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**Geology.** — “*On the Age of the Igneous Rocks in the Moluccas*”.  
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MOLENGRAAFF).

(Communicated in the meeting of Jan. 27, 1917).

In VERBEEK's<sup>1)</sup> latest geological memoir on the Moluccas, eruptive rocks have been classified as follows:

1. *old basic igneous rocks* mostly of pre-permian age (azoic and palaeozoic). Some may possibly be mesozoic. Petrographically are distinguished peridotite, serpentine, gabbro, diabase porphyrite with their tuffs and breccias, diorite and diorite-porphyrity, the last two of minor significance, etc.

2. *granitic rocks* probably all of pre-permian age.

3. *old-meso-volcanic igneous rocks*. Older melaphyres, quartz-porphyrityes and quartz-porphyrityes, probably also some diabases and diabase porphyrites. VERBEEK points out that no conclusive evidence has as yet been adduced to establish the age of the rocks classed among this group; he also surmises that part of them still belongs to the permian formation.

4. *young-meso-volcanic igneous rocks (cretaceous)*, andesites, dacites and acid melaphyres with bronzite. Perhaps they belong partly to the old-meso-volcanic igneous rocks, another part may be even of old-tertiary age.

5. *tertiary igneous rocks* nowhere seem to go back to the eocene, because the nummulitic limestones are entirely devoid of debris of andesites, with which miocene sediments abound.

*a.* leucite- and nepheline rocks (old miocene or younger) considered to be the oldest group on account of the structure of the volcano Lurus in Java with an older rim of leucite basalt and a younger cone of hornblende-andesite.

*b.* old hornblende-andesites and biotite andesites with their tuffs and breccias (miocene). They have an individual existence, rarely do they constitute the base or the oldest rim of the large volcanoes of which some are still active. The latter cannot be separated from

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<sup>1)</sup> R. D. M. VERBEEK. Molukken Verslag. Jaarb v. h. Mijnwezen 1908. Wetensch. Ged. p. 737 seqq. (Rapport sur les Moluques).

the younger volcanic products and therefore they have been united with them.

c. old pyroxene-andesites and basalts with their breccias and tuffs (miocene). What has been said sub *b* also refers to them.

6. *young volcanic products*, chiefly of quaternary age, also pliocene and recent. They form the young volcanoes which have been formed from the young-tertiary through the quaternary period while some of them are still active.

The above goes to show that of many igneous rocks, that have been classed among a certain group, the age is difficult to establish. Recent investigations have yielded fresh data which prompted us to study again the age of the several igneous rocks.

*Ad 1.*

VERBEEK suggests the possibility that some of these rocks are mesozoic, without being able to adduce any evidence for his hypothesis. According to him only some places show distinctly the presence of pre-permian rocks, for example the island of Letti, where diabase-breccias are believed to be superposed with permian limestone with crinoids. Moreover the peridotite of Ambon, as is proved by the granite dykes, is older than the last-mentioned rocks, while the granites themselves are believed to be of permian age, as the sandstone formation of Ambon, to which permian or anyhow young-palaeozoic age was assigned, consists of débris of granite.

We must contend that:

a. the argument for a pre-permian age in the island of Letti falls through, as the permian limestones occur as blocks only, which may have been brought to this place by overthrusts<sup>1)</sup>.

b. It is not possible yet to determine the age of the sandstone formation of Ambon, by the fossils which have been found in the limestones that occur in the formation<sup>2)</sup>. However, the facies is very much like that of the upper-triassic-rocks of Ceram<sup>3)</sup>, in the neighbourhood of Ambon and we believe it to be of the same age. Proofs of the pre-permian age of granites and peridotites are neither afforded by sandstones built up of the débris of granites. Failing any evidence for a pre-permian age we must draw attention to the

<sup>1)</sup> G. A. F. MOLENGRAAFF and H. A. BROUWER. De geologie van het eiland Letti. Ned. Timor Exped. I Jaarboek v. h. Mijnwezen. 1914. Verh. Deel I. p. 28.

<sup>2)</sup> K. MARTIN in Tijdschr. Kon. Ned. Aardr. Gen. XVI. 1899. p. 656.

G. BOEHM. Ueber Brachiopoden aus einem älteren Kalkstein der Insel Ambon. Jaarb. v. h. Mijnwezen. 1905. Wet. Ged. p. 88. seqq.

<sup>3)</sup> H. A. BROUWER. Geol. Verkenningen in de oostelijke Molukken. Feestbundel Prof. G. A. F. MOLENGRAAFF. Verh. Geol. Mijnb. Gen. Geol.-Serie III. 1915. p. 36.

fact that in the islands of the archipelago outside the region of the Moluccas such rocks as the "old basic igneous rocks" are of frequent occurrence, for instance in Celebes, Borneo, and Sumatra. For many of them in Sumatra only a pre-ocene age has been established; in Borneo several must be grouped as cretaceous, as has also been observed already by VERBEEK.

In the eastern peninsula of Celebes (near the Moluccas Hotz<sup>1)</sup> describes peridotites and volcanic breccias conformable between the lower neogene strata, and not far from it sheets of amphibole diorite have been observed by WANNER<sup>2)</sup> between the marls of the same age. In the environs of the Tukul mountains peridotites and volcanic breccias occur conformably in the partly tertiary, perhaps partly mesozoic "Buru-formation", while, conversely, limestone with chert occurs also in the basic eruptive rocks.

Furthermore it may be added:

a. that in Timor in the permian and triassic sediments basic intrusive and effusive rocks and their tuffs are of frequent occurrence.<sup>3)</sup>

b. that in the valley of the Nimassi (Central Timor) intrusive sheets of diabase occur with distinct contact phenomena in upper-triassic limestone, as demonstrated by me during Prof. MOLENGRAAFF'S Timor Expedition.

c. that along the coast of Dutch Timor basic and more acid eruptive rocks occur frequently together with serpentine and serpentine conglomerate, which may belong to the tertiary (or young mesozoic) period as deemed plausible by me elsewhere.<sup>4)</sup>

d. that in the North-Western part of the island of Great-Obi andesite which is quite similar to the young andesites of the archipelago is overlain conformably by serpentine.<sup>5)</sup>

e. that in the island of Letti are found partly intensely metamorphosed basic effusive rocks of permian and probably also of later origin.<sup>6)</sup>

<sup>1)</sup> W. HOTZ. Vorläufige Mitteilung über geologische Beobachtungen in Ost-Celebes. Zeitschr. der Deutsch. Geol. Ges. 1913. Monatsber. n<sup>o</sup>. 6. p. 329.

<sup>2)</sup> J. WANNER. Beiträge zur Geologie des Ost-Arms der Insel Celebes. Neues Jahrb. f. Min. etc. Beil. Bd. XXIX. 1910. p. 765.

<sup>3)</sup> J. WANNER. Geol. von West-Timor. Geol. Rundsch. IV. 1913. p. 145.

<sup>4)</sup> G. A. F. MOLENGRAAFF. Folded mountain chains, overthrust sheets and block faulted mountains in the East Indian Archipelago. Comptes Rendu du XII<sup>me</sup> Congr. Geol. Intern. Toronto. 1913. p. 689 seqq.

<sup>5)</sup> H. A. BROUWER, l. c. p. 38.

<sup>6)</sup> Ibid. p. 45.

<sup>7)</sup> G. A. F. MOLENGRAAFF and H. A. BROUWER. De geologie van het eiland Letti. l. c. p. 22 seqq.

From the foregoing we feel safe to conclude *that among the so-called old basic eruptive rocks of the Moluccas there are rocks of young palaeozoic, mesozoic and probably of tertiary age, and that nothing can be said for certain about the occurrence of rocks older than permian.*

*Ad. 2.*

It has been supposed that the granitic rocks of the Moluccas are of pre-permian age, because, anyhow in Ambon, a young palaeozoic sandstone-formation consists of débris of granite. As observed above, we could for this formation rather assume an upper triassic age and the sandstones may as well consist of the débris of crystalline schists, so that there is no proof for the supposed pre-permian age of granites in Ambon.

Elsewhere we reported <sup>1)</sup> that in the islands of the archipelago outside the Moluccas the occurrence of mesozoic granites has been proved or rendered highly plausible by the investigations of MOLENGRAAFF, SCRIVENOR (for Malacca), TOBLER, VOLZ and the present writer. To this we can add for Celebes the investigations of VAN WATERSCHOOT VAN DER GRACHT <sup>2)</sup> and ABENDANON <sup>3)</sup>, which even lend support to the supposition that tertiary granitic to dioritic rocks occur in this island. For the Moluccas we refer to the following facts:

a. that granitic to dioritic and gabbro-like to peridotitic rocks sometimes occur in close alliance. Even where dykes of granite occur in peridotites, the granitic rocks can in some places be little younger than the peridotites and may have originated by differentiation from the same mother magma.

b. Investigations in the Sulu-islands by WICHMANN <sup>4)</sup> and myself <sup>5)</sup> point to the occurrence of post-jurassic granitic rocks in connection with contact-phenomena which have been observed in rocks of jurassic appearance.

Again the above warrants the conclusion *that no positive evidence has as yet been brought forward supporting the occurrence of pre-permian granitic rocks, whereas it has positively been proved that*

<sup>1)</sup> H. A. BROUWER. On the post-carboniferous age of granites of the highlands of Padang. *Proceed. Kon. Ak. v. Wet. Amst.* XVIII. 1915. p. 1513 seqq.

<sup>2)</sup> W. A. J. M. VAN WATERSCHOOT VAN DER GRACHT. Voorloopige mededeeling in zake de Geologie van Centr.-Celebes *Tijdschr. Kon. Ned. Aandr. Gen.* XXXII. 1915. p. 118 seqq. en *Jaarb. v. h. Mijnwezen* 1914. Vol. II.

<sup>3)</sup> E. C. ABENDANON. *Geologische en Geographische doorkruisingen van Midden-Celebes.* Deel I. Leiden 1915 p. 58.

<sup>4)</sup> A. WICHMANN. Over gesteenten van het eiland Taliaboe. *Versl. Kon. Ak. v. Wet. Amst.* Juni 1914.

<sup>5)</sup> H. A. BROUWER *Geologische Verkenningen enz., l. c.* p. 43.

*younger, even tertiary granites are recognised in the Moluccas or in the neighbouring regions.*

*Ad 3.*

Only few rocks are included by VERBEEK among his group of old-meso-volcanic igneous rocks. He deems it possible that part of it still belongs to the permian formation, while he emphasizes the impossibility of settling the age-question.

As regards the melaphyres of Timor, some of these rocks we consider to be of permian age, to which view also VERBEEK inclines <sup>1)</sup>, and which has also been established by our as yet unpublished investigations of the Timor-Expedition led by Prof. MOLENGRAAFF.

These investigations also established the occurrence of similar old mesozoic rocks, while it is possible that a large part of the so-called "old-mesozoic eruptive rocks" is of much later young-mesozoic or tertiary age. To the latter belong for instance the melaphyres with hyaline crust, quartz-porphyrines and dacites of Timor's north coast; besides the latter rocks also serpentines, serpentine breccias, serpentine conglomerates and tuffs occur.

In our judgment, therefore, not only among the so-called "old-basic-igneous rocks", but also *among the so-called "old-meso-volcanic-igneous of the Moluccas rocks occur of young palaeozoic, mesozoic and probably also of tertiary age.*

*Ad 4.*

Likewise the age of the young-meso-volcanic igneous rocks of cretaceous(?) age has, according to VERBEEK, not yet been ascertained. Part of them he is inclined to include under his old-meso-volcanic igneous rocks, others may even be old-tertiary. This group comprises only andesites, dacites and acid melaphyres with bronzite of Ambon, further andesites and dacites of the neighbouring islands of Haruku, Saparua and Nusalant and of Western-Ceram, and finally hornblende-pyroxene-andesites of Amblau and pyroxene-andesites with vitreous crust of Wetter. Their being grouped together is due on the one hand to their fresh appearance, whereby they distinguish themselves from older rocks, while on the other hand they are different from the East-Indian tertiary igneous rocks.

In another paper <sup>2)</sup> we have described in detail that the points of distinction from other tertiary igneous rocks are immaterial to the establishment of the age. So, for instance, the enclosures of garnet

<sup>1)</sup> R. D. M. VERBEEK. l. c. p. 359.

<sup>2)</sup> H. A. BROUWER. Geologische Verkenningen. l. c. p. 34 seqq.

and cordierite, recognised in rocks of Ambon, originate from the substratum, while the considerable amount of bronzite typifies the ambonites, it is true, so that they are designated by a separate name, but this does not necessarily point to a difference in age.

In discussing the "old-meso-volcanic igneous rocks" we have already observed that a great number of the rocks of this group may very well be looked upon as a much younger, young-mesozoic or tertiary formation. We alluded first of all to the melaphyres, some with a vitreous crust, of Ambon, Kelang, Wetter and Timor's northcoast and the quartz-porphyrines and dacites of the same coast. Whereas VERBEEK does not separate the melaphyres of Timor and asserts this to be a reason for surmising that melaphyres of various ages occur in the eastern archipelago, and that, for example, in Ambon the melaphyres can be divided into two groups, I on the other hand feel inclined to class together the rocks of Ambon and to separate in Timor an older group (among which the permian melaphyres) from a younger (among which the rocks with the vitreous crust of the northcoast).

The melaphyres with a vitreous crust of Timor's north coast, namely, are of a totally different character and appear under totally different conditions, from the permian melaphyre-like rocks of the island. The former are limited to the north coast and united as one whole with other basic and also with more acid rocks (quartz-porphyrines, dacites) presenting a great similarity to the known Ambon rocks. A typical feature for instance is the occurrence of melaphyres with vitreous crust, common to the rocks of either island. The glassy Java melaphyre, which VERBEEK invariably called cretaceous<sup>1)</sup>, but now considers to be older with reference to the data from Timor, can, on this basis, be comprised again among the cretaceous system, and the rocks of Timor's north coast, Wetter, Ambon and South-West-Ceram can for the present be all assigned to the tertiary or young-mesozoic rocks. To this it may be added that MARTIN<sup>2)</sup> adopts a probable tertiary age for the rocks in Ambon.

When summarising the above we arrive at the following conclusions:

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<sup>1)</sup> R. D. M. VERBEEK and R. FENNEMA. Geologische Beschrijving van Java en Madoera, Amsterdam 1896.

<sup>2)</sup> K. MARTIN. Einige Worte über den Wawani, sowie über Spaltenbildungen und Strandverschiebungen in den Molukken Tijdschr. Kon. Ned. Aardr. Gen. XVI. 1899. p. 709 seqq.

Ibid. Reisen in den Molukken. Geol. Teil. Leiden. 1903. Nachträge:

a. the available data do not justify us in separating a group of older melaphyres from the so-called ambonites;

b. there is no reason for classing as a separate group the ambonites which present some typical characteristics, as regards their age.

c. together with the rocks with a vitreous crust of Timor and the accompanying rocks they should be included under one group of the same probably tertiary or young-mesozoic age, assumed by VERBEEK<sup>1)</sup> for some of these rocks.

We conclude, then, that the so-called "young-meso-volcanic igneous rocks" are also considered by us to be of tertiary or young-mesozoic age, but most likely the number of rocks to be brought together under this group may be much larger.

It may also be stated that andesitic to basaltic and augitic rocks of islands of the Misool-archipelago are held by WANNER<sup>2)</sup> to belong to the cretaceous system.

#### Ad 5.

It has been suggested of the tertiary igneous rocks that their age in the Moluccas and in Celebes nowhere goes back to the eocene, since the nummulitic limestones are entirely devoid of debris of andesites, which on the contrary occurs abundantly in the miocene rocks.

In the following pages we will comprise the Southern part of Central Celebes, because recent investigations have furnished us with important data concerning the age of tertiary igneous rocks.

That the leucite- and nepheline rocks are not the oldest tertiary igneous rocks, as VERBEEK<sup>3)</sup> presumed, because the volcano Lurus in Besuki (Java) consists of an older rim of leucite-basalt with a younger cone of hornblende-andesite, appears from the following considerations:

a. Close to the east of the Gg Lurus, leucite-free rocks are found<sup>4)</sup> side by side with leucite-bearing rocks in the old craterwall of the Gg Ringgit composed of leucite rocks. These leucite-free rocks (olivine- and basalts rich in iron ore, olivine-poor basalts or olivine-bearing augite-andesites and amphibole-augite-andesites) must therefore be older than a great part of the leucite rocks.

<sup>1)</sup> R. D. M. VERBEEK. Molukken Verslag. l. c. p. 360.

<sup>2)</sup> J. WANNER. Beitr. zur Geol. Kenntniss der Insel Misol. Tijdschr. Kōn. Ned. Aandr. Gen. XXVII. 1910. p. 194.

<sup>3)</sup> R. D. M. VERBEEK. Molukken Verslag. l. c. p. 757.

<sup>4)</sup> H. A. BROUWER. Ueber leucitreiche bis leucitfreie Gesteine vom Gg. Beser (Ost Java) Central Blatt f. Min. etc. 1914. p. 1.



b. In the thick tuff-formation along the Saädangriver (South part of Central Celebes) may be distinguished according to ABENDANON<sup>1)</sup>:  
trachyte- and andesite-tuffs,  
basalt- and leucitetephrite tuffs, leucite-basalt, leucitite and leucite-  
tephrite breccias,  
trachyte-, andesite-, and liparitetuffs.

ABENDANON<sup>2)</sup> takes this tuff formation to be of old-eocene age i.e. younger than the old-eocene sandstone- and shale series of Pasar Kira and older than the lutetien-limestone. It is not certain though, whether this formation, as a whole, is posterior to the sandstone- and shale-series; maybe there are also pre-tertiary rocks among them. VAN WATERSCHOOT VAN DER GRACHT<sup>3)</sup> reports that the eruptions in the West seem to have been anterior to those in the East and that the age of the volcanic series varies from the lower, anyhow the middle eocene to probably the miocene. The lowermost banks are still eocene as proved by nummulites occurring by the side of globigerines in the matrix and inclusions.

In the district east of the Latimodjong mountain range, where numerous varieties of andesites and mostly silicified andesitic tuffs occur, the oldest eruptions are deemed to be pre-tertiary, while the youngest seem to have stopped before the neogene. Beside eruptions of andesite others of liparite, trachyte, and dacite also occur<sup>4)</sup>.

As to the age of the igneous rocks of South Celebes opinions differed very much up to very recently. VON STEIGER<sup>5)</sup> gave us a general view of the various opinions, to which we shall refer the reader.

That also here in the eocene, and perhaps prior to it, eruptions took place, is borne out by the occurrence of a silicified plagioclase-orthoclase tuff at the bottom of the limestone formation of the coal-field Tondong KURAH<sup>6)</sup> and by the andesite tuffs below the limestone near Kantisang, as described by BÜCKING<sup>7)</sup>. The majority of the

1) E. C. ABENDANON. Celebes in of uit de Tethys? Tijdschr. Kon. Ned. Aandr. Gen. 1915. p. 358 seqq.

2) Ib. Geologische en Geographische enz. l. c. p. 222.

3) W. A. J. M. VAN W. v. D. GR. l. c.

4) E. C. ABENDANON. Geologische etc. l. c. p. 59, 60.

5) H. VON STEIGER. Petrographische beschrijving van eenige gesteenten uit de onderafdeeling Pangkadjene en het landschap Tanette van het gouvernement Celebes en onderhoorigheden. Jaarb. v. h. Mijnw. 1913. pag. 171 seqq.

6) Id. p. 217.

7) H. BÜCKING. Beiträge zur Geologie von Celebes. Samml. des Geol. Reichsmus. in Leiden VII. Heft 1. pag 124.

eruptions, however, is younger, according to a record of 'T HOEN, who examined the coalfields of South Celebes. According to him, probably a short time before the deposition of the tertiary limestones had completely terminated, eruptions began all along the western side of South Celebes, which gave rise to the high western mountains; for the greater part they consist of tuffs, breccias and volcanic conglomerates of andesites, basalts and also of leucite-rocks. The fragment of leucitite, mentioned by VON STEIGER <sup>1)</sup>, as originating from a tuff between the coal-layers I and II of Bonto, appears on closer examination to belong to a weathered eruptive rock, as established by the engineer 'T HOEN. Considering that several weathered intrusive rocks occur in the neighbourhood, it is rendered highly plausible that the rock, from which the fragment of leucitite originates is also of an intrusive character; similarly the biotite leucite basalt found by BÜCKING <sup>2)</sup> near Kantisang overlain by old-tertiary limestone may also be an intrusive sheet. If so it would disprove the hypothesis of an eocene age of leucite rocks in South-Celebes.

Prof. IDDINGS, who travelled over this district in 1913, reports that numerous intrusive rocks occur, as dykes, intrusive sheets and perhaps as laccolites and as batholites, in the above-mentioned volcanic series and also in the tertiary sandstones with coal-measures and limestones. He mentions among others coarse grained shonkinites and Essexites. These, then, are still younger than the volcanic series, which for the greater part is believed to be younger than the limestones. As known, the limestones of this district are assigned partly to the eocene and partly to the miocene period <sup>3)</sup>.

In addition we refer to HOTZ <sup>4)</sup> who assumes tertiary (to miocene) age for most of the basic eruptive rocks in the eastern peninsula of Celebes.

Available data, in some degree contradictory, seem to point out that the violent eruptions in South-Central-Celebes may have begun prior to the outbursts in South-Celebes; however, they may have been contemporaneous for a considerable time, especially if the volcanic formation in the former region goes back into the miocene, as is deemed probable by VAN WATERSCHOOT VAN DER GRACHT. Anyhow a considerable number of the tertiary igneous rocks in Celebes must be of eocene age.

<sup>1)</sup> H. VON STEIGER. l. c. p. 124.

<sup>2)</sup> H. BÜCKING. l. c. p. 000.

<sup>3)</sup> R. D. M. VERBEEK. Molukken Verslag l. c. p. 55 seqq.

<sup>4)</sup> W. HOTZ. Vorläufige Mitteilung über geologische Beobachtungen in Celebes. Zeitschr. d. deutsch. geol. Ges. Monatsb. 1913 Bd. 65. p. 333.

In this connection it must be kept in view that MARTIN<sup>1)</sup> adopts eocene age for a portion of the andesite breccias and the andesite tuffs in Java (étage  $m_1$  of VERBEEK) and it is not out of the bounds of probability that similar rocks more to the east in the Sunda row of islands and elsewhere are likewise of old-tertiary age.

We have already pointed to the occurrence of numerous tertiary igneous rocks also in the eastern part of the Archipelago, when discussing the previous groups. When we dwelt on the rocks of Timor's north coast we abstained from mentioning that WANNER<sup>2)</sup> inclines to adopt a young-miocene age for the augite- and hypersthene-andesites and the andesite-tuffs in West-Timor between the rivers N. Bonat and Kapsali.

According to VERBEEK the tertiary igneous rocks are independent mountain ridges or cone-shaped hills, the bases of the old, crater-rims of the large, in part still active volcanoes, often made up of pyroxene-andesite and basalt, are probably somewhat younger (pliocene), they cannot, however, be separated from the younger volcanic products and will, therefore be treated together with the young volcanic products.

#### *Ad 6.*

The young-volcanic products (pyroxene-andesites to basalts) build up the volcanic massifs, which are often more or less coniform in consequence of the materials being ejected on all sides round the vent of eruption. They were built up from the young-tertiary period through the quaternary into the present time.

From the above considerations, to which others could be added, it is sufficiently evident that the results of recent investigations necessitate a revision of VERBEEK's Memoir published in 1908, as the writer himself has anticipated repeatedly. Whereas he confines almost exclusively the intrusive rocks to his two oldest groups, it has been proved conclusively that basic and acid intrusive rocks occur in totally different geological series, while volcanic eruptions took place down from the young-palaeozoic, through the mesozoic and the tertiary up to the present period. They were extremely violent in the first and partly also in the second period, but seem to have been restricted chiefly to the region now occupied by Timor and

1) K. MARTIN. Vorläufiger Bericht über geologische Forschungen auf Java II. Samml. des geol. Reichsmus. in Leiden. Bd. IX. p. 194.

2) J. WANNER. Geologie von West-Timor. Geol. Rundsch. Bd. IV. 1913. p. 146.

the adjacent islands. Very likely in young-mesozoic time a new period began of markedly violent igneous activity, which culminated in the tertiary and persists even in our days. Traces of this new period are scattered over a considerable part of the eastern archipelago.

When subdividing the eruptive rocks of the Moluccas according to their relative age into the following groups:

*a* young-palaeozoic to old-mesozoic igneous rocks

*b* young-mesozoic to tertiary igneous rocks

*c* young-volcanic products,

we are in a position to distribute a large number of the known eruptive rocks with complete certainty among one of these groups; for many rocks the subdivision might be carried down still farther. In every group the rocks might be subdivided again according to their petrographic characteristics. Some rocks, however, there are that may be older than young palaeozoic, while a large number are still known as boulders. Too little is known of them to establish their ages. In this connection we can subdivide the eruptive rocks first of all according to their petrographic characteristics. However, here again we meet with the difficulty that of a great many rocks no or, at all events, no detailed descriptions are at our disposal, so that we are not competent to judge of their structure and their mineralogical properties; moreover we are entirely or partially ignorant of the geological occurrence of many of them. For a classification from a chemical point of view we are absolutely destitute of sufficient information.

We distinguish the subjoined groups:

*a.* granitic to dioritic rocks

*b.* gabbro-like to peridotitic rocks (with part of the serpentines and diabases)

*c.* foyaitic to theralitic rocks

*d.* rhyolites and quartz-porphyrines, trachytes and porphyries without quartz, andesites and porphyrites with keratophyres, alkalirhyolites, alkalitrachytes, trachyandesites

*e.* basalts, melaphyres, pikrites etc. (with part of the serpentines and diabases).

*f.* phonolites, leucite- and nepheline-rocks, trachydiorites, tephrites and basanites, melilitebasalts, limburgites and augitites.

To each group should be added that part of the graniteporphyric and fine-grained equivalents and of the aplitic, lamprophyric and pegmatitic rocks, which corresponds most with it on the ground of the available data.

For every separate group we will communicate what is known concerning the geological age:

*Group a.* The composition of the sandstone formation of Ambon composed of debris of granite, may indicate, but does not prove the occurrence of granites, which are older than upper triassic. Besides these we recognize numerous younger, post-jurassic and tertiary granitic and dioritic rocks in the Moluccas, in Celebes and also in the other islands of the archipelago.

*Group b.* Of this group rocks of young-palaeozoic, mesozoic, and tertiary age are known.

*Group c.* These rocks are known from Timor<sup>1) 2)</sup>, but no reliable evidence of their age has been brought forward. In South Celebes there are shonkinites and essexites intrusive in the tertiary volcanic series of this region, from which a tertiary age can be deduced for these rocks.

*Group d.* Many of the rocks belonging to this group in the Moluccas and in Celebes are of tertiary age, may perhaps go back to a mesozoic age, while the basic representatives of this group among the basic eruptive rocks are numerous in the permian and old-mesozoic sediment series of Timor and adjacent islands. Among the younger volcanic rocks there are many andesites (in Celebes also acid effusiva). They are often hard to distinguish from the basalts, the two species of rocks being united by numerous transitions.

*Group e.* Are numerous in the permian and old mesozoic sediment series of Timor and adjacent islands; a great part belongs to the tertiary eruptive rocks mentioned sub *d*, a considerable portion of which may perhaps be traced back to the mesozoic. Basalts also are very numerous among the young-volcanic products.

*Group f.* We know leucite-bearing rocks of Sumbawa. They seem to be of young-tertiary age<sup>3)</sup>, while even leucite-basanite has been recorded as a lavaflow on the Southern slope of the Tambora<sup>4)</sup>. In Celebes leucite- and nepheline-bearing rocks are abundant. We have already observed that in South Celebes and in Southern Central

<sup>1)</sup> A. WICHMANN. Gesteine von Timor. Samml. Geol. Reichsmus. in Leiden. Serie I. 2. p. 85.

<sup>2)</sup> H. A. BROUWER. Neue Funde von Gesteinen der Alkalireihe auf Timor. Central Bl. für Min. etc. 1913. p. 570 seqq.

<sup>3)</sup> J. ELBERT. Die Sunda Expedition. Bd. II. Frankfurt a. M. 1912.

Cf. also G. RACK. Petrographische Untersuchungen an Ergussgesteinen von Sumbawa und Flores. Neues Jahrb. für Min. etc. Beil. Band 34. 1912. p. 42 seqq.

<sup>4)</sup> J. J. PANNEKOEK VAN RHEDEN. Voorloopige mededeelingen over de geologie van Soembawa. Jaarb. v. h. Mijnw. 1913. p. 20.

Celebes they are of tertiary, in part of young tertiary age. According to WANNER <sup>1)</sup> an augitite-like rock in the island of Bamdie of the Misool archipelago, seems to be of cretaceous age.

In Timor and Rotti camptonitic rocks occur, which probably are of permian age <sup>2)</sup>.

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<sup>1)</sup> J. WANNER. Beiträge etc. loc. cit. p. 494.

<sup>2)</sup> H. A. BROUWER. Neue Funde. loc. cit. p. 576.

Ib. Voorloopig Overzicht der geologie van het eiland Rotti. Tijdschr. Kon. Ned. Aandr. Gen.°XXXI. 1914. p. 613.