nitely thin perfectly conducting screen. We could scarcely be sure beforehand that the conditions are sufficiently satisfied even by a scratch upon a silver deposit. The case of an ordinary spectroscope slit is quite different. It seems that here the polarisation observed with the finest practicable slits corresponds to that from the less fine scratches on silver deposits".

With the last words RAYLEIGH refers to an observation by FIZEAU, who on scratching in a silver layer on glass perceived that the transmitted light was polarized perpendicularly to the direction of the scratch, if the width of the latter was $\frac{1}{1000}$ mm. If this width however was estimated at $\frac{1}{10000}$ mm. the polarisation was in the direction of the scratch, viz. the electric vibrations were chiefly perpendicular to it. With spectroscope slits the latter case does not occur.

It will be remembered that DU BOIS and RUBENS [1]) found with a wire grating a point of inversion for ultra-red light, just as FIZEAU observed with scratches.

Geology. — *"On the occurrence of nodules of manganese in mesozoic deep-sea deposits from Borneo, Timor, and Rotti, their significance and mode of formation"*. By Prof. G. A. F. MOLENGRAAFF.

(Communicated in the meeting of January 30, 1915).

The question whether deep-sea deposits, and more especially oceanic abysmal deposits, of earlier geological ages, take part in more or less appreciable degree in the formation of the existing continental masses, may be considered of prime importance for the solution of several geological problems. If answered in the affirmative, the conclusion at once follows that movements of the earth's crust must have taken place of an amplitude, sufficiently great, to bring deposits formed at a depth of 5000 metres or more, above the surface of the sea.

Some twenty years ago the opinion prevailed, that true abysmal deposits of former geological ages, had nowhere been proved, with certainty, to exist in the continental areas. It must be admitted that at that time, descriptions of occurrences of such abysmal deposits were scanty and far from convincing. This may have been partly caused by the fact, that fossil deep-sea deposits are not conspicuous

[1]) H. DU BOIS and H. RUBENS. Ber. Berl. Akademie 1129. 1892.

as such, and that the organisms they contain, being only clearly visible with the aid of a strong pocket lens, or a microscope, are easily overlooked.

At all events, MURRAY and RENARD, in their classical treatise on recent deep-sea deposits, were very sceptical with regard to the question whether these play a role of any importance in the structure of the continents, as can clearly be proved by the following quotations: "With some doubtful exceptions it has been impossible to recognise in the rocks of the continents formations identical with these (i. e. the recent) pelagic deposits", [1]) and "It seems doubtful if the deposits of the abysmal areas have in the past taken any part in the formation of the existing continental masses". [2])

Later, it must be admitted, strong proofs have been given [3]) of the deep-sea character of certain red shales with radiolaria, and certain cherts and hornstones with radiolaria, the former being the fossil equivalents of the recent red clay, the latter, the typical radiolarites, being the fossil equivalents of the recent radiolarian ooze. And it also has been pointed out that their occurrences in the continents, must be found strictly limited to folded mountain ranges of recent and earlier ages i. e. to the movable or geosynclinal areas of the earth's crust[4]) and cannot be expected to occur in the original stable or continental masses i. e. the "aires continentales" in the sense of HAUG. Although it has thus been distinctly proved that the occurrences of deep-sea deposits of earlier ages in the continental masses cannot be regarded as "some doubtful exceptions" yet, as is clearly reflected in the most modern handbooks of geology, the doubt regarding their importance has not yet been dispelled.

One of the most prominent American geologists recently in a study on the testimony of the deep-sea deposits [5]) strongly supports the view held by MURRAY and RENARD in 1891.

It is evident that in proportion to the strength of the arguments

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[1]) Report on the scientific results of the voyage of H. M. S Challenger. J. MURRAY and A. F. RENARD. Deep-sea deposits, p 189, London 1891.

[2]) Ibidem, Introduction p. XXIX.

[3]) See i. a. G. A. F. MOLENGRAAFF. Geological explorations in Central Borneo p. 91 and again pp. 439—442. Leiden 1900 and G. STEINMANN. Geol. Beobachtungen in den Alpen. 2. Die SCHARDT'sche Ueberfaltungstheorie und die geologische Bedeutung der Tiefseeabsätze und der ophiolitischen Massengesteine. Berichte d naturfor. Ges. zu Freiburg XVI, p. 33, 1905.

[4]) G. A. F. MOLENGRAAFF. On oceanic deep-sea deposits of Central-Borneo. Proc. of the Royal Academy of Sciences, Amsterdam XII, p. 141. Amsterdam. 1909.

[5]) T C. CHAMBERLIN. Diastrophism and the formative processes. V. The testimony of the deep-sea deposits. Journal of Geology XXII p. 137, 1914.

afforded for the identity between *all* the characteristics of the rocks which are maintained to be the fossil equivalents of the recent deep-sea deposits and of those latter deposits themselves the probability must increase of this equivalency being generally accepted. Up to the present it must be admitted, notwithstanding the almost absolute similarity, which has been proved to exist between recent radiolarian ooze, and triassic and jurassic radiolarites from some Alpine localities, from Borneo, and some other islands in the East Indian archipelago, one *important and remarkable characteristic* of recent abysmal deposits, i.e. *the concentration of oxides of manganese in nodules has hitherto never been observed in fossil deep-sea* deposits forming part of continental areas [1]).

To what extent, and in which way manganese nodules are characteristic of abysmal deposits?

The accumulation of oxide of manganese or shortly of manganese in recent deep-sea deposits is very striking; almost without exception manganese [2]) is found in all deep-sea deposits. Concretions of manganese of various dimensions are especially abundant in true abysmal deposits, i. e. the red clay and the radiolarian ooze.

MURRAY [3]) in his latest book on deep-sea deposits remarks: "The oxydes of iron and manganese ... in certain abysmal regions of the ocean ... form concretions of larger or smaller size, which are among the most striking characteristics of the oceanic red clay."

The question arises, whether, and to what extent, nodules of manganese must be considered characteristic *exclusively* of abysmal deposits; do they occur in such deposits *only* or also elsewhere?

In the report of the Challenger-expedition, and in the memoir of MURRAY and HJORT [4]) quoted above it is reported that such nodules of manganese have been dredged from shallow depths, and that they have been found to occur there even in abundance, in some places,

[1]) PHILIPPI says about this while treating the probability of the occurrence of deep-sea deposits in former geological formations: "Auch sind meinens Wissens die für recente Tiefseeablagerungen so charakteristischen Manganknollen .... bisher noch aus keiner Formation bekannt geworden." E. PHILIPPI. Ueber das Problem der Schichtung und über Schichtbildung am Boden der heutigen Meere. Zeitschr. d deutschen geol. Ges. LX, p 356, 1908.

[2]) T. MURRAY and A. F. RENARD say: "Rarely can a large sample of any mud, clay or ooze be examined with care without traces of the oxides of this metal being discovered, either as coatings or minute grains."

[3]) J. MURRAY and J. HJORT. The depths of the ocean, p. 155, Londen 1912.

[4]) l.c. p. 157.

where volcanic material forms a large proportion of the constituents of the deposit on the bottom of the sea.

In the Kara-sea, highly ferruginous nodules of manganese have been brought to the surface from terrigenous muds, at a moderate depth by the Netherlands Arctic expedition in the years 1882/83.

During the Siboga-expedition, WEBER, in the deep-sea basins of the Netherlands East-Indian archipelago, has found manganese nodules on one spot only between the islands of Letti and Timor, at a depth of 1224 metres, in mud containing a strong proportion of terrigenous material, being in no way a true pelagic deposit; manganese forming an incrustation on a fragment of dead coral, has moreover been observed in a sample dredged from a depth of 1633 metres, between the islands of Misol and Ceram. [1])

As to the fossil occurrences, I have found in Upper-Triassic deposits, on the eiland of Timor, roots of Crinoids which certainly did not grow on the bottom of an ocean of abysmal depth, heavily incrusstated with a coating of concretionary manganese.

Nodules and concretions of manganese 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 and could only have been formed on the bottom of a very deep ocean. On the contrary, concretions of manganese have been formed on the bottom of all oceans in varying depths when the conditions for their formation were favourable.

MURRAY and RENARD maintain — and I have no reason to diverge from this opinion — that these favourable conditions are afforded by the presence of basic volcanic material in an easily decomposable form. As soon as this condition is fulfilled the possibility is realized for the formation of concretions of manganese, but the chemical process of their growth is a very slow one, as has been amply proved by the researches of the Challenger-expedition. In shallow seas, especially at small distances from the mainland, sediments derived from land or from a planctonic and neritic fauna accumulate rapidly, so rapidly indeed, that there is only a remote chance of finding by dredging, concretions of manganese, which in the mud in odd places grow very slowly. In abysmal seas far from land very different conditions prevail, the rate of accumulation of sediment is an extremely slow one there, the afflux of terrigenous material is reduced almost to nil, whereas from the plankton only the siliceous

[1]) Siboga-Expeditie I, M. WEBER. Introduction et description de l'expédition, p. 81 and p. 137. Leiden 1902.

tests i. e. these of radiolaria and diatoms reach the bottom, the calcareous test being dissolved by the cold water of the deep seas with its high ratio of oxygenium and carbonic acid held in solution, before they reach the bottom. The growth of the concretions of manganese, however, is not hampered in these depths; on the contrary it even appears as if in abysmal depths in water of a temperature very near the freezing point and containing much oxygenium in solution, the conditions for the formation of concretions of oxydes of manganese, are more favourable than in shallow seas, provided that traces of volcanic material occur as a source of manganese from whence the manganese could have been derived. Thus, concretions of manganese, slow as they are in their process of formation, and inconspicuous as they are in sediments in places where the rate of accumulation is rapid, can become an important constituent where the rate of accumulation of a deposit is extremely slow, as is the case in the abysmal areas.

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.*

And from this it is easy to conclude that concretions of manganese are characteristic of abysmal deposits in the same manner as the tests of radiolaria. The latter sink to the bottom of the ocean from the plankton everywhere within the limits of their geographical distribution, just as well near the mainland as far from the shore. Near the land these tests, owing to their minuteness, however, disappear being incorporated in enormous quantities of other chiefly terrigenous material which there comes to deposition; far from land, on the contrary, at the bottom of the very deep ocean-basins at depths over 5000 metres, where calcareous tests sinking down are dissolved before reaching the bottom of the ocean, these siliceous tests, small as is their individual mass, may form a great, sometimes a preponderating portion of whatsoever is deposited.

It is therefore quite justifiable to maintain, that radiolaria and concretions of manganese, form part of the most characteristic constituents of abysmal oceanic deposits, and further that nodules of manganese containing radiolaria almost with certainty must have been formed in the deeper portions of the ocean basins.

Localities where concretions of manganese have been found in deep-sea deposits of mesozoic age.

Concretions of manganese have been discovered by the geological

expedition to the islands of the Timor group in 1910—1912 in triassic and jurassic deep-sea deposits, on the Island of Timor, and also well developed in similar jurassic deposits on the Island of Rotti, and previously, (in 1894, and later) I had noticed them in abysmal deposits of the precretaceous probably jurassic Danau formation, occurring in West and East Borneo.

Rock specimens were collected by the undermentioned observers, and their examination has afforded proof from which several deductions have been included in this paper.

a. In 1894 in Central Borneo by the author.

b. In 1898—1900 in the basin of the Mahakkam River by Prof. A. W. NIEUWENHUIS.

c. In 1902 in the Long Keloh, a small branch of the Long Kelai, which is one of the great tributaries of the Berau-stream in East-Borneo, by Mr. VAN MAARSEVEEN,

d. in 1911, on the island of Timor by the Netherlands Timor-expedition led by the author,

e. in 1911 and 1912, on the island of Rotti, by Dr. H. A. BROUWER, one of the members of the same expedition.

All the specimens collected with the exception only of these of Central-Borneo are stored in the geological museum of the Technical Highschool at Delft.

On the mode of occurrence of the manganese in the rocks.

In the rocks just mentioned the manganese has been concentrated in various ways:

1. *As grains,* i.e. minute concretions, frequently only recognisable as such under the microscope, occurring throughout the rock. This form of concentration is very common in red shales, which are the equivalent of recent red clays. These shales vary in colour from brick red to chocolate brown, they invariably include a noticeable proportion of silica, (in places a little lime) and, in varying quantities, tests of radiolaria. The characteristic red colouration is due to the presence of oxide of iron, and this tint deepens into chocolate brown in proportion to the increase in the percentage of manganese, entering into the composition of the rock.

This mode of accumulation is of almost general occurrence in all deep-sea deposits containing much clay [1]), but is of less import-

[1]) In modern deep-sea deposits the bulk of the manganese is just as well concentrated in small grains, causing the brownish red and chocolate brown colour of the deep sea silt, especially of the *red-clay* of the Pacific and the Indian Ocean. Compare J. MURRAY and A. F. RENARD l. c. p. 191, p. 341 and Pl. XXII fig. 1.

ance, and may even be wanting in siliceous deposits, i.e. the cherts and hornstones, which are predominantly composed of tests of radiolaria.

I have observed manganese accumulated as grains in the following deep-sea rocks:

a. in red limeless siliceous clayshales with radioloria, probably of jurassic age, which are the prevailing rocks in the entire area of the Danau-formation of Central-Borneo, and in lesser quantities also in the cherts, jaspers and hornstones, which occur interstratified between the layers of the clayshales.

b. in red and brown, mostly limeless, siliceous clayshales of triassic age in several localities spread over the island of Timor, and also less abundant in the nodules and layers of chert and hornstone accompanying these shales.

c. in siliceous limestones, marls[1]) and more or less siliceous and calcareous clayshales with radiolaria, as well as in the nodules and layers of hornstone contained in those rocks of jurassic age which occur very plentiful in a great portion of the island of Timor.

d. in jurassic deep-sea deposits on the island of Rotti[2]), being identical which those just mentioned from Timor.

Probably the precipitation and accumulation of manganese is always initiated by the formation of such grains and a gradual transition can be observed between this mode of concentration and others by which the ore is more strongly localized.

2. *as nodules.* Nodules of manganese are accumulations or rather concretions of larger size than grains, being either perfectly round, or more irregular and nodular, but always well rounded[3]). They

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[1]) The strong proportion of lime contained in these rocks gives rise to the question, whether the jurassic deep-sea deposits of Timor and Rotti, although they are formed far from land and thus truly oceanic, might have been deposited in water less deep than the sea, in which the entirely limeless precretaceous deep-sea deposits of the Danau-formation of Central-Borneo have been formed The author intends to discuss elsewhere the far reaching problem, connected with this question.

[2]) Possibly also triassic and cretaceous deposits are comprised within this series of folded strata. Compare H. A. Brouwer. Voorloopig overzicht der geologie van het eiland Rotti. Tijdschr Kon. Ned. Aardr. Genootsch 2, XXXI, p. 614, 1914.

[3]) As far as the shape is concerned, the nodules found in radiolarites of jurassic age on the island of Rotti, are in every respect similar to those which have been dredged at great depths from the bottom of the ocean Compare J. Murray and J. Hjort. The depths of the ocean p. 156: "The commonest form of the manganese nodules is that of more or less rounded nodules . . . looking like marbles at one place, like potatoes or like cricket balls at other places".

are found both in the red deep-sea shale and in the hornstone and chert with radiolaria (radiolarite).

As to their occurrence the following information may be given:

a. The author possesses from the island of Borneo a single, mediumsized nodule, only collected by VAN MAARSEVEEN in chert from the Danau-formation in the bed of the Long Keloh river in East-Borneo.

b. On the island of Timor nodules of manganese have been observed in several places in deep-sea deposits; a very beautiful specimen (Pl. I, fig. 2) was collected in clayshale with radiolaria, probably of triassic age near the hill Somoholle in the Beboki-district, about 720 metres above sea-level.

c. On the island of Rotti nodules of manganese were found in several localities in siliceous limestones, marls, siliceous and calcareous clayshales with nodules and flat concretions of chert all of jurassic age, which are full of tests of radiolaria. Exceedingly well preserved are the nodules of manganese in rocks from fatu Sua Lain[1]) on the north coast of Rotti and the author refers to this locality where in the following pages he describes the composition and the mode of formation of these nodules. They are always macroscopically well demarcated from the enclosing rock and in consequence of their greater resistance to weathering they gradually more and more protude from the red shales, and white marls in which they are found included, and thus often get detached from the rocks by the process of weathering. Such detached nodules of manganese can be collected in quantities on the beach near Sua Lain. Thus there is evidently a great chance that these loose nodules may be incorporated later on in younger deposits. VERBEEK, on the island of Rotti near Bebalain, has found nodules of manganese in marls of plistocene age. I have examined these nodules, and have found that they contain radiolaria identical to those which occur in the nodules found "in situ" in radiolarites of jurassic age at different localities on the island of Rotti. These nodules of Bebalain evidently have not originated in the marls of plistocene age, but have been incorporated as such in the rock.

3. *as slabs or flat concretions.* The concretions of mangenese often, are flat, and in this case more or less restricted to definite layers of great horizontal extent; in this way true bedded manganese deposits may originate.

[1]) Fatu = isolated rock or isolated group of rocks. R. D. M. VERBEEK gives a picture of the Fatu Sua Lain in his report on the geology of the Moluccas. Jaarboek van het Mijnwezen. 37. Wetensch. ged. p. 317 Batavia 1908.

Manganese accumulated in this manner has been found by the author in more than one locality.

A good example of this mode of occurrence is given in a complex of upper-triassic deep-sea deposits in the left slope of the valley of the Noil Bisnain, near the track from Kapan to Fatu Naisusu (commonly called the rock of Kapan) in Middle Timor. The ore-bearing portion of this complex of strata is 25 metres thick, and about 10 beds of manganese are found in it closely connected with variegated, siliceous clayshales and cherts with radiolaria, the entire complex being intercalated in strata containing limestones with tests of Radiolaria and shells of Halobia. The beds of manganese vary in thickness between 2 and 30 centimeters. Microscopical examination reveals traces of tests of radiolaria in the ore as well as in the rock.

4. in thin films on fragments of rock formed by the infiltration of manganese in cracks of the rock from which these fragments were derived.

In this way manganese is found infiltrated in the cracks of all the shales and in the majority of the cherts of the abysmal series on the islands of Borneo, Timor, and Rotti.

The chemical composition of the nodules of manganese.

I am indebted to Prof. H. TER MEULEN in Delft for a chemical analysis of a nodule of manganese taken from a marl bed with concretions of hornstone, from Sua Lain mentioned previously.

The result of the analysis in as follows:

Nodule of manganese from Sua Lain

SiO_2	2.9 [1])
$Fe_2O_3 + Al_2O_3$	2.3
MnO_2	57.7
MnO	10.5
CoO	0.3
BaO	11.7
CaO	5.6
Na_2O	1.1
CO_2	small quantity

The substance loses 1.05 % of its weight at a temperature of 125° C. and 15.3 % on roasting.

A similar analysis has been made by Mr. G. WITTEVEEN of the

[1]) In the original Dutch edition of this paper erroneously the figure 2.09 has been given for the percentage of SiO_2.

small nodules of manganese mentioned above, which have been collected by VERBEEK [1]) in plistocene marl near Bebalain on the island of Rotti. The result of their analyses was as follows:

Nodule of manganese from Bebalain	
SiO_2	3.44
Al_2O_3	—
Fe_2O_3	1.45
MnO_2	62.06
MnO	6.03
BaO	9.18
H_2O	8.86
CaO and alkalis	not determined

Obviously there is a great similarity in chemical composition between the concretions of manganese from Sua Lain and those of Bebalain. Baryum figures highly in both the analyses. Comparing these two analyses with 45 analyses [2]) made from concretions of manganese dredged by the Challenger from recent deep-sea deposits, the proportion of iron proves to be low in the mesozoic nodules of Rotti. In recent nodules of manganese from the deep-sea the proportion of iron, determined as oxyde of iron, varies from 6.46 to 46.4. The proportion of manganese determined as MnO, in these two extreme cases proved to be 63.23 and 14.82 respectively.

On the relations between the concentration of manganese in the form of grains and of nodules.

It is not an easy matter to study the manner in which the accumulation of manganese in recent deep-sea oozes takes place, because in the process of dredging the samples from a great depth, the sediment is agitated more or less and therefore the sample does not show any more the original position and mutual arrangement of the grains and the nodules of manganese in the mud or ooze at the bottom of the ocean. As soon as, however, the deep-sea ooze is cemented into rock as is the case with these deposits of former geological ages the mutual arrangement of the grains and nodules of manganese is no more modified, and can be studied under the microscope in slides made of these rocks. These slides will show

[1]) R. D. M. VERBEEK l.c. p 393.

[2]) J. MURRAY and A. F. RENARD l.c. p. 464—487.

so to say the process of the accumulation of the manganese in full progress but fixed or petrified at a certain moment.

Rocks from certain localities on the island of Rotti, which proved to be suitable for microscopical examination, have been studied by the author, and therefore a few words on the mode of occurrence of these rocks may serve as an introduction, before the results of this study will be dealt with.

On the island of Rotti deep-sea deposits, both of triassic and of jurassic age occur, but concretions of manganese in their original position, have as yet only been found in sediments the jurassic age of which has been determined in more than one locality. These sedimentary rocks are characteristically exposed in the rocky cliffs of Sua Lain near Termànoe situated on the north coast[1]) of the island.

They are well stratified here, and the strata folded and tilted, but not so disturbed, that the original sequence of the beds could not be determined with certainty.

The bulk of this complex of strata is composed of true abysmal deposits in which exclusively tests of radiolaria occur, but in the same complex also limestones are found which contain both radiolaria and belemnites of jurassic[2]) age. The geological age of these deep-sea deposits has thus been proved beyond doubt.

The deep-sea deposits are here represented by siliceous and slightly calcareous red clay shales, which pass into reddish marls and limestones in proportion as the content of lime in the rock increases, the latter containing numerous concentrations of silica in nodules grouped together in more or less distinct layers. The shales, marls, limestones and cherts are completely studded with tests of radiolaria. Manganese is concentrated irregularly in fairly equal proportions, however, in the calcareous clay shale, in the siliceous limestone

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1) H. A. Brouwer. l.c p. 614.

2) Wichmann, who in his journey to the island of Rotti in the year 1889 visited Sua Lain, reports as follows on the geological structure of this groups of rocks: "Der Fels besteht aus einem wahrscheinlich tertiären Kalkstein, die sehr reich an Foraminiferen, namentlich Globigerinen ist und ausserdem von zahlreichen Kalkspathtrümmern durchzogen wird." (A. Wichmann, Tijdschr. Kon. Ned. Aardr. Genootsch. 2, IX, p. 231, 1892). This statement is erroneous. Verbeek has proved that the rock is not filled by tests of Globigerina but of Radioloria and Hinde takes them to be of triassic age. (compare: R. D. M. Verbeek l.c. p. 317 and G. J. Hinde, ibid. p. 696) moreover, in the numerous samples, taken by Brouwer from the strata of these rocks, no Globigerina, but exclusively Radiolaria are found, whereas it follows from the Belemnites, occurring in the same complex of strata, that these rocks cannot possibly be of tertiary age."

and in the chert. Manganese is present in small grains and in nodules, which are either spheroidal (Pl. I, fig. 1) or possess various irregular, often flat cake-like shapes, but are always rounded.

Microscopical examination shows that the ore is found as black dust all through the rock, and that it is, moreover, concentrated on numerous spots in larger grains, which tend to cluster together. In some spots these grains are so congregated together that with the naked eye the presence of a concretion of pure manganese is surmised, but the microscope reveals that in such a case the grains, though very closely packed together and thus resembling a cloud, still remain isolated from each other.

In other spots the accumulation is still more compact and a true concretion or nodule is thus formed, composed exclusively of manganese and tests of radiolaria.

Surrounding such a nodule or concretion, there is generally a concentration of the grains of ore, forming an opaque halo or border, which however rapidly diminishes in density with increasing distance from the nodule.

The larger and smaller nodules are more or less arranged and connected together in layers, thus tending to form beds or flat deposits of manganese. In recent deep-sea deposits flat concretions forming a kind of cake or slab of ore are similarly found. [1])

A great number of slides of nodules have been examined under the microscope in order to determine whether, in the interior of the nodulus, particles of minerals or remains of organisms were present, that had acted as a centre or nucleus, around which the ore had grown, thus giving rise to a concentrical structure of the nodule around one or more nuclei. As a rule no nuclei and no arrangement in concentric layers have been found within the nodules. Sometimes the manganese is first deposited within the tests of radiolaria, and the author has found cherts in which the accumulation of manganese has remained strictly limited to the interior of the tests of radiolaria In some cases the nodules may grow from such filled tests as centres, and thus polynucleal concretions may be formed. This is, however, rather of rare occurrence, and as a rule no nucleus whatever, and no concentric arrangement could be detected in the fossil nodules [2]).

[1]) J. Murray and A. E. Renard. l c. Pl. III fig. 3.

[2]) In this respect there is a difference between the fossil nodules of manganese and those of the existing deep-seas, for the latter very often, although not always, show a concentric arrangement around a nucleus as e.g. around a crystal of phillipsite, a shark's tooth or an otolith of a cetacean. It is clear that otoliths could

Polished slabs of nodules, examined in reflected light, in many cases proved to be better fitted for microscopic study than slides, the coherence in the nodulus being often not sufficient for the preparation of thin slides.

In cases where slides of sufficient thinness could be made, the effect was striking, the perforated tests of the radiolaria, which are composed of silica, and are distinctly pellucid, contrasting strongly with the completely opaque manganese both without and within.

On the mode of accumulation of manganese in the deep-sea ooze.

From the mutual relations between grains and nodules of manganese in mesozoic deep-sea deposits and the pecularities of the occurrence of radiolaria therein, deductions may be made regarding the mode of accumulation of ore in deep-sea ooze.

Manganese is precipitated on numerous spots as minute grains in the deep-sea ooze, which is a siliceous and somewhat argillaceous colloid in which tests of radiolaria are found suspended. In some places the precipitation is evidently more rapid than in others, and thus grains of different size are formed, all of them floating in a similar manner to the tests of radiolaria in the siliceous colloid. It appears that by mutual attraction [1]) the grains pack together and thus form stronger and stronger centra of attraction for other grains, forming eventually clouds, which on closer packing together, are gradually transformed into concretions or nodules, composed of pure ore.

During this process of gradual concentration of the ore into nodules, the tests of radiolaria are surrounded by the ore, without being shifted from their position, and finally are found in the nodules just at these places where they had been floating, suspended in the ooze. As long as the ooze remains viscous, a nodule once formed, continues to be a centre of attraction and collecting more and more minute grains of

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not be expected in jurassic deposits, but sharks' teeth and remains of other animals as e. g. belemnites could be expected to occur as nuclei in the jurassic nodules of manganese This difference, certainly, is remarkable, and as yet cannot be explained, but not too much importance ought to be attached to it, according to the author's opinion, firstly because many nodules from recent deep-sea deposits in a similar manner do not show a concentrical structure, and secondly because the fossil nodules, which hitherto have been examined microscopically, come from three localities only, not far distant from each other, all from the island of Rotti.

[1]) The existence of this attraction is deduced by the author from the observed facts, without giving an explanation of its cause; a fair proportion of iron always entering into the composition of the nodules of manganese it might be suggested that magnetic forces could be the cause of the mutual attraction of the small grains.

ore, becomes surrounded by a kind of halo in which grains of ore travelling slowly towards the focus of attraction, become more numerous than at a certain distance from the growing nodule beyond its sphere of influence, where the grains are found equally distributed in the ooze. The grains, it may be safely admitted, travel very slowly towards the larger nodules, and evidently the position of the tests of radiolaria in the ooze is not altered by their slow movement. The radiolaria are just as numerous and are spread in the same irregular manner both without or within the nodules.

Although the mode of formation of the concretions by the close packing together of grains of manganese fairly well explains the observed facts, it is, however, not quite clear how finally concretions are formed, composed of manganese and tests of radiolaria exclusively without traces of the ooze being enclosed.

It might be supposed that in the ooze diffusion currents around the growing nodules, carrying manganese in solution towards them are stronger around grains which are larger, and that consequently the latter grow faster, and by their growth may incorporate and absorb the smaller ones, and finally by this process a concretion or nodule may be formed. Also in this case the tests of radiolaria might be surrounded and absorbed by the growing concretions without being shifted from their original position, but it is not possible to explain why in this case halos of higher concentration with minute grains of manganese abundantly in suspension, should be found around the larger grains.

Probably these two processes collaborate in the mode of formation of the nodules, firstly growth by precipitation of manganese from convergent diffusion currents and secondly growth by accumulation and packing of preexisting minute grains [1]).

The result is the formation of a concretion with fairly well demarcated outlines, surrounded by a cloud of smaller grains rapidly diminishing in density. The concretion itself is composed almost

[1]) In the discussion following on the reading of this paper Mr. WICHMANN remarked that according to his opinion, the nodules in deep-sea deposits are not formed by anorganic processes, but by biochemical processes caused by bacteria He drew the attention of the members to experiments made by Mr. BEIJERINCK, who proved the existence of bacteria possessing the quality to precipitate manganese as superoxyde from solutions of carbonate of manganese. The author admitted the possibility of such biochemical processes as the cause of the accumulation of manganese in deep-sea ooze, but he pointed out that hitherto the existence of bacterial life in abysmal depths had not been proved. Compare M. W. BEIJERINCK. Oxidation of mangano carbinate by microbes. Proc. of the section of sciences of the Kon. Akad. der Wetensch. Amsterdam XVI I. p. 397, 1914.

exclusively of manganese but as a rule [1]) contains numerous tests of radiolaria, which in the nodules show a lack of any regular arrangement just as is the case outside the nodules in the surrounding ooze.

The mutual relation between the accumulation of manganese and of silica.

The study of fossil deep-sea deposits reveals that, before these deposits had been converted into rock, the silica in the ooze has been concentrated in the same manner as the manganese, with this difference only, that the concretions of silica, as chert, or hornstone have much greater dimensions, and are far more numerous than those of manganese.

Silica just as well as manganese is accumulated in fossil deep-sea deposits in concretions or nodules of manifold shapes, originally having been formed in an ooze or colloid, which itself by cementation (petrification) has been converted later into siliceous clayshale, marl or limestone.[2]) The process of aggregation of the silica is, however, posterior to that of the manganese. The silica, in concentrating, not only envelops, and encloses, the tests of radiolaria which float suspended in the ooze, but in the same way also the nodules of manganese. Both, the tests of the radiolaria and the nodules of manganese, remain in their places, and, being enveloped by the silica, are not shifted from their original position.

The radiolarites (radiolarian rocks) from the island of Rotti thus prove that in their origin and development the nodules of manganese are absolutely independent of those formed of silica; they are just as numerous within as without the nodules of hornstone, and frequently one nodule of manganese is found enclosed partially by hornstone, and partially by siliceous clayshale or marl. Radiolaria occur just as plentiful and scattered in the same way in the nodules of manganese, in the concretions of hornstone, and in the surrounding clayshale of marly clayshale.

It is further obvious that the two processes of the accumulation of manganese and of silica are not only entirely independent of each other, but are also not synchronous; in fact, the process, i.e.

[1]) On the island of Rotti the author has found several jurassic nodules of manganese containing hardly any test of radiolaria.

[2]) According to the results of an analysis, for which I am indebted to Mr. J. DE VRIES, in a siliceous limestone with nodules both of manganese and hornstone, the proportion of silica of the rock outside of the nodules of hornstone amounted to 4.94%, notwithstanding obviously the bulk of the silica in this rock had been concentrated into the nodules of hornstone.

the accumulation of the manganese, must have reached its final stage, before the second commenced. This is quite in harmony with the testimony given by modern deep-sea deposits. Nodules of manganese are found in abundance in the deep-sea oozes, but concretions of silica e. g. as nodules of hornstone, have not yet been met with. Obviously, in the recent deep-sea oozes (especially in the red clay and the radiolarian ooze), the process of accumulation of manganese partly has been completed, partly is still in full progress, but the process of concentration of silica into hornstone, chert, jasper etc. has not yet commenced.

It might be questioned, whether possibly the concentration of the manganese and a fortiori of the silica, might have taken place after the deep-sea deposits, by diastrophism, had been brought into the position, where they take part now in the formation of mountain-ranges. This question has to be answered in the negative; the concretions of manganese and those of silica have been influenced by the mountain-building processes precisely in the same way as the rocks in which they are found enclosed, and it is easy to prove that before the mountain-making processes came into operation they had already been solidified, and had attained their full size.

It is only the last of the possible modes of accumulation mentioned on p. 421—423 i.e. the infiltration of manganese in the cracks of the rocks, which according to the opinion of the author has taken place entirely, or almost entirely after the deep-sea ooze had been solidified into firm rock, and had been crushed more or less by pressure.

Iron and manganese are generally found together in cracks of fossil deep-sea deposits, especially in cherts. In some places, as is the case in West-Borneo, iron predominates, in other places, as in East-Borneo, manganese prevails. In case of strong pressure the chert is often converted into a crush-breccia cemented by manganiferous iron-ore. Frequently the chert is then found altered into white amorphous silica, in which case beautiful rocks originate, being composed of a mosaic of pure white angular fragments, cemented by chocolate-brown films of iron-ore.[1])

[1]) G. A. F. Molengraaff, Geological explorations in Central-Borneo, p. 92, 1902.

G. A. F. MOLENGRAAFF. "On the occurrence of nodules of manganese in mesozoic deep-sea deposits of Borneo, Timor and Rotti, their significance and their mode of formation."

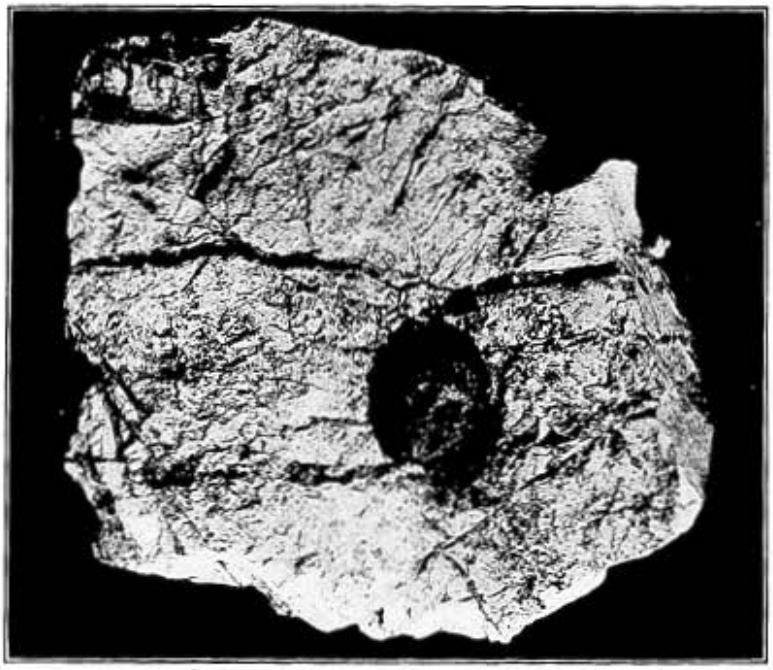

Fig. 1. Manganese nodule in jurassic marl with chert-nodules and radiolaria from Sua Lain, Island of Rotti. Original size.

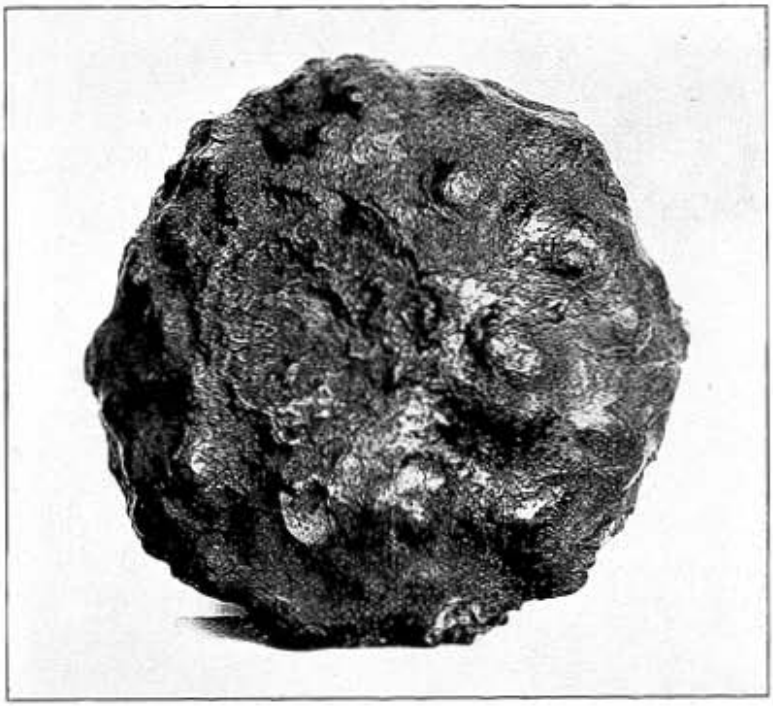

Fig. 2. Manganese nodule in triassic deep-sea deposits, in the vicinity of the mountain Somoholle, district Beboki, Island of Timor. Original size.