FELIX hat von Timor beschrieben: Araucarioxylon Martensi FELIX [1]. Die Beschreibung ist ungenügend. Die Tracheidenhoftüpfel scheinen denjenigen des Soegi-Holzes einigermassen ähnlich. Das Alter dieses Holzes ist unbekannt.

POSTHUMUS gibt Dadoxylon sp. an aus den pflanzenführenden jungpaläozoischen Schichten von Djambi, Sumatra [2]. Eine Beschreibung ist noch nicht gegeben worden.

Weiter hat POSTHUMUS Cedroxylon erwähnt von zwei Stellen [3]:

a. Aus der oberen Trias von Boeton.

b. Von West Borneo. Das Alter wird nicht angegeben.

SCRIVENOR berichtet, dass POSTHUMUS in Material von Sarawak (Upper Sadong) auch Cedroxylon angetroffen hat. Dort kommt es unter Monotisführenden Schichten vor [4]. Keines dieser Hölzer ist jedoch beschrieben worden, was um so mehr bedauernswert ist, weil bis jetzt Cedroxylon noch nie mit Sicherheit aus Schichten älter als Tertiär erwähnt worden ist.

SCRIVENOR gibt das Vorkommen Koniferenholzes an von Pahang in Malakka [5]. Dieses Holz ist von SEWARD untersucht worden, der es für Araucarioxylon hält. Eine Beschreibung fehlt, die photographische Abbildung eines Tangentialschnittes ist undeutlich. Das Holz ist triadisch oder älter.

Das Fehlen von Beschreibungen der in Ost-Indien und Malakka gefundenen fossilen Koniferen macht also eine Vergleichung mit dem Soegi-Holz unmöglich.

Bussum, 17 April, 1932.

---

1) J. B. SCRIVENOR: loc. cit. S. 78, 79. Fig. 11.

2) J. FELIX: Untersuchungen über fossile Hölzer. 3tes Stück. Zschr. d. Deutschen Geol. Ges., Bd. XXXIX, 1887. S. 519.

3) O. POSTHUMUS: Eenige opmerkingen betreffende de palaeozoïsche flora van Djambi. Verh. Kon. Akad. v. Wetensch. XXXVI, 1927. S. 429.

ZWIERZYCKI & POSTHUMUS: De palaeobotanische Djambi-expeditie. Tschr. Kon. Ned. Aardr. Gen., 2de serie, XLIII, 1926. S. 210.

4) O. POSTHUMUS: On palaeobotanical investigations in the Dutch East Indies and adjacent regions. Bull. d. Jardin Bot. de Buitenzorg. Sér. III, Vol. **10**, 1929. S. 378.

5) J. B. SCRIVENOR: loc. cit. S. 80.

Geology. — *The tertiary virgations on Java and Sumatra, their relation and origin.* By G. L. SMIT SIBINGA. (Communicated by Prof. H. A. BROUWER.)

(Communicated at the meeting of April 30, 1932.)

More than once already the attention has been drawn to the remarkable fact of the virgations of the Barison fold-axes on Sumatra, i.e. the property of these axes to diverge successively towards the east and to disappear one by one in the adjoining tertiary geosyncline, causing a gradual narrowing of the mountainbelt from north to south. This branching of the trend lines is most clearly visible in the region between the Highlands of Padang and the Lampong Districts.

Less distinctly the same phenomenon may be observed on Java, however in an opposite sense. Several anticlinoria deviate in a northern direction from the geanticlinal axis of the island, so that the javanese virgations form more or less the reflected image of the sumatranese ones. A satisfactory explanation of this phenomenon, thus occurring as well on Java as on Sumatra, has not yet been given.

The object of this communication is to trace the relations between both systems of branching trend lines and to give a reasonable explanation of the origin of this remarkable phenomenon.

Sumatra.

In the middle and southern part of Sumatra, from north to south, the following anticlinoria can be discerned as tectonic units:

1. The Suligi-Lipatkain-range with the adjoining Bt. Kelam fold, running nearly parallel to it, which anticlinorium firstly plunging to the east, reappears afterwards in the Tigapuluh-mountainrange. Having passed the Batang Hari, it finally disappears under the Quaternary of the Lalang river.
2. The Udjung-Bt. Serasah- and Lisun-Kwantan-Lalo-ranges with their eastern continuation: the Bt. Limau, finishing in the Kilis-Ketalo-fold. This anticlinorium is rooted in the Barisan in the region of Tapanuli.
3. The Prebarisan-ranges, continuing by broad folds via the Duablas-mountains to the east up to the Palambang-Bt. Batu-anticline, which disappears under the Quaternary of the coastplain. This anticlinorium is rooted in the Barisan southeast of Padang.
4. The Tembesi-Rawas-range, continuing via the Bt. Pendoppo and disappearing in the Limau- and Prabamulih-folds under the Quaternary of the Ogan river. It is rooted in the Barisan in the region of the G. Pandan.
5. The Gumai-mountainrange, continuing in the Muara-enim- and Baturadja-anticlinoria.
6. The Bt. Garba-range, the continuation of which is still unknown.
7. The Benkulen-Bt. Sawoh-ranges.

On fig. 1 the main trend lines of the 7 anticlinoria are indicated and numbered conformably.

All these anticlinoria proceed from the Barisan, diverge with the geanticlinal axis of this mountainrange (Sumatra-direction) and disappear towards the east under younger deposits.

Java.

The plan of Java is similar to that of Sumatra, although the branching of the tertiary trend lines is not so distinctly pronounced. On closer inspection, however, a configuration analogous to that on Sumatra can be established. The javanese geanticlinal axis, the analogon of the sumatranese

Barisan, is mostly covered by tertiary and still younger strata. Only in three limited areas it reaches the surface (Tjiletu, Lokula, Djiwo), which

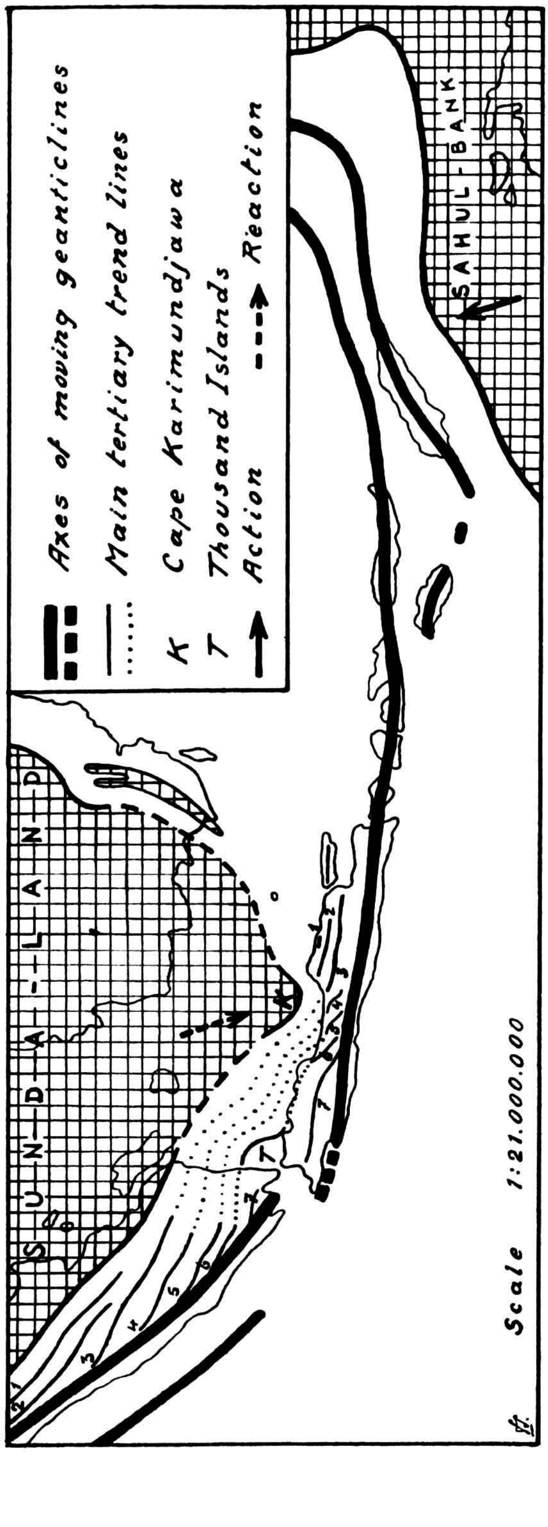

Fig. 1. Sketchy outlines of the tertiary folding-scheme on Java and Sumatra.

three points approximately define its main trend, nearly conciding with the longer axis of the island (Java-direction).

The following anticlinoria can be discerned as tectonic units on Java:

1 and 2. In the younger Tertiary of Northern Rembang and Madura two anticlinoria with a general trend parallel to the axis of the island, in the middle part slightly bending off to the north.

3. The Southern Rembang-anticlinorium, running for the greater part parallel to the Java-direction and showing a slight northward divergence near Semarang.

4. The anticlinorium southwest of the Ungaran, widely diverging from the Java-axis.

5. The anticlinorium rising west of Worawari, continuing between the Slamat- and Kendeng-volcanoes up to in the district of Pekalongan, likewise strongly diverging from the general Java-direction.

6. The anticlinorium emerging south of Prupug from young volcanic deposits, continuing up to about Cheribon.

7. The anticlinorium rising south of Banjumas and continuing through the districts of Eastern Priangan, Krawang and Bantam.

On the accompanying map the main trend lines of these 7 anticlinoria are indicated and numbered conformably. The latter four strongly diverge from the geanticlinal axis of the island, the Southern Rembang-anticlinorium however only slightly in its most western part.

The roots of the diverging anticlinoria cannot be observed as clearly as on Sumatra on account of the slight degree of Java's upheaval and consequently its but fragmentary perceptible backbone. However the roots of the anticlinoria 5 and 7 e.g. are distinctly recognizable. The undeniable element of congruency between the javanese and sumatranese systems of branching trend lines is striking, on the understanding that both are developed in an opposite sense to each other and form more or less each other's reflected image.

The primary connection between Java and Sumatra.

The question now arises: does there exist some relation between both reflected images and what may be or may have been this relation.

In answering this question we must not lose sight of the fact. that the present situation of Java with regard to Sumatra is not a primary one [1]).

The following facts may prove this. The great stratigraphical conformity between the tertiary strata of the Bantam- and Lampong districts show that both originally have been deposited in one and the same geosynclinal basin. At present, however, the javanese part of this basin is situated in the elongated trend of the pretertiary Barisan, therefore, with regard to the sumatranese part of the basin many tens of kilometres displaced towards the south. The same applies to the javanese geanticlinal axis, the analogon and pro-

[1]) L. J. C. VAN ES, De tektoniek van de westelijke helft van den Oost-Indischen archipel. Jaarb. v.h. Mijnwezen in Ned. Oost-Indië. Verhand. **II**, 1917, p. 110, 111.

longation of the Barisan. Its most western part, situated south of Bantam and during the Paleogene still above sealevel, with regard to the sumatranese Barisan-end, has at present, in a similar way, been displaced many tens of kilometres towards the south.

Sometimes the divergent opinion is met with, that the southern end of Sumatra with regard to Western Java has been displaced towards the north. Although the effect apparently is the same, there is a fundamental diversity between both points of view, which here however can be left out of consideration. To the first mentioned conception the preference has to be given, if only for this reason, that it is supported by the distribution of the epicentra of earthquakes, which show a considerably greater freqµency on the southcoast of Western Java than on the coast of Benkulen [1]).

The bending of the geanticlinal axis between Sumatra and Java firstly brought the javanese axis out of the Sumatra-direction into a more west-eastern position. Afterwards, in consequence of the intensified bending and through a second cause, which will be discussed further below, the still joint geanticlinal axis was broken at the bendingpoint (,Sunda Straits). The javanese part was bent still further into the present Java-direction, while Western Java with regard to Southern Sumatra was displaced considerably to the south.

BROUWER [2]) already repeatedly pointed out that considerable transverse fractures near the surface of moving geanticlines coincide with their bendingpoints. Sunda Straits now is one of the most typical exemples in the western part of the Archipelago, representing such a bendingpoint and likewise the locus of transverse fractures, caused by considerable horizontal movements.

In answering the question put above: which relation can there exist between both systems of branching trend lines on Java and Sumatra? it should be born in mind that a complicated horizontal movement has disturbed the primary connection between both parts of the geanticline as well as of the adjoining geosyncline, i.e. a sharp bending and consequently fracturing, complicated by faulting and considerable horizontal displacement of the javanese part.

The thousand islands.

How radically the primary connection between Java and Sumatra at present may be disturbed, yet one link still exists, i.e. the row of small islands, which connects Java with Sumatra: the group of the Thousand Islands.

UMBGROVE [3]) has suggested that the coral reefs of this row of islands

[1]) S. W. VISSER, On the distribution of earthquakes in the Netherlands East Indian Archipelago. **II**, 1920—1926, 1930.

[2]) H. A. BROUWER, The horizontal movement of geanticlines and the fractures near their surface. Journal of Geology, Vol. **XXIX** (1921).

H. A. BROUWER, The Geology of the Netherlands East Indies, 1925, p. 63, 89, 90.

[3]) J. H. F. UMBGROVE, De koraalriffen der Duizendeilanden (Javazee). Summary in English. Wetensch. Meded. v. d. Mijnbouw in Ned. Indië, No. **12**, 1929.

could have been developed on a ridge-shaped elevation of perhaps anticlinal character, already existing in the Pleistocene. Although it has sofar not been possible to establish the correctness of this supposition, it seems however highly probable. For, on Java as well as on Sumatra the tertiary folds pitch under the quaternary coastplains. Now one can hardly assume, that in a system of folds as extensive and as regular in its main features as that of the Java-Sumatra-geosyncline, these folds would suddenly terminate, to be covered subsequently by younger deposits. On the contrary, no argument can be advanced against the opinion, that also those parts of the tertiary geosynclinal basin, which at present are withdrawn from direct observation, must have a tectonic structure similar to that of the area's, which are accessible to direct observation. Moreover we know, that the tertiary folding on Sumatra extends to the border of the relatively stable Sundaland, nay, that the adaptation of the folds to that border is so exact, that the latter has been reconstructed according to the scheme of these tertiary fold-axes [1]. Is it logical, to assume, that the same system of fold-axes elsewhere does not extend to the border of the Sundaland and does not adapt itself to it in the same way, but has come to a sudden stop, because we are not able to observe it any longer?

The existing relation between the scheme of folding and the geosyncline's border in the sumatranese part, implies a conformable or nearly conformable relation in the javanese part. I.o.w. if on Sumatra the whole tertiary geosyncline is folded from the Barisan up to the boundary of the Sundaland, in the corresponding part on Java the same must have happened, as well in the area's accessible to direct observation as in those parts of the geosyncline which at present are withdrawn from direct observation by younger deposits and by the sea.

Furthermore it is obvious, that the arc of the Thousand Islands cannot represent an isolated fold-axis within a section of the geosynclinal basin, for the rest devoid of folds. Tectonically it is only thinkable and comprehensible, if it is a part of the whole geosynclinal folding-plan. As such, it forms an important link between the two parts of the system accessible to observation on Java and Sumatra.

The southern border of the Sundaland.

Before tracing further, which relation could have existed between the virgations on Java and Sumatra, we have to ascertain, how far the tertiary folding on both islands extended towards the north, i.e. where the northern border of the tertiary geosyncline, i.c. the southern border of the Sundaland was situated. ZWIERZYCKI (l.c.) lately tried to deduce the southern boundary from the direction of the tertiary folds and their rate of compression, considering the Sundaland as foreland. In following this method, the great

---

[1]) J. ZWIERZYCKI, Toelichting bij de geotektonische kaart van Nederlandsch Indië. Summary in English. Jaarb. Mijnwezen Ned. Indië, Verh. 1929.

difficulty is, that in those parts of the geosyncline, which are not accessible to direct observation, the direction and intensity of folding are unknown, but can only be indicated approximately by extrapolation. An exact delimination of the Sundaland in this way seems therefore as yet scarcely possible. For the time being we can only connect those points, which are for certain lying outside the tertiary geosynclinal area and which belong to the more stable Sundaland. As such points can be considered on Sumatra e.g. the eruptive rock near Pakanbaru, the pretertiary coasthills at the B. Hari and, northeast of Palembang and north of Java, only the group of the Karimundjawa Islands.

The situation of the southern border of the Sundaland, deduced from these points shows, that for a not unimportant part of the Java-sea, including the area of the Thousand Islands, the possibility, nay, the probability of the existence of tertiary folding under recent deposits is given. In future more detailed data about submarine topography than at present at our disposal will doubtless procure further information about the direction of the main trend lines in this part of the geosyncline. For the present, only the arc of the Thousand Islands can be considered as a trend line, while the continuation of the main trend lines on Java and Sumatra can be deduced approximately by extrapolation (dotted on the map).

The southern border of the Sundaland shows, off the Karimundjawa Islands, an outstanding cape, here briefly called Cape Karimundjawa. From the intensive compression of the Neogene between Cheribon and Semarang and the slighter folding west and east of this section, ZWIERZYCKI (l.c.) has drawn the conclusion that an outlying peninsula of the Sundaland must be situated opposite the compressed zone. This cannot but be Cape Karimundjawa. The slighter folded sections of Batavia-Bantam and Northern Rembang-Madura must be situated opposite corresponding depressions in the Sundaland.

The origin of the virgations on Java and Sumatra.

The foregoing statements lead to the following conclusions:

1. the tertiary plans of folding on Java and Sumatra show great regularity and conformity;
2. both belong to one and the same folded geosyncline and consequently to one and the same plan of folding;
3. no reasonable grounds can be adduced in support of the supposition, that the geosyncline should not be folded, where it is withdrawn from direct observation;
4. the primary connection between the sumatranese and javanese part of the geosyncline however has been disturbed in consequence of a complicated movement of the javanese part;
5. the row of the Thousand Islands represents a still perceptible link of this former connection.

If we now consider the separated parts of the geosyncline in their former connection, the great regularity of the whole plan of tertiary folding is striking. The remarkable branching of the trend lines on either part, be it

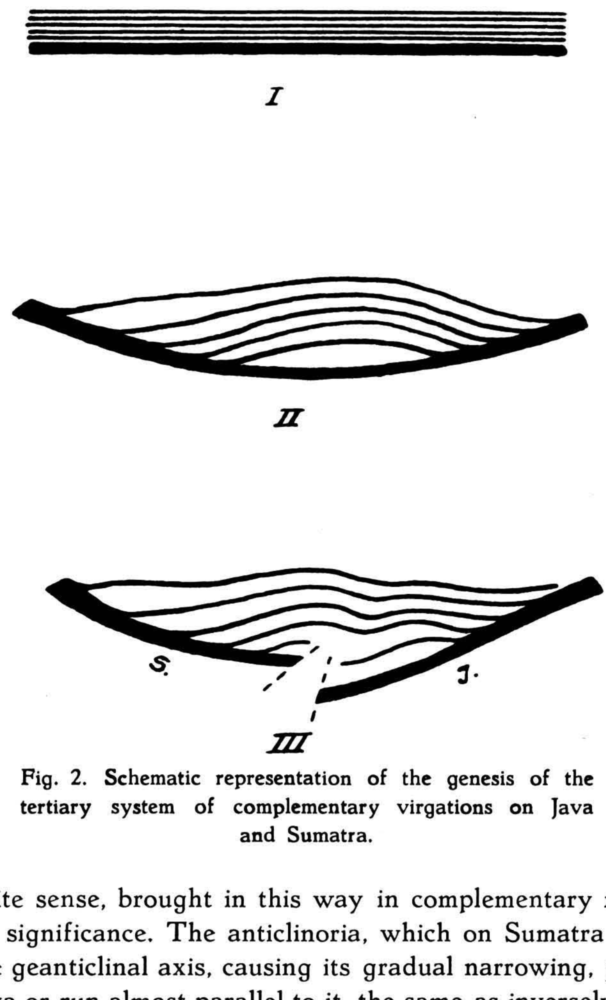

Fig. 2. Schematic representation of the genesis of the tertiary system of complementary virgations on Java and Sumatra.

in an opposite sense, brought in this way in complementary relation, gets a particular significance. The anticlinoria, which on Sumatra successively bend off the geanticlinal axis, causing its gradual narrowing, join this axis again on Java or run almost parallel to it, the same as inversely. The whole system of branching anticlinoria proves to be the result of the bending of the primary joint-geanticlinal axis.

Fig. 2 shows, schematically, the genesis of the tertiary plan of folding and branching in three stages.

Fig. 2, I represents the primary and theoretically regular, geosynclinal folding, parallel to the still joint, uncurved and unfractured geanticlinal axis.

Fig. 2, II shows the genesis of the complementary virgations on Sumatra and Java, caused by the bending of the still joint axis.

Fig. 2, III finally represents, on the same scale as the map, but somewhat schematized, the present plan, originated after the fracturing of the axis and faulting of the eastern, javanese section.

This schematized process gives a simple and reasonable explanation of the genesis of complementary virgations on Java and Sumatra.

We now have to trace the forces, which caused the bending and, ultimately, the fracturing of the Sunda-geanticline at the bendingpoint in Sunda Straits. Though east of the Djiwo-hills, neither on Java nor on the minor Sunda-Islands, pretertiary rocks of the substructure have been found, it is generally accepted, that the pretertiary Sumatra-Java-core continues at greater depth towards the east and that these minor Sunda-Islands belong to the same geanticline. If therefore the forces are to be considered, which in tertiary time acted upon the western part of the Sunda-geanticline, it will be necessary to keep in view the eastern part. Now we know, that in the eastern, unstable portion of the Archipelago in tertiary and even younger time enormous forces have acted, which caused great horizontal movements. On Timor e.g. alpine structures could arise, while the Timor-arc was exposed to such a stress, that it was pressed against the Sunda-arc. The Sunda-geanticline could not withstand this stress and receded, but was nevertheless compressed at such a rate, that the lack of younger volcanism between Pantar and Dammer has been imputed by BROUWER [1]) to that compression. Thus it is quite certain, that not only the Timor-geanticline, but also the Sunda-geanticline under the influence of compressional stress, originating with the Sahul-bank, which constitutes the Australian continental shelf, must have been displaced considerably in an horizontal direction.

In the foregoing we have pointed out, that the movement of the javanese part of the Sunda-geanticline with regard to the sumatranese part has been a complicated one, i.e. a sharp bending followed by fracturing and considerable faulting. The curving of the Sunda-geanticline at the bendingpoint in Sunda Straits can easily be explained by the stress, acting at the eastern part of the geanticline. So far also the process of folding and branching in the western part of the adjoining geosyncline can readily be explained by transmission of the forces, acting in the eastern part of the geanticline and causing counter-pressure (reaction) of the stable Sunda-land. The displacement of Java with regard to Sumatra and the radical disturbance of the primary connection, however, near the submarine locus of the bendingpoint, forms a complication, which cannot sufficiently be cleared up by this mechanism only.

Fixing the southern border of the Sunda-land, the attention has been drawn to the group of the Karimundjawa Islands and the important part acted by this most southern cape of the Sundaland in the process of folding of middle Java. Cape Karimundjawa, being a pretertiary consolidated obstaculum, now proves to have caused the complication in the Java-movement. It prevented the javanese part of the Sunda-geanticline from further bending and forced its fracturing at the bendingpoint in Sunda Straits.

[1]) H. A. BROUWER, On the non-existence of active volcanoes between Pantar and Dammer, in connection with the Tectonic movements in this region. These Proceedings **XXI**, 1917.

Summarizing, the following line of thought may elucidate the whole process.

Northward directed forces acting on the eastern part of the Sunda-geanticline, pressed the western part off Java and Sumatra against the stable Sunda-land, folding the interjacent tertiary geosyncline, at first normally. Continued stress in the east caused bending of the geanticline. Consequently on Java and Sumatra at the concave side of the curve, opposite a depression in the Sunda-land, complementary virgations originated. Opposite Cape Karimundjawa the strongest compression of the tertiary geosyncline took place, which caused the differing and complicated tectonic structure of alpine character in Middle-Java (Lokula). By still continued stress in the east, Middle-Java, arrested by Cape Karimundjawa, did neither allow of further compression, nor bending. Consequently the transmissed stress, concentrated on the geanticlinal bendingpoint, caused the fracturing and faulting of the geanticlinal axis at Sunda Straits and the displacement of Western Java to the south.

The line of thought, developed here, gives a simple and reasonable explanation of several apparently heterogeneous phenomena in the plan of tertiary folding on Java and Sumatra, as e.g. that of the complementary virgations.

In the following lines the direction of the stress will be briefly discussed.

The tertiary folding on Java and Sumatra is generally considered to be directed towards the Sunda-land, on Timor however towards the Sahul-bank. Now one may dispute long and fruitlessly about directions of stress. One thing however should always be borne in mind, namely, that primary pressure (action) on the one side, always causes counter-pressure (reaction) on the other side. A geosyncline, folded by compressional stress will meet action on the one border, reaction on the other. On the side of the stronger folding, the primary action, on the side of slighter folding the secondary reaction will be found. In the case before us, the pressure lies not directly opposite to the counterpressure, but form more or less a torsion-system. Notwithstanding this, the effect of compressional stress on Timor has been undoubtedly stronger than on Sumatra and Java, so that the primary action must have originated with the Sahul-bank (full arrow), the reaction with the Sunda-land (dotted arrow).

Relation between the plan of branching and the distribution of volcanoes.

Finally some words may be added about the relation between the system of branching anticlinoria and the distribution of quaternary volcanism.

The following remarkable facts may be stated:

In Middle and Southern Sumatra the great majority of extinct and still active quaternary volcanoes is situated on the geanticlinal axis. The row of the Barisan-volcanoes however is not continual but intermittent, in this sense, that quaternary volcanism always is lacking in the sections, where anticlinoria are rooted in the Barisan. As soon as the diverging ranges have left the geanticlinal axis, quaternary volcanism starts, extending often at some distance into the characteristic depressions between the diverging anticlinoria. These intercalated synclinal depressions of great amplitude, are filled up by quaternary volcanic tuffs, descending from the separated groups of volcanoes mentioned.

On Java these phenomena are less clearly visible. Closer inspection however shows, that the javanese quaternary volcanoes are situated likewise in separated rows or groups between the branching anticlinoria, and are lacking where these — as far as observable — are rooted in the geosynclinal axis. This noticeable distribution of younger volcanoes undoubtedly is closely connected with the process of folding and branching as described above. For, the bending off and branching of the anticlinoria will have caused tensional stress just within the depressions between the anticlinoria, so that here in the first place magmatic eruption might be expected.