ANGEFÜHRTE SCHRIFTEN:

BEMMELEN, R. W. VAN, 1931*a*: Kritische beschouwingen over geotektonische hypothesen. Natuurk. Tijdschr. Ned. Indië, **91**, 2, S. 93—117.

———— 1931*b*: De bicausaliteit der bodembewegingen, (With English Summary). Ibidem, **91**, 3, S. 363—413.

———— 1931*c*: Magma- und Krusten-Undationen. Verh. VIe Natuurw. Congr. Bandoeng (Java), Sept. 1931, S. 645—655.

———— 1932*a*: Ueber die möglichen Ursachen der Undationen der Erdkruste. Proc. Kon. Ak. v. Wetensch. Amsterdam, **35**, S. 392—399.

———— 1932*b*: De Undatietheorie (hare afleiding en hare toepassing op het westelijk deel van den Soendaboog). (With English Summary). Natuurk. Tijdschr. Ned. Indië, **92**, 1, S. 85—242.

———— 1932*c*: Nadere toelichting der Undatietheorie. (With English Summary). Ibidem, **92**, 2, S. 373—403.

———— 1932*d*: Die Undationstheorie und ihre Anwendung auf die mittelatlantische Schwelle. Zeitschr. Deutsch. Geol. Ges., im Druck.

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STILLE, H. 1924: Grundfragen der vergleichenden Tektonik. Berlin, 1924.

Geology. — *The Malay double (triple) orogen.* (With 1 map). By G. L. SMIT SIBINGA. (Communicated by Prof. G. A. F. MOLENGRAAFF).

(Communicated at the meeting of February 25, 1933.)

PART I.

Introduction.

The idea of the duplexity and partly triplicity of the Malay orogen originated in 1922, being for the greater part the result of geological study but being no less the result of the collaboration of geologist and biologist. It has been a first serious attempt to explain the origin of the Eastern entangled part of the Malay Archipelago and the migration of its fauna by a reconstruction of the original arcuate orogens by accepting the principle of horizontal continental crustmovement.

First communicated in a lecture by L. F. DE BEAUFORT and the writer, delivered before the Geological Section of the Geologisch Mijnbouwkundig Genootschap on May 26, 1923 [1]), a subsequent summarizing account has been given by L. F. DE BEAUFORT in 1926 [2]), while a short geological treatise on the subject was published by the writer in 1927 [3]).

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[1]) G. L. SMIT SIBINGA en L. F. DE BEAUFORT: Over het ontstaan van den Maleischen Archipel. Versl. d. geol. sectie v. h. Geol. Mijnb. Gen. 1925. p. 64.

[2]) L. F. DE BEAUFORT: Zoögeographie van den Indischen Archipel. 1926.

[3]) G. L. SMIT SIBINGA: WEGENER's theorie en het ontstaan van den oostelijken O. I. Archipel. Tijdschr. Kon. Ned. Aardr. Gen. Dl. 44, 1927, p. 581.

Both from a zoögeographical [2]) as well as from a phytogeographical [4]) point of view interest has been taken in the idea of the originally arcuate and undisturbed Malay orogens being a working hypothesis to find a reasonable explanation of the migration and distribution of fauna and flora in the Archipelago.

During the past decennium the geological knowledge of the Malay Archipelago has increased in many respects. The writer himself had the opportunity to do geological work in the East Indies, the character of which could give him an insight into stratigraphical and tectonical details particularly of the tertiary strata surrounding the continental Asiatic part of the Archipelago.

The important results obtained by F. A. VENING MEINESZ [5]) during his maritime gravity survey in the Netherlands East Indies appear to be in harmony in every respect with the writer's ideas.

It seems desirable therefore to present a paper that takes into account all new facts. Although the fundamental principle of the idea : the existence of an originally undisturbed arcuate Malay double, partly triple orogen remained unaltered — on the contrary could be substantiated much stronger — several details will have to be modified, several others will appear to have conclusively proved their exactness.

The writer fully realizes that increasing geological knowledge will amend perhaps many other details, but at the same time he feels sure that it will not change the fundamental principle.

In previous papers the writer used terms as island arcs, geanticlines, etc. According to modern geotectonic nomenclature the term "orogen" seems more preferable. For the greater part the Malay island arcs already have left the geanticlinal stage and may be considered as well developed orogens. Only the submarine ridge South of Java seems still a real geanticline.

Fundamentals of the Malay orogens.

The Sea of Okhotsk, the Sea of Japan, the Yellow Sea, the South China Sea and the Malay Archipelago are each but a part of a geosyncline on the border of Eastern Asia. Numerous observations indicate that this gigantic trough is an active geosyncline which originated for the greater part in Mesozoic times. It is an active marginal trough in the primitive sense of HALL and DANA. The Malay part of this originally purely Asiatic geosyncline, in consequence of the encounter at the border of the Pacific

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[4]) H. J. LAM : Het genetisch-plantengeografisch onderzoek van den Indischen Archipel en WEGENER's verschuivingstheorie. (The genetic phytogeography of the Malay Archipelago and WEGENER's theory of continental shift. English summary of the dutch paper). Tijdschr. Kon. Ned. Aardr. Gen. Dl. 47. 1930. p. 553.

[5]) F. A. VENING MEINESZ : Maritime gravity survey in the Netherlands East Indies ; tentative interpretation of the provisional results. These Proceedings. Vol. 33, 1930, p. 566.

F. A. VENING MEINESZ : Gravity anomalies in the East Indian Archipelago. The Geographical Journal. Vol. 77, 1931, p. 323.

of Asiatic and Australian crustmovements grew to a mesogeosyncline in the sense of SCHUCHERT. The Malay geosyncline primary has been exclusively marginal as all other Eastasiatic geosynclinal basins still are at the present day. Later on in earth's history it became intercontinental, the present intercontinental character thus being a secondary property.

STILLE [6]) has rightly pointed out that HAUG postulated a great Pacific continent principally for that reason to afford the North- and South-American cordilleras an intercontinental character. The instance of the Malay Archipelago shows obviously to which confusion of ideas HAUG's assumption of the primary intercontinentality has led.

HAUG's postulate already has been opposed in 1920 by MOLENGRAAFF [7]) who stated the fact that in Neogene time a continuous geosynclinal area (which was folded afterwards) extended in a semicircle along the coast of the continental Sundaland, which made it doubtful whether HAUG and P. SARASIN were right in considering the East Indian Archipelago as the area where the Alpine and the Circum-Pacific orogenetic systems meet or are interlaced. MOLENGRAAFF therefore prefers to distinguish between a Circum-Asiatic and an Australo-Pacific orogenetic system as those which may be surmised to meet or to be interlaced in the East Indian Archipelago.

The writer pointed out in 1928 [8]) that the mode of origin of the Upper-triassic deposits in the Molucca's in a similar semicircle marginal to the Mesozoic Sundaland implied the same doubt with regard to the earlier Mesozoicum.

Recently VENING MEINESZ (l.c.) has come to the same conclusion on account of his gravity measurements, stating that the Eastasiatic orogenetic system seems to be the continuation of the Alpine-Himalayan system.

The recognition of the secondary intercontinentality of the Malay geosyncline is of principal fundamentality. It leads to the acknowledgment that the geological history of the Malay Archipelago passed through two principal different stages of evolution, the problem of its origin being a binary problem.

The first stage of evolution deals with the development of the marginal purely Asiatic geosyncline; an Asiatic problem in sensu lato. The second stage of evolution deals with the development of the Australo-Asiatic mesogeosyncline. This is a Malay problem in sensu stricto.

Considering the first stage of development, the Asiatic crustmovement still finding an unobstructed path, there is no conclusive reason to assume that the Malay part of the Asiatic marginal belt should have had an abnormal evolution, nor to postulate a structural plan divergent from the quite regular, at present still undisturbed Eastasiatic scheme of arcuate

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[6]) H. STILLE: Grundfragen der vergleichenden Tektonik. 1924, p. 7.

[7]) G. A. F. MOLENGRAAFF: On the geological position of the oilfields of the Dutch East Indies. These Proceedings. Vol. 23, 1920, p. 448.

[8]) G. L. SMIT SIBINGA: De geologische ligging der boventriadische olie- en asfalt-afzettingen in de Molukken. Natuurk. Tijdschr. v. Ned. Indië, Dl. 88, 1928, p. 111.

mountainranges. This consideration leads to the logical conclusion that in the Asiatic stage of evolution undisturbed arcuate orogens existed likewise in the Malay Archipelago. Accepting the principle of continental crust-movement, the disturbance of these originally arcuate orogens is to be imputed to the Australian crustmovement. With the beginning of the Australian action in the Archipelago the second stage of evolution, namely the development of the Australo-Asiatic mesogeosyncline set in.

To unravel the problem of the origin of the East Indian Archipelago it seems a question of first-order importance to determine the primary arcuate orogens. It will never be possible to conceive the development of the at present chaotic Molucca Archipelago if we do not know from what it has been originated. It is certainly a curious fact that most geologists do not seem to realize the paramount importance of this starting point and never seriously approached it with an open mind.

The still undisturbed parts of that primary arcuate Malay orogen show that it was not a single but a double and partly even triple orogen. Along the Southwestern border of the Asiatic continent (the Sundaland) the still almost undisturbed orogens form two nearly parallel arcuate rows of islands, only South of Java interrupted by a still submarine geanticline. Entering within the reach of the Australian continent the Southern one: the Molucca-orogen, is crushed many a time, while the Northern one: the Sunda-orogen, lying out of the immediate sphere of action of this continent remained fairly undisturbed.

From the most Southern Philippine-island Mindanao likewise a double-orogen starts to the South. The Sunda-orogen runs through the Sangi Is. to the Northern peninsula of Celebes; the Molucca-orogen runs to the Talaud Is. South of which the surface connection is entirely disrupted. Further to the South the primary connection of the surface layers is still more disturbed and the positive part of the orogen is shattered to pieces. Thus from the Southern border of the Sundaland as well as from the Eastern border a double-orogen runs into the Molucca Archipelago. This fact proves conclusively that the primary Malay orogen must have been in the main a double-orogen.

The duplexity of the Malay orogen however is complicated by the entry of the Pelew-Ladrone (Marianne)-orogen. Formerly Halmaheira has been considered the point, where the Pelew-orogen was rooted in the Molucca-orogen, Halmaheira thus being a bifurcation-point in the Eastasiatic orogenetic system, similar to Hondo. There is some reason to surmise however, that the Pelew-orogen does not end in the Halmaheira-group, but continues in the Archipelago at least up to Northern Buru and most probably still further.

In a following chapter it will be shown that the Sunda-orogen as well as the Molucca-orogen each may be sharply characterized as geological units by divergent orogenetic and magmatic cycles. Though our limited knowledge does not yet allow to characterize the Pelew-orogen as an

orogenetic-magmatic unit in a similar way, several elements in the Malay Archipelago which neither belong to the Sunda-orogen nor to the Molucca-orogen nor to the Australian orogens as e.g. the Sula-Banggai Is. show some undeniable affinity to the Pelew-orogen.

Reconstruction and characterization of the Malay orogens.

When ten years ago the writer made a first attempt to disconnect and to reconstruct the Malay orogens it could not be based otherwise than in the main on general geological affinities and contrasts, therefore more on relative than on absolute characteristics. Since geological knowledge advanced in many respects so that the reconstruction of the primary Sunda- and Molucca-orogens at present may be better founded. With regard to the Pelew-orogen we are not yet in a position to give a sharp characterization of its typical orogenetic and magmatic main features and still only may dispose of general geological affinities.

The discernment of two, partly three orogens has been proved to be quite correct; however, the reconstruction of the highly disturbed Molucca-orogen has to be changed in some details as several new facts point to a further continuation of the Pelew-orogen in the Molucca-Archipelago. With regard to the different ways which lead to the undermentioned reconstruction the writer may refer to his paper of 1927.

It is generally accepted that in the earth's history similar geological circumstances generate similar series of igneous rocks. On this consanguinity well-defined petrographical provinces, groups of comagmatic rocks in space and time are built up. Experience further taught us that magmatic rocks, which occur in great abundance and variety in the geosynclines and in the orogens that originated from them, show a distinct and well-defined historical sequence, which regularly appears in all geosynclines. Tectonic and magmatic evolution show intimate relations. The beginning of the geosynclinal phase is characterized by the abundant eruption of submarine basic and ultrabasic igneous rocks. In a later phase volcanism is changing both in chemical constitution and in mode of eruption. Igneous rocks occur in greater variability; next to undersaturated, saturated and oversaturated igneous rocks appear. The orogenetic main phase is typified by the abundant eruption of granites or granodiorites, foreboding the end of the orogenetic and the magmatic cycle. The magmatic cycle is characteristic for the geosyncline and is lacking in all other elements of the earth's crust.

Tectonic elements thus may be defined almost more sharply by their magmatic evolution than by purely tectonical processes. The evolution of each orogen is characterized by its orogenetic cycles, but much sharper by its typical magmatic cycles. The petrology of the Malay Archipelago however is still in its infancy. Modern petrographical descriptions are as yet scarce and reliable magmatic analyses are still rarer. A plutogenetic analysis

of the Archipelago thus for the time being will be a vain wish. The only thing we can do on the strength of the available facts is to determine the historical sequence, i.e. the magmatic cycles and to trace their relation to the orogenetic cycles.

The Sunda-orogen.

The Sunda-orogen principally consists of the following elements: Sumatra, Java, the little Sunda Is. (Bali-Roma), the s.c. inner Banda-arc (Damar-G. Api), the Tiger Is., Tanah Djampea, Saleyer, Western Celebes (i.e. Celebes West of the divisional line), the Sangi Is., the Sarangani Is.

Generally speaking the Sunda-orogen is characterized by the quantitative predominance of oversaturated igneous rocks in contradistinction to the Molucca-orogen. The oldest orogenetic and corresponding magmatic cycle that can be traced in the Sunda-orogen ended with the old variscic (caledonic?) main orogenesis and the eruption of Precarboniferous granites (Sumatra, W. Celebes). The next orogenetic and parallel magmatic cycle ended with the Cretaceous main orogenesis, which has been very intensive in the Sunda-orogen (isoclinal folding and overthrusting on Sumatra and Java) and the abundant intrusion of Cretaceous granites (Sumatra, W. Celebes). The Tertiary cycle ended with the Plio-pleistocene main orogenesis and is characterized by Tertiary grano-diorites (Sumatra, Java, W. Celebes, etc.).

The Sunda-orogen showing at least three orogenetic and magmatic cycles may be typified as an orogenetically and magmatically well developed orogen.

The Molucca-orogen.

To the Molucca-orogen belong principally the following elements: the Mentawei Is. (Simeulu—Enggano), the submarine ridge South of Java, the s.c. outer Banda-arc (Sumba—Buru) pp., the Tukang Besi Is., the Buton Archipelago, Eastern Celebes (i.e. Celebes East of the divisional line), Batjan, Western Halmaheira, Morotai, the Talaud Is.

Generally speaking the Molucca-orogen is characterized by the quantitative predominance of undersaturated igneous rocks in contradistinction to the Sunda-orogen. It is still unknown whether and how the old variscic (caledonic?) orogenetic and magmatic cycles are developed in the Molucca-orogen as the age of the oldest tectonic movements and the oldest Molucca-granites cannot yet be determined exactly. The cretaceous main orogenesis has but slightly affected the Molucca-orogen. A limited occurrence of cretaceous granites may be considered to be probable. The main Tertiary orogenesis, which has been very intensive in the part of the Molucca-orogen opposite the Australian continent and in the part that now forms Eastern Celebes (overfolding and overthrusting) took place in Miocene time; Tertiary granites or grano-diorites however, as far the writer is aware, have not yet been discovered, which is certainly a curious fact. If they exist their occurrence may be a very limited one.

The Molucca-orogen showing at least two orogenetic cycles, few oversaturated igneous rocks and as far we know at present no well developed magmatic cycles, may be typified as an orogenetically perhaps well developed but magmatically at all events less developed orogen.

Comparing the two orogens, both are characterized at least since young Mesozoic time by a divergent as well plutogenetic as orogenetic evolution, which divergency is still continuing down to the present day.

The Pelew-orogen.

As already stated above our limited knowledge does not yet allow us to determine the orogenetic and magmatic cycles of the Pelew-orogen. For the time being all Asiatic elements in the Archipelago, which on the one side orogenetically and magmatically do neither belong to the Sunda- nor to the Molucca-orogen, but which on the other side show geological affinities to the Pelew-orogen are to be classed among the latter, with a certain reservation. The reconstruction of the Pelew-orogen has therefore still to be considered as a tentative and provisional one.

The Pelew-orogen is characterized by a substructure consisting of Pretertiary crystalline schists, oversaturated, saturated and undersaturated igneous rocks. From the Pelew Is. the orogen without difficulty may be pursued up to the Asia Is. and the Aju Is. Between Halmaheira and New Guinea the orogen seems to be highly disturbed. Our scanty geological knowledge of this area, which belongs to the least explored parts of the Archipelago, makes it still very difficult to trace it here with any certainty. It seems probable that the morphological analogy between Halmaheira and Celebes is founded on the same structural analogy and that Halmaheira consists of two different, secondary jointed orogens. In the case of Celebes a part of the Molucca-orogen has been squeezed into the Sunda-orogen, in the case of Halmaheira a part of the Pelew-orogen would have been squeezed into the Molucca-orogen.

Obi is characterized by a Prejurassique substructure of crystalline schists, oversaturated, saturated and predominant undersaturated igneous rocks.

The Sula-Banggai-group consists of a partly Pre-upperliasique (Sula Is.), partly at least Pre-tertiary (Banggai Is.) substructure of crystalline schists, predominantly oversaturated, and saturated igneous rocks. This group of islands, which has neither any magmatic affinity to the Sunda-orogen (lack of Cretaceous and Tertiary granites) nor to the Molucca-orogen (predominance of oversaturated igneous rocks) shows some undeniable magmatic relation to the Pelew-orogen.

The geological affinity of Sula Sanana to the crystalline area of Northern Buru has been advocated with argumentative force by WANNER[9]), whose publications mentioned below may be referred to.

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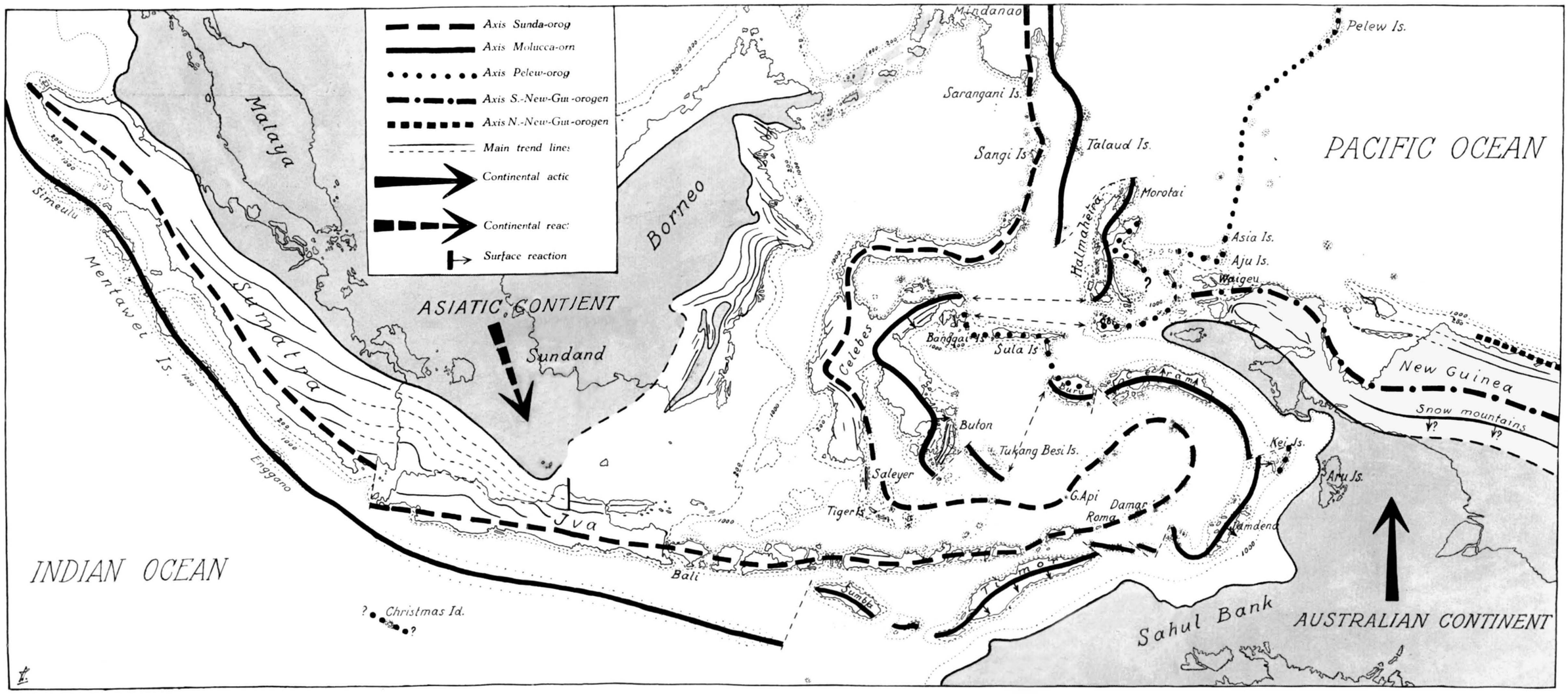
[9]) J. WANNER: Zur Tektonik der Molukken. Geol. Rundschau, Bd. 12, 1921, p. 155.
J. WANNER: Geol. Ergebnisse der Reisen K. DENINGER's in den Molukken. I Beitrag z. Geologie d. Insel Buru. Palaeontographica, Suppl. IV, Abt. III, Lfg. 3, 1922.

YOUNG TETIARY TECTONIC PLAN OF THE MALAY ARCHIPELAGO



From Ceram up to Timor the Molucca-orogen is strongly squeezed and crushed under the immediate influence of the Australian continent. There is some reason to surmise that the Pelew-orogen here entirely joined the Molucca-orogen. The fact that the abundant basic and ultrabasic igneous rocks, which are more or less an index-rock of the Molucca-orogen, for the greater part occur at the concave side of this part of the orogen would be in support of this view. Off the Aru Is. however, where due to an inlet of the continental border the joining squeeze must have been less intensive, the two orogens seem to be still more or less independent. In this connection special attention should be drawn to the different tectonic structure of the Kei Is. The most western islands of the group (Fadoh, Kur) have a crystalline substructure pointing to a geological relation with Ceram. The substructure of the most eastern island Great Kei is unknown, but the tectonic structure and main trend are quite divergent.

Perhaps the Pelew-orogen may be pursued still further to the curious Christmas Island and the submarine ridge West of the Nicobar and Andaman Is. It hardly needs emphasis that the latter is a mere suggestion, as we do not know anything about the Pretertiary substructure of Christmas Island [10]).

The most prominent features of the above reconstruction and characterization will be discussed somewhat further.

Western Celebes belongs to the Sunda-orogen on account of the predominance of oversaturated igneous rocks in general and the presence of at least three complete orogenetic and corresponding magmatic cycles in particular. Eastern Celebes is a part of the Molucca-orogen on account of the predominance of undersaturated igneous rocks, the absence or scarce occurrence of Youngmesozoic and Tertiary oversaturated igneous rocks, feeble Youngmesozoic and very intensive Youngtertiary orogenesis.

During the past years extensive geological investigations have been carried out on Celebes by the Royal Dutch under the leadership of FR. WEBER and L. VON LÓCZY and by the Indian Government under the leadership of H. A. BROUWER. Of all these important investigations very little is as yet available. The little that has been published however is already interesting enough to be looked at in the proper light.

On account of different associations of rocks BROUWER [11]) divides central Celebes in three zones. The most Eastern zone, which continues in the Northeastern and Southeastern peninsula's is characterized by the abundance of basic and ultrabasic igneous rocks, cherts partly full of Radiolaria and limestones which principally are of Mesozoic age. The most Western zone is characterized by the abundance of granitic rocks, its sediments being partly of Mesozoic age but of a facies different from that of the

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[10]) G. A. F. MOLENGRAAFF: Geologie in: De Zeeën van Nederlandsch Oost Indie, 1921, p. 293.

[11]) H. A. BROUWER: The major tectonic features of Celebes. These Proceedings, Vol. 33, 1930, p. 338.

Eastern zone. Between these two zones BROUWER distinguishes a third middle-zone in which crystalline schists predominate and not sharply separated from the Eastern zone, as e.g. to the North and to the South of Posso-lake rocks are found similar to those of the Eastern zone.

KÜNDIG [12]), one of the fellow-workers of FR. WEBER, recently published a tentative characterization of the crystalline schists of Celebes, from which it appears that the crystalline schists of the middle-zone of central Celebes form a natural unit with those of the Southeastern peninsula. KÜNDIG describes this unit as a metamorphic series of sediments, characterized by a typical mineral association of typomorphic authigenous minerals like Glaukophane, Lawsonite, Ottrelite and Piemontite. This type of crystalline schists nowhere occur in Western Celebes. The middle-zone of predominant crystalline schists consequently has to be reckoned to Eastern Celebes. This fact is of utmost importance as it establishes the existence of *one* curious meridional divisional line that runs through central Celebes, emphasizing the duplexity of Celebes to which MOLENGRAAFF (l.c. p. 303) already drew the attention in 1921.

In the writer's opinion the divisional line of central Celebes represents the cicatrix between the two orogens, separating a geological element characteristic for the Sunda-orogen from a geological element typical for the Molucca-orogen.

The complementary features of the junction of Eastern Celebes to Western Celebes are the two great disjunctions between Eastern Celebes and the other parts of the Molucca-orogen, i.e. the disruption Tukang Besi — Buru (MOLENGRAAFF, l.c. p. 303) and the disruption Bualemo-peninsula — Batjan. Both disjunctions have been confirmed by the gravity measurements as will be discussed in the last chapter.

12) E. KÜNDIG: Versuch einer petrographischen Characteristik des kristallinen Grundgebirges von Celebes, Schweiz. Min. Petr. Mitt., Bd. XII, 1932, p. 450.

Plantkunde. — *De invloed van lage temperaturen op het snelle strekken en bloeien van Convallaria majalis.* II [1]). (Mit Zusammenfassung). Door ANNIE M. HARTSEMA en IDA LUYTEN. (Meded. N°. 37 van het Laboratorium voor Plantenphysiologisch Onderzoek te Wageningen). (Communicated by Prof. A. H. BLAAUW).

(Communicated at the meeting of February 25, 1933.)

In 1931—'32 werden de proeven met *Convallaria* voortgezet. Daarbij hebben wij eerst getracht iets te weten te komen van den groei van de verschillende organen in verschillende temperaturen, voor en tijdens den rust-

1) Zie voor I Proceedings Vol. 36, N°. 1.