacteria consume the nitrates almost completely.

It is possible too that this part of the lagoon runs dry when the tide is low, but for this I have no indication. (e.g. mud-cracks).

Laboratory of Stratigraphical Geology and Palaeontology.
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