then continually under the pressure of the saturated vapour, so that we reach the point S along the line KS.[1])

3. The cooling has not been continued sufficiently long. For in cases as in fig. 9 the triple point S lies mostly at very low temperatures. Then, of course, only the cooling must be continued. It is however to be feared then, that the case 1 occurs before the line SM is reached.

4. There is no crystallized state (fig. 10 and 11). Then we may wait very long before the amorphous glassy mass crystallizes.

(*To be continued*).

Geology. — "*On oceanic deep-sea deposits of Central-Borneo*". By Prof. G. A. F. MOLENGRAAFF.

In the year 1894 I discovered in the basin of the Upper Kapoewas in Western Borneo[2]) cherts and hornstones, consisting almost entirely of tests of Radiolaria, which I described as deep-sea deposits. Such rocks are also known as Radiolarite.

The Radiolaria from these deposits were examined by HINDE [3]) and in consequence the age of these rocks was determined as pre-cretaceous, probably as jurassic.

The formation, of which these Radiolarites form part, I named the Danau-formation, after the large danaus or lakes of Western Borneo, where this formation is well-developed and was first observed by me. The Danau-formation there occupies a strip of country of an average breadth of 60—70 K.M. which is bordered on the north side by older formations, namely of the old-slate-formation, while on the south side it disappears under younger tertiary sandstones and volcanic products. The whole formation is strongly folded with an east-west strike, and forms part of the Upper Kapoewas mountain range.

From the lake district I could follow this formation eastward as far as the watershed between the Upper Kapoewas and the Upper

[1]) Might it not be possible to try to make some of the many substances mentioned to me by Mr. JAEGER crystallise as e. g. several esters of organic acids, amber-acid-nitril, and others?

[2]) G. A. F. MOLENGRAAFF. Geological explorations in Central Borneo. p p. 123 & 414, Leiden 1902.

[3]) G. J. HINDE, ibidem, Appendix I.

Mahakkam rivers and just beyond it, for a distance of 230 K.M. At that time nothing was known regarding the geological structure of the basin of the Upper Mahakkam, but a short time ago I was enabled to resume my studies on the distribution of these Radiolarites since there have been placed at my disposal the collections made by NIEUWENHUIS[1]) in the riverbasins of the Mahakkam and Upper Kajan in the years 1896—97 and 1898—1900, also the unpublished results of investigations made by BONARELLI along the rivers Kĕlai and Sĕgah in the Bĕrau district in the years 1905 and 1906, and finally a collection of rocks made by VAN MAARSEVEEN along the river Kĕlai and its tributary the Kĕloh in the year 1907. From these studies it results that the Danau-formation extends eastward, without changing its character, from West Borneo into East Borneo right through the basin of the Upper Mahakkam; it reaches the watershed between the Mahakkam and the Kĕlai eastwards of the Boh-river, and is finally also found on the north side of this watershed in the basin of the Kĕlai in the Bĕrau district, always with the same strike from west to east or nearly so. At an average distance of 50 K.M. from the East coast of Borneo it finally disappears in the Bĕrau district under the younger, tertiary coast-range of East Borneo.

The total length of the strip of country, in which the occurrence of the Radiolarian rocks has now been demonstrated, is 650 KM. and if the average width be taken at somewhat over 60 KM. this area occupies roughly 40000 square kilometers. The composition of the cherts and hornstones remains perfectly constant over the entire distance, and in every locality the same types of rocks are found again and again presenting the same macroscopical and microscopical characteristics.

The first type is the Radiolarian hornstone, the true Radiolarite. This rock is semitransparent, hard, brittle and splintery and of a colour varying between milkwhite, red and greenish. It consists for about 97% of silica and is composed almost exclusively of closely packed tests of Radiolaria, joined together by a siliceous cement. The red-coloured varieties may be called Radiolarian jasper; they contain a small percentage of iron. The tests of the Radiolaria are difficult to distinguish under the microscope in the milk-white varieties; they can be much better distinguished in the red jaspery varieties, but best of all they are preserved and discernable in the greenish varieties of the Long Kĕloh in the Bĕrau district.

The second type is an argillaceous chert or siliceous clay-shale,

[1]) A. W. NIEUWENHUIS. Quer durch Borneo. Leiden 1904.

which is always coloured bright red and contains more clay and iron and less silica than the first type. Radiolaria occur in it in variable quantity, but always much less than in the first type.

The two types pass one into the other quite gradually and all sorts of intermediate types occur. The distinct stratification of the cherts of the Danau-formation is caused by thicker strata of pure Radiolarian hornstone alternating with thin layers which contain more clay and less Radiolaria.

Both types and all intermediate stages agree in this respect, that they do not contain any constituents indicative of a terrigenous origin, and that the organic remains they contain all belong to Planeton organisms with siliceous tests, chiefly Radiolaria.

In an uncemented state, in which such deposits are still continually laid down on the bottom of the oceans at the present day, the deposits of the first type are called Radiolarian ooze and those of the second type red clay. Radiolarian ooze and red clay gradually pass one into the other, and only differ in the percentage of organic remains they contain. MURRAY, for instance, places the limit between red clay and Radiolarian ooze at a point where 20% of the deposit consists of tests of Radiolaria. It has been observed, that such deposits only occur in those parts of oceans which are far removed from land, and then again only in the very deepest portions.

This is explained by assuming that at very great depths calcium carbonate is dissolved by sea water, so that of the tests of the Planeton organisms,which continually sink down to the bottom of the sea only the siliceous tests ever reach the bottom in such depths, and consequently they alone are deposited and preserved.

As soon as one assumes that Radiolarian ooze and red clay are oceanic, abyssic sediments, deposited at very great depths, then, on account of the complete agreement, between Radiolarian hornstone and Radiolarian ooze on the one hand, and between red, cherty clay-shale and red deep-sea clay on the other hand, one must also conclude that the cherty rocks of the Danau-formation in Borneo are oceanic, abyssic sediments. It follows then further that at the time when these sediments were deposited, which was probably in the jurassic period, the greater portion of Borneo was the floor of a deep sea far away from land of any importance.

The view, which forms the starting point to this conclusion, and according to which calcium carbonate is dissolved by sea water at great depths, has been subjected to criticism bij THOULET[1]), a criticism

[1]) I. THOULET. Précis d'analyse des fonds sous-marins actuels et anciens p.p. 16 en 33. Paris 1907.

which therefore also applies to the supposition, that Radiolarian ooze is only deposited in the deepest portions of the oceans. THOULET's doubt arose from his observing stratification in some specimens of deep-sea ooze, in such a way that layers of Radiolarian ooze alternated with Globigerina ooze.

PHILIPPI and MURRAY [1]) observed in the specimens of deep-sea deposits collected by the Valdivia, that such a stratification is of common occurrence in deep-sea sediments. They showed that the power to dissolve calcium carbonate belongs especially to the ice-cold water from the polar regions which sinks down at high latitudes and moves very slowly along the bottom of the ocean to the lower latitudes. As this ice-cold water slowly gives off its oxygen it gradually loses its power of oxidizing organic substances into carbon dioxide, and consequently of dissolving calcium carbonate. In consequence the upper limit at which red clay and Radiolarian ooze occur, is deepest at the equator, namely at 5500 M., whereas at higher latitudes in the sub-arctic parts of the oceans, this upper limit is already found between 2000 and 3000 Meters. The position of this limit must therefore be dependent on climatic conditions and in general would be less deep in cold periods with strong development of the polar ice caps, than during warmer periods, when the ice-cold polar water only descends in smaller quantities and at very high altitudes.

PHILIPPI believes that the variations in the extent of the polar ice coverings, which certainly have taken place, explain the stratification of deep-sea sediments in a quite satisfactory manner, and that it is not permissible to doubt the correctness of the hypothesis that at great depths calcium carbonate is dissolved by sea water.

For the present I too find no reason for doubting that Radiolarian ooze and red clay *in equatorial regions* are only formed at great depths, below 5000 Meters, and just as well were formed exclusively at such depths in former ages, and that therefore the Radiolarian cherts and hornstones and the red cherty clay-shales of the Danau-formation in Borneo must have been deposited in an ocean of similar great depth [2]).

[1]) J. MURRAY and E. PHILLIPPI, Die Grundproben der Deutschen Tiefsee Expedition. Wiss. Ergebnisse der Deutsche Tiefsee Expedition. Bd. X. p 200, 1908.

E. PHILIPPI. Ueber Schichtbildung am Boden der heutigen und vorweltlichen Meere. Intern. Revue der ges. Hydrobiologie und Hydrographie II. p. 1. Leipzig. 1909.

[2]) E. PHILIPPI. Ueber das Problem der Schichtung und über Schichtbildung am Boden der heutigen Meere. Zeitschr. der deutschen geol. Ges. LX, p. 359, 1908. PHILIPPI suggests that during warm epochs in the earth's history with a mild climate prevailing even in the polar regions, the oceanic sediments laid down on the bottom of the oceans could possess a high percentage of carbonate of lime,

Hitherto not so keen attention has generally been paid to fossil, oceanic, abyssic deposits [1]) as might have been expected, considering that they indicate one of the most extreme situations into which a portion of the surface of the lithosphere can be brought, and considering that 40 % of the bottom of all oceans on earth consist of such deposits, which are still formed there continually.

Probably this is caused by the fact that such sediments have as yet been found in a fossil condition as rocks in but very few places under such conditions as permitting of their character as abyssic sediments being established beyond controversy [2]). This is again intelligible if we bear in mind that only under very special conditions deposits formed at a depth of more than 5000 meters below the surface of the sea, can be lifted so high as to form part of the dry land and become accessible to investigation. Theoretically the only chance of this occurs in mountain chains where sediments, formed at widely different depths, can be forced up by folding to a great height above sea-level.

The conviction that the earth's crust consists of parts of widely different stability, is gaining more and more ground. The more stable portions form extensive blocks which apparently can only change their position relative to each other and to sea-level by very slow upward and downward vertical movements. HAUG [3]) calls these stable blocks, whether situated above or below sea-level, *aires continentales* or simply continents. If they are situated above sea-level the formation of deep-sea deposits is excluded a priori, and if they are situated below the level of the sea, oceanic deep-sea deposits may be formed in case the depth of the sea is sufficiently great, but they have a very small chance indeed to get accessible to investigation.

The more mobile portions of the earth's crust, the geosynclinal areas, separate in broader or narrower strips the stable continental

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even in case they were deposited in abysmal depths. I personally doubt whether climatic changes could bring out such a radical change and consider the explanation given in the next pages for the possible cause of the paucity of fossil, oceanic, abyssic, siliceous sediments more likely.

[1]) Their very existence is even doubted by one of the leading text-books where it is only admitted for Barbados. O. KRÜMMEL. Handbuch der Oceanographie, p. 211. 1907.

[2]) For this a large area of distribution is necessary in the first place, because locally Radiolian rocks can be formed, which are not originated from abyssic sediments. Limestone containing Radiolaria e g. may be locally changed into Radiolarite through silicification and destruction of all organisms with calcareous tests.

[3]) EM. HAUG. Les géosynclinaux et les aires continentales. Bull. de la Soc. Géol. de France. 3. XXXVIII. p. 617. 1900 and Traité de géologie I. p. 157. 1907.

blocks [1]). The movements of the earth's crust which are probably in the first instance a result of the progressive cooling of the lithosphere, are concentrated in these strips. It may be that for a long time they form submarine troughs of very varying depths, the geosynclinals, in which a strong sedimentation and considerable piling up of sediments takes place. Only exceptionally where both the depth is very great and the nearest land surface remote (one can imagine this condition for instance when one or both of the adjoining continental blocks is wholly or partially submerged) oceanic abyssic sediments can be formed in portions of a geosynclinal. Afterwards, however, perhaps in consequence of this considerable sedimentation itself, the conditions of equilibrium of this labile strip may be changed, the geosynclinal may be compressed and thrust up to a mountain chain; the causes of these changes are still very imperfectly known, but in any case the study of the composition of the mountain chains themselves proves that before they were folded up they were geosynclinals. By the folding process the sediments are forced up, at whatsoever depth they might have been formed, and finally they may form part of high mountains [2]). Oceanic, abyssic sediments may in this way come to lie high above the level of the sea, and become accessible to investigation. Thus in mountain chains there is theoretically nearly the only chance, and even that is a small one, that fossil deep-sea sediments come to form part of the dry land. For this reason such deposits will be found limited to mountain chains and be relatively rare on land, however widely they may be distributed at present on the bottom of the oceans, and certainly always have been.

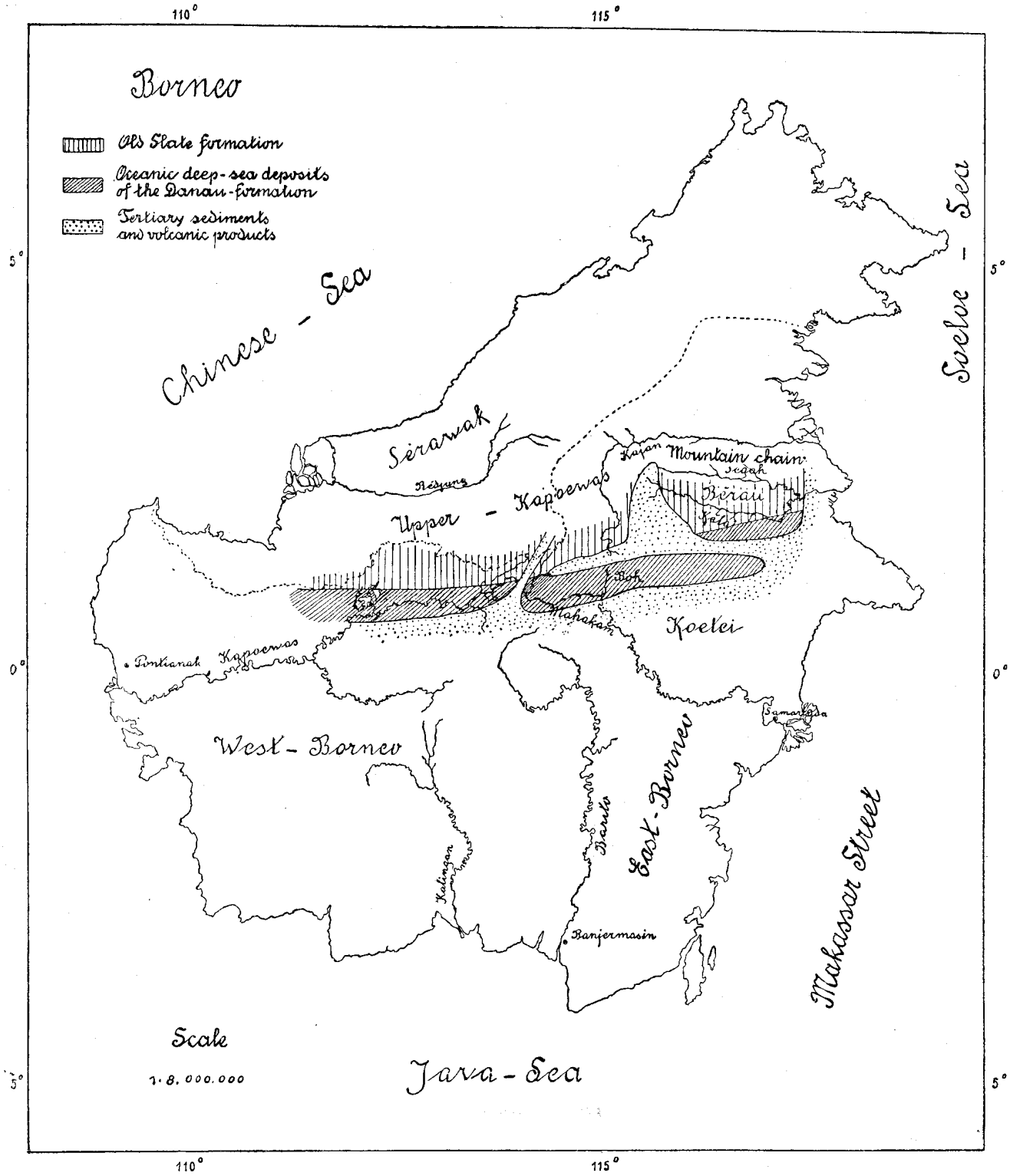
The facts hitherto known completely confirm this theory; all deep-sea rocks, which have so far been discovered occur in mountain chains or at least in geosynclinal areas.

In the first place this applies to the Danau-formation, the largest continuous area of fossil deep-sea deposits which is at present known.

Tectonically the Danau-formation forms part of the Upper Kapoewas mountain range (perhaps it would be better to call this now the Central Borneo mountain range) which extends with an east-westerly strike right across almost the whole of Borneo. The time when this important range was formed, is not yet known with certainty. The

[1]) The relative position of continents and geosynclinals changes but very slowly and remains permanent during long geological periods.

[2]) VERBEEK believes that if the folding takes place at great depth, the upper sediments need not be folded too but may be pressed up more or less vertically to a considerable height. In the West Indian as well as in the East Indian Archipelago such movements appear to have taken place on a large scale. R. D. M. VERBEEK, Molukken Verslag p. 816. Batavia 1908.


Borneo
Als Slate formation
Oceanic deep-sea deposits of the Danau-formation
Tertiary sediments and volcanic products
110°
115°
5°
0°
Chinese - Sea
Sulu - Sea
Serawak
Kapoewas
Mountain chain
Koetei
Pontianak
West - Borneo
East - Borneo
Banjermasin
Makassar Street
Java - Sea
Scale
1 : 8.000.000

youngest sediments which still have undergone folding belong to the cenomanian epoch whilst the tertiary sandstone which overlies the tilted rocks of the range inconformably is probably of miocene age.

One may assume that the Central-Borneo mountain range probably is the result of the oldest foldings of the Alpine system of crustal movements.

Mesozoic Radiolarian rocks have been described from various other parts of the East Indian Archipelago [1]) e. g. from Ceram, Boeroe, Rotti, Savoe, Celebes, but our knowledge of the tectonic conditions of these islands is still inadequate, and one can only say that the presence of these rocks in our archipelago, which is wholly situated in the area of the so-called Alpine folding system, is not at variance with the theory outlined above.

The upper-jurassic Radiolarian cherts of the Grisons and other parts of the Alps, the jurassic Radiolarian rocks of the Coast Range of California, and also the miocene oceanic deep-sea deposits of Trinidad, Barbados and Cuba, all belong to the same Alpine mountain system, originated during the same period of crustal movements.

The cherts with Radiolaria of the Culm period, which are found for instance in the Harts mountains, in Devonshire, Cornwall etc. form part of a more ancient system of folding, of the Hercynian (variscian-armorican) mountain chain.

The cherts with Radiolaria of the lower silurian of Scotland belong to a still older system of folding i.e. the Caledonian mountain system.

The devonian Radiolarites of New South Wales have been found in palaeozoic rocks probably folded in the carboniferous period.

It is clear from these examples to which various others might be added, that the fossil oceanic, abyssic sediments are exclusively found in strata, which form part of mountain systems due to folding or are in any case limited to the labile portions of the earth's crust, the areas of geosynclinals.

The rarity of these rocks and their peculiar distribution are arguments in favour of the permanence of continents and oceanic basins, but with this restriction that the permanence only applies to such parts of continents and oceanic basins as lie outside the geosynclinals, therefore in favour of the permanence or rather geological longevity of the continental blocks in HAUG's sense.

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[1]) On this the following may be consulted: R. D. M. VERBEEK, Molukken Report p.p. 767, 773, 803 et seq.; and K. MARTIN. "Ein zweiter Beitrag zur Frage nach der Entstehung des Ostindischen Archipels." Geogr. Zeitschr. XIII. p. 425, 1907.