It will be of interest to investigate whether a similar relation holds for other series of analogous products: if so, it would indeed be possible, as STAUDINGER contends, to calculate the molecular weight from viscosity measurements. It even appears that STAUDINGER's formula may be derived — for extremely diluted solutions — from the general one which has been put forward above.

The investigations are being continued. An extensive communication will follow elsewhere.

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Geology. — *On the relation between the volcanic activity in the Netherlands East Indies and the belt of negative gravity anomalies discovered by* VENING MEINESZ. By B. G. ESCHER. (Communicated by Prof. F. A. VENING MEINESZ).

(Communicated at the meeting of June 24, 1933).

In 1912 G. A. F. MOLENGRAAFF for the first time distinguished in the East Indian Archipelago two stable regions and a labile region in between with a strong relief of the sea bottom (bibl. 1, p. 131).

This opinion was strikingly confirmed by the distribution of the epicentra of the earthquakes that were registered between 1909 and 1925 at Weltevreden and in Malabar, the position of which were determined by S. W. VISSER (bibl. 2). One stable region is formed by the continuation of the Asiatic continent in the China sea, Sumatra, the Malay peninsula, Borneo, the Java sea and Java. The second stable region is formed by Australia, the Arafoera sea and the southern portion of New Guinea. The labile region not only comprises the area between the line of Wallace and the Arafoera sea, but also a belt of the Indian Ocean to the south-west of Sumatra and south of Java, a belt to the east of the arc Minahassa-Eastern Mindanao and a belt to the north of New Guinae. To these labile belts must also be counted parts of Sumatra and Java along the Indian ocean and the northern part of New Guinea (see fig 1).

Our knowledge of this part of the earth's crust was greatly increased recently by the investigation of the force of gravity by VENING MEINESZ (bibl. 3—7). It is of great importance that the principle belt of negative anomalies of the force of gravity coincides with a large part of the epicentres of earthquakes as determined by VISSER. It is especially on New Guinea that part of the epicentres of severe earthquakes fall outside the belt of anomalies, so far as it is yet known, but the gravimetrical survey has not yet been carried out here. The concentration of earth-

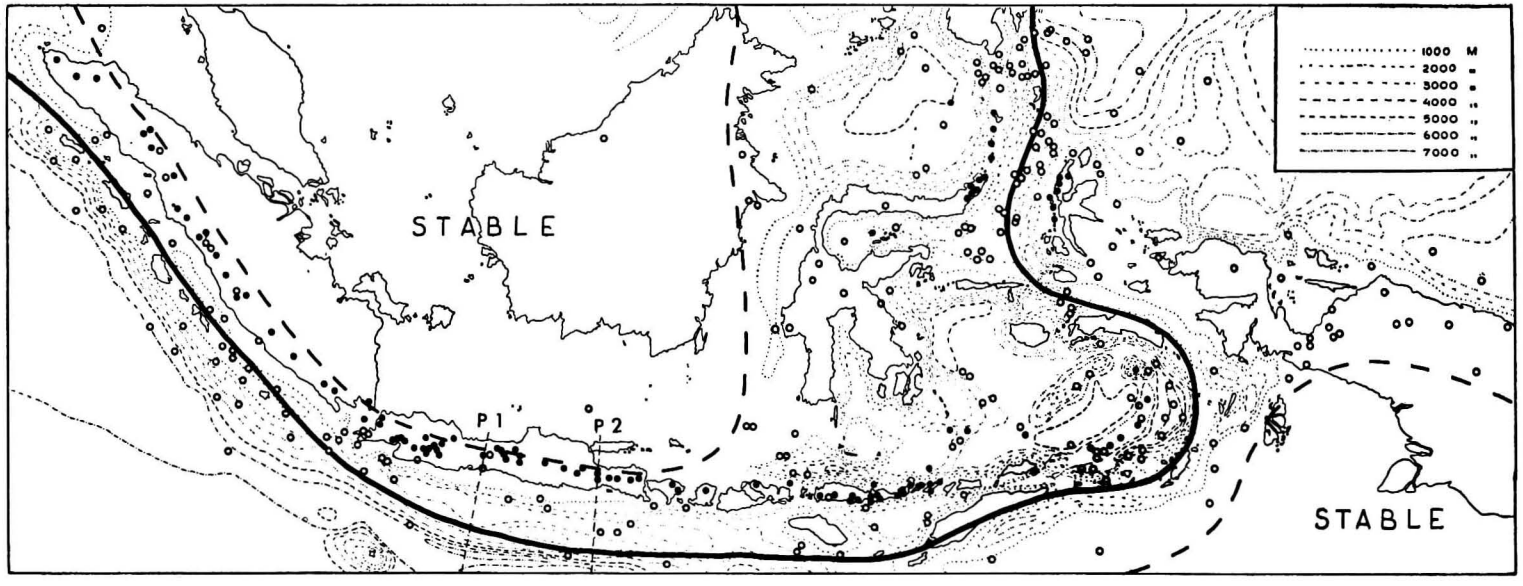


Fig. 1. Map of the Netherlands East Indian Archipelago with Active Volcanoes, Epicentra of Earthquakes and the Axis of the belt of Negative Anomalies of the Gravity.
P_1 indicates the situation of a former section, P_2 that of the section fig. 2.

quakes in the belt of VENING MEINESZ proves that a final adjustment has not been obtained here, but that the belt is in a state of motion.

The Volcanological Survey in the East Indies has ascertained the existence of 109 active volcanoes in the Netherlands Indies (bibl. 8 and 9). Of these, 86 are situated on a belt that begins in Atjeh, that continues over Sumatra, Java, Bali, Lombok, Soembawa, Flores to Lomblen, where it is discontinued on Alor, Wetar and Roma, and finally follows the row of six volcanic islands: Damar, Teoen, Nila, Seroea, Manoek and Banda-Api. The axis of this belt lies at a distance of some 100 to 250 kilometers from the axis of VENING MEINESZ.

The second region of active volcanism in the Netherlands Indies is divided into two belts on both sides of the axis of VENING MEINESZ. Ten active volcanoes lie on the western row that stretches from the Minahassa in the south to Awoe in the north, eight lie on the eastern row from Makian in the south to the volcanoes in northern Halmahera in the north. The axis of VENING MEINESZ runs in between at a distance of 100 kilometers from both rows.

Of the 109 active volcanoes $86 + 10 + 8 = 104$ can be counted to three groups, that are situated at a distance of 100 to 250 km from the axis of VENING MEINESZ. Of the remaining 5 active volcanoes two belong to submarine eruption points reconstructed from ship's journals and therefore not established with absolute certainty. The three others are the volcanic island Api, north of Wetar, Oena-Oena in the Gulf of Tomini and a submarine volcano west of Awoe.

The parallelism of the rows of volcanoes and the belt of negative anomalies is so striking, that some causal nexus between the two types of disturbed belts of the earth's crust must be assumed. The distance between the two categories of belts is so large, however, that no direct connection between the active volcanism and the shortage in the force of gravity can exist. It appears more likely that the two phenomena have a common cause.

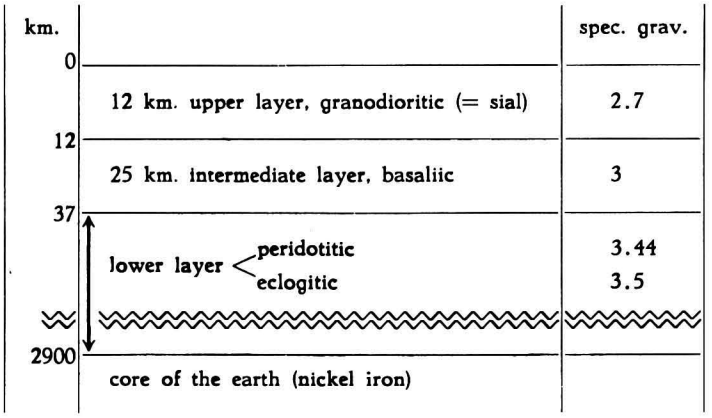
In September 1931 I pointed to such a common cause (bibl. 10) in the currents of the substratum, that lies below the earth's crust, thus making use of the idea's of AMPFERER (bibl. 11 and 12) and SCHWINNER (bibl. 13), after already having given as my opinion in 1922 that currents of magma are the common cause of mountain forming, earthquakes and volcanism (bibl. 14).

It was not until after 1931, that I came to know the very important work of ARTHUR HOLMES on currents in the substratum (bibl. 15, 16 and 17). He was the first to point to a motor that causes these currents to flow. According to HOLMES they are convection currents, that owe their origin to unequal radioactive heating. Besides planetary circulation in the substratum, he distinguishes currents, that may be compared with the monsoons and that he attributes to more intensive heating beneath the

continents, below which more radioactive substances are present than under the oceans.

The principle features are, that the warm currents ascend and flow outwards centrifugally below the continents. This causes on the one hand a drifting of the continents, by which the Atlantic Ocean with the Mid-Atlantic ridge were formed, on the other hand compression along the edges of the continents, by which marginal folded mountains are produced. Java also belongs to the marginal area of compression of Asia.

In the following I accept the subdivision in spherical shells proposed by HOLMES for the outer parts of the earth (bibl. 15). Apart from the sediments, that show considerable local variations in thickness, HOLMES distinguishes the following spherical shells below the continents, while under the oceans the sial is absent, or is only very thin.



Where continental and oceanic currents meet in the substratum, the earth's crust, that is carried along, is piled up. This piling up causes a thickening of the edge of the continent, bij which the supply of heat is gradually increased. This in turn results in the forming of a vortex that exerts a horizontal tension on the crust, and at the same time at the side of it a horizontal compression which condenses basalt to the high-pressure facies eclogite. This eclogite being denser than peridotite sinks downwards. HOLMES illustrates the principle features of this continental drift by sections (bibl. 15, 16, 17) and also the vortices, that are of the greatest importance for our problem (bibl. 15). In all these sections the strata are consciously represented too thick as compared with the horizontal dimensions.

The section through Java and the axis of VENING MEINESZ, that I published in September 1931 was titled: "first attempt for a hypothetical section". The profile reproduced here in fig. 2, reaching to a depth of 160 km., is a second attempt, in which I took the views of HOLMES into account.

VENING MEINESZ considers that the deficit of gravity in the East Indian

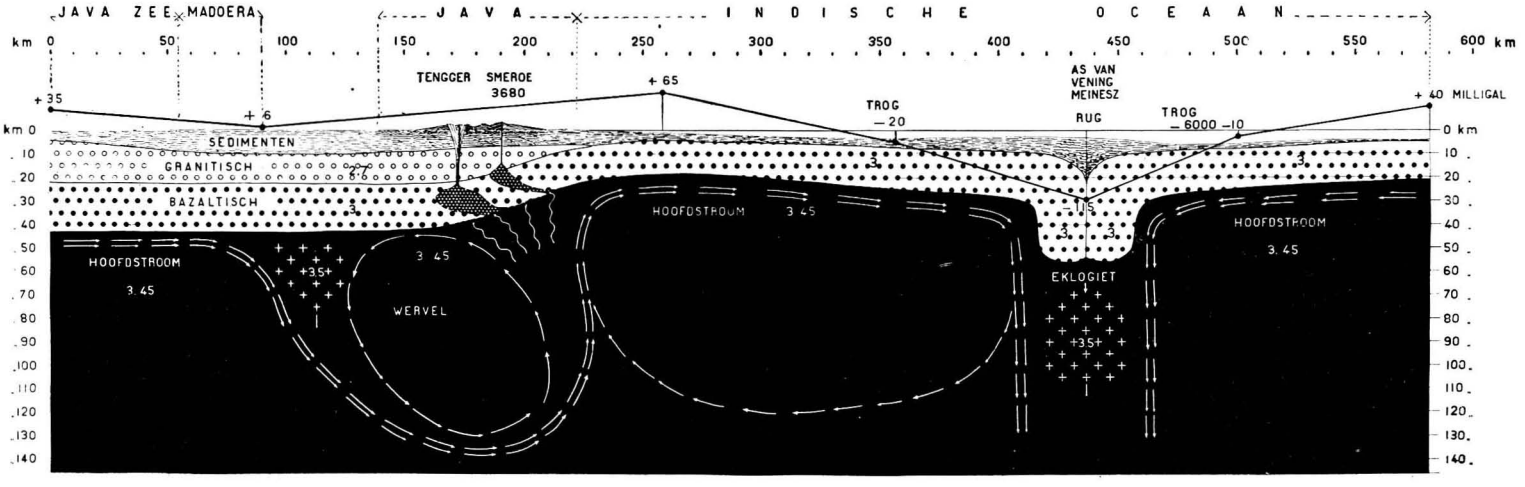


Fig. 2. Hypothetical section through Java and the Axis of VENING MEINESZ,

Scale about 1: 3.180.000

Hoofdstroom = Main current Wervel = Vortex Trog = Trench Rug = Ridge

Archipelago can only be explained by a root of the earth's crust buckled downwards, so as to force aside the heavier substratum locally. If the difference in specific gravity of 0.5 is assumed between the displacing and the displaced rocks, the vertical section of the root must possess an area of 1000 km², for instance 25 × 40 km or 20 × 50 km.

On the first of September 1931 I attributed the formation of this lighter root to two opposing currents in the substratum and four weeks later in a discussion on the earth's crust in the geographical section of the British Association, on September the 28th 1931, HOLMES quite independently said:

"The only kind of process competent to provide compression and at the "same time to exert a downward drag against gravity would seem to "involve the operation of two opposing subcrustal currents which "approach the strip and turn down beneath it" (bibl. 18, p. 447).

In my first section a vortex was drawn, because only thus could the volcanic activity on Java be plausibly explained.

In the second section the views of HOLMES are taken into account by the introduction of a general circulation (main current). The following remarks may help to explain this section:

1. The horizontal and the vertical scale are the same, both 1 : 3.180.000.
2. The topographic line both above and below sealevel was constructed from the most recent data.
3. For the gravimetrical section, expressed in milligals, sea level was taken as datum line. For this profile a section was interpolated between two sections of the force of gravity determined by VENING MEINESZ to the south of Java. The data were taken from a map of the East Indies, kindly supplied by Prof. VENING MEINESZ on which were marked the corrected values for the anomalies he determined.
4. Below Java the existence was supposed of a layer of sial with the specific gravity of 2, 7, that is absent on the bottom of the Indian Ocean.
5. Sediments occur above the sial. According to RUTTEN the thickness of the tertiary strata of Java exceed 7 km. in some places (bibl. 19, p. 96). In the section the total thickness of the sediments was represented with a maximum of 10 km., the remaining parts being given a thickness roughly estimated from the gravimetrical section.
6. The thickness and depth of the upper margin of the intermediate layer with a basaltic composition and a specific gravity of 3, were made to correspond roughly with the gravimetrical section.
7. The specific gravity for a substratum of peridotitic composition would be 3.45, sothat the difference in density between the displacing and the displaced rocks in the root is 0.45. The root of VENING MEINESZ is thus formed by the intermediate layer in our section.
8. The currents in the substratum are divided in main currents, denoted by double arrows and vortices, denoted by single arrows. We must suppose, that at first only the main currents existed, of which

the continental current was the stronger. In consequence of the meeting and plunging downwards of these principle currents the protuberance in the intermediate layer was formed, while the sedimentary strata above it were crumpled into folds.

The piling up of sial beneath Java caused a gradual increase in the supply of heat and finally produced a vortex, that exerted a contrary drag on the earth's crust below Java.

I believe that from these principles at last a plausible explanation can be deduced for the parallelism of the volcanism to, and in, folded mountain chains.

It has already for a long time been clear, that volcanism manifests itself in regions where tangential tension occurs. Iceland, where the most violent manifestations of volcanism in the form of fissure eruptions, take place, may be cited as example. There it is through tectonic tension-fissures that the magma is produced. The Laki-eruption of 1783 is the greatest known volcanic eruption of historic times.

It has always been an unsolved problem, why folded mountains are also accompanied by volcanic activity. The Circum Pacific zone is the most striking example of this combination. Folding is produced by tangential compression in the earth's crust, but this agent is not apt to allow passage for the magma through the earth's crust. It is known, that during the orogenetic proces injections of magma occur along thrusting planes, that probably act as lubricant of the tectonic movements. Basic intrusives, greenstones, ophiolites, pietre verdi, have played this part and have become known amongst others through E. ARGAND from the mesozoic envelopment of the Penninic nappes. The serpentine of the Gornergrat is an example. But it is not probable, that these injections have formed volcanic chambres, considering their slight thickness and volume and their swift crystallisation.

For volcanism considerable plutonic chambres in the earth's crust are necessary and these can only be expected where tension prevails in the earth's crust. The tension, that is called forth in the anticlinal bends under a small load, is of no importance for this problem.

The vortices that gradually evolve in the main current of the substratum, as HOLMES believes, offer an acceptable explanation for the occurrence of stretching in the earth's crust and this would also render the formation of plutonic chambres more plausible, that turn to volcanic chambres during the process of crystallisation.

I will not enter further into the problem of the shapes of the volcanic chambres here. To my mind a great difficulty is, that during the whole process there is slow motion, that must result in continuous deformations.

In accordance with the views of HOLMES concerning acid and basic injections in eruptive centra (bibl. 20), I drew the top of the volcanic chambre of the Tengger mountains (basaltic) deeper than the sial, at a

depth of 23 km., that of the Smeroe (andesitic) less deep than the sial at about 15 km. below sea level.

Finally it should be pointed out, that two regions of tangential pressure occur in the section. The most important is situated in the region of the root, where eclogite is probably formed, while a secondary region of pressure is formed to the north of the vortex, that according to HOLMES will also tend to produce eclogite. The sinking eclogite is conductive to the production of a geosyncline below Strait Madoera. Here the hypotheses of HOLMES can be brought into line with the opinion of UMBGROVE (bibl. 21, p. 36 and 39), that Strait Madoera might be a geosyncline, a view already indicated by VAN ES (bibl. 22, p. 91).

In order to render the importance of the factor time evident for our problem, I have attempted in the diagram, fig 3, to reconstruct three stages in the evolution of the section under consideration.

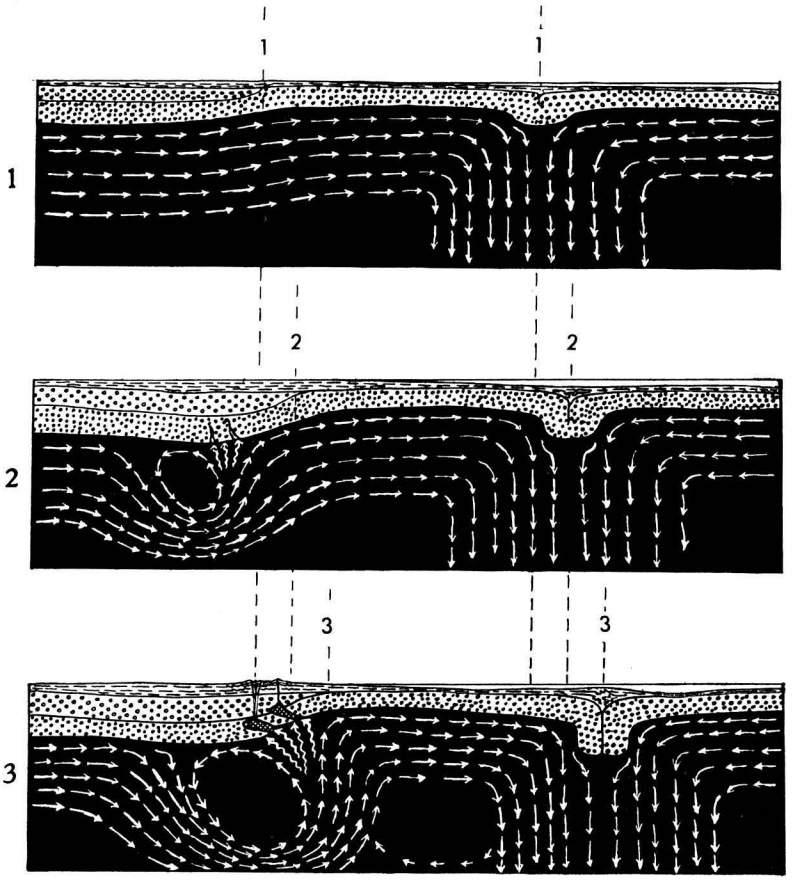


Fig. 3. Three stages in the evolution of the section through Java and the belt of negative anomalies of the gravity.

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