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CRUSTAL CONVERGENCE OR DIVERGE IN THE BANDA SEA REGION OF INDONESIA?

REIN W. VAN BEMMELEN[1]

Foreword

On February 12, 1979, Carl Bowin asked Van Bemmelen to give his comments on a manuscript, prepared by a team of authors, and called 'Arc-continent collision in the Banda Sea region'. Van Bemmelen answered in March, and his comments were accompanied by his own interpretation of the evolution of the Banda Arcs.

This interpretation exposes Van Bemmelen's ideas on the structural evolution of that region. It should be considered as an alternative to the interpretations that fall within the context of plate tectonics, or what he calls 'the modern paradigm in geonomy'.

In the introduction to his interpretation he sketches (in narrative form) the development of his geodynamic concepts, following his experiences and work over a period of more than half a century. The note itself focuses on the main elements in the undation theory; the evolution of the Banda Arcs is his test case.

Although Van Bemmelen's contribution in some respects deviates from the strict (almost rigid) form of a research paper (complete with abstract and easily accessible list of references) to which this journal adheres, we have decided to publish it as it is. Our reasons for doing this are that the way it is written typifies the author; it gives an overview of Van Bemmelen's present geodynamic concepts and it provides an interesting glimpse at the way these ideas took shape. Therefore, a critical evaluation and editing of the manuscript has been omitted.

The editors

To Carl Bowin The Hague, March 1979

Dear Carl,

..... Your interpretation is clearly written from the standpoint of 'plate-tectonics', the modern paradigma in geonomy. As I followed during my long professional career a somewhat independent course, I will try to expose in the following pages some alternative possibilities of interpretation. I agree that I have the disadvantantage of not belonging to the concensus group of geonomers, the enthusiastic promotors and advocates of the so-called 'new global tectonics'.

On the other hand, I might put forward some positive aspects of my approach to the Banda problem.

The Banda islets and the surrounding arc system have fascinated me for some sixty years, since I visited them as a highschool pupil, living at Batavia[2].

In contrast to the apparent quietude of Banda it is actually situated at the centre of one of the most active areas of the world, geodynamically speaking. I discovered this when I was a student at the Technical University of Delft, The Netherlands, where my teachers *G. A. F. Molengraaff* and *H. A. Brouwer* introduced me into the enigma of the Indonesian island-arc systems. My doctoral thesis in 1927 was on the Betic-Rif arc in the westernmost part of the Mediterranean. I interpreted the origin of the newly discovered nappes of the Sierra Nevada as the result of a 'collision' between the African and European Shields, thus following the mobilistic syntheses of *Alfred Wegener, Emile Argand,* and *Rudolf Staub.*

Later on, however, I found during my fieldwork in Indonesia that many tectonic processes were the result of potential energy of a gravitational character. Especially *E. Haarmann's* book 'Die Oszillationstheorie' (1930) was a source of inspiration. The idea of gravity-tectonics in combination with observations which pointed to a sideward migration of the geanticlinal island-arcs, led me to a concept of crustal waves (undations) formed by differential vertical movements of the crust, and gravity tectonics which were a reaction to these vertical movements. This 'undation theory' was conceived in 1931 and 1932. It was essentially a fixistic concept although the sideward migration of the undations and the rafting of crustal and sedimentary material by a kind of 'surf-riding' provided a mechanism for considerable lateral displacements.

In the early thirties we knew but little of the deeper spheres of our globe. As an explanation for this island-arc mig-

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[1] Wassenaarseweg 142, DEN HAAG, The Netherlands.

[2] Batavia is now called Jakarta. After the termination of worldwar I, I wanted to see something of the world abroad. So I joined the crew of the steamer 'Houtman' (which made a return-cruise from Batavia to Adelaide during the long vacation between the schoolyears), scrubbing the decks and doing all kinds of odd and dirty jobs for 25 guilders a month, free board and lodging, and the return passage to a foreign country.

ration I applied the ideas of *Ernst Kraus,* who supposed the presence of an undifferentiated primeval magma (salsima) which differentiated into a heavier fraction (sima) and a lighter one (sial) which possessed a certain buoyancy. With the advance of the seismic techniques in post-Worldwar II days, this idea appeared to be incorrect. But in the beginning, at the time of the original formulation of the undation theory, it covered satisfactorily the basic facts of observation which were at my disposal; this model was 'functionally correct' for the level of geonomic knowledge before and shortly after Worldwar II. It served as a basis for the theoretical premises in my books 'Geology of Indonesia' (1949) and 'Mountainbuilding' (1954).

But then a new branch of the sciences of the earth started, paleomagnetism, which provided new and independent facts for drift and rotation of lithospheric units. During the Iceland expedition in 1950 I advised *Jan Hospers* to study the remanent magnetic properties of a sequence of Plateau-basalts in Northern Iceland (*Van Bemmelen & Rutten:* 'Tablemountains in Northern Iceland" edit. Brill, Leyden, 1955). The results of this new specialism in geonomy induced me to switch again to more mobilistic concepts (*Van Bemmelen,* 'Flowsystems in the silicate mantle', Geol. Mijnbouw 20: 1-17, Jan. 1958), notwithstanding the early verdicts of great scientists like *Schuchert, Jeffreys* and *Stille.*

My Indonesian experiences and the acquired insight into the importance of gravity tectonics, however, made me more cautious for the extreme mobilism in its simplified form as presented by 'plate-tectonics'. I remained interested in the problems of alpine-type orogenesis and the presence of centres of diastrophism at the concave side of the arcuate ranges. In 1968 I organized at Delft (under the auspices of the Royal Geological and Mining Society of The Netherlands) a symposium on geodynamic processes in the Mediterranean area. The proceedings appeared in the Transactions of the Society (nr. 26).

Meanwhile my ideas on a synthesis of structural processes at a global scale ripened into a model of 'relativism in time and space', which was exposed in my book on 'Geodynamic models', published by Elsevier in 1972.

Thereafter, I investigated three test-cases of island- or mountain-arc formation:

(1) 'Driving forces of Mediterranean orogeny (Test-case I: the Tyrrhenian area)', Geol. Mijnbouw 51: 548-573, 1972.
(2) 'Geodynamic models of the Alpine type of orogeny (Testcase II: the Alps in central Europe)', Tectonophysics 18: 33-79, 1973.
(3) 'Driving forces of orogeny, with emphasis on the blueschist facies of metamorphism (Test-case III: The Japan Arc)', Tectonophysics 22: 83-125, 1974.

In 1975 I was invited for a lecture at Budapest, where I had discussions with *G. Barta,* who considered the distortions of the earth's gravity field to be permanent features of the geoid, whereas I advanced the idea, that these anomalies might be changing in magnitude and place in the course of time. They might be the expression of mega-circuits of matter in the mantle and thus indirectly related to mega-geodynamic phenomena in the lithosphere. This opinion appeared to be fruitful and it was elaborated in three papers:

(1) 'Some basic problems in geonomy', Symposium on geodynamics, organized by the Dutch Committee on the International Geodynamics Project: Progress in Geodynamics, Amsterdam 1975, Geodynamics Project Sci. Report 13: 9-20.
(2) 'Plate Tectonics and the undation model: a comparison', Tectonophysics 32: 145-182 (1976).
(3) 'The present formulation of the undation theory', Lecture at Uppsala, published in 'The Frontiers of human knowledge' (Skrifter rörande Uppsala Universitet, C:38), Acta Univ. Upsaliensis, 1978: 255-274.

This lecture was also published in the Zeitschr. f. Geol. Wissenschaften, Berlin 6 (1978): 523-540.

In these papers I gave an outline of an alternative view on the origin of the Banda Arcs, which will be elaborated in this letter, making use of the new data given in the Bowin cs. MS. In an additional part[3] page-wise comments are given, whereas I will end with some general remarks.

Before focusing our attention on the Banda Arcs two basic principles of my mega-tectonic views should be mentioned:

(1) The bumps and depressions of the geoid (expressed in metres as deviations from a rotating, somewhat flattened sphere) are not really topographical highs and lows; they are merely a way of indicating by mathematical method the presence of masses inside the globe, which are relatively too heavy or too light (according to their mean density) for the place they occupy in the gravity field of the earth. These masses have either a tendency to sink down or a certain buoyancy to rise. They thus will cause mega-circuits of matter in the mantle (heterogeneous convection systems). The rising and descending columns will be connected by links of more or less horizontal flow. The circuits might be restricted to the lower mantle (see Van Bemmelen, 1976, Fig. 15 on p. 175), but also compensatory flow in the asthenosphere can be expected (Van Bemmelen, 1978).

(2) At the earth's surface the subvertical columns of the convection systems manifest themselves as mega-undatory rising areas, measuring some thousands of km in diameter with a prevailing tendency for subsidence (such as the eastern active Ceylon (Sri Lanka) mega-undation), and large areas with a prevailing tendency for subsidence (such as the eastern part of the North Atlantic Basin and the western part of Europe in the western hemisphere, and the Melanesian area with North Irian (New Guinea) in the eastern hemisphere).

The crest of mega-undatory upwellings can migrate over

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[3] Not published in this issue.

the earth's surface at a rate of about 20 cm/year and they have a life-span in the order of 100 million years (see Van Bemmelen, 1976, p. 167-178).

For the geodynamics of the Banda Region it is of importance to consider the active mantle upwelling which causes the Ceylon mega-undation (maximum -113m), and the subsiding column under the moribund Melanesian mega-undation (maximum +81 m), or 'Darwin Rise' as I called it in previous papers. In younger Mesozoic and Cenozoic time the crest of the Indian Ocean mega-undation has been shifting northward, causing the northward drift of Indian subcontinent on its northflank, and leaving in its wake extended (trailing), N-S trending, marine ridges ('nemataths', such as the Maldive-Laccadive Ridge and the Ninety-east Ridge). At the northern side of the drifting Indian shield the Himalayan ranges came into existence. In this sector of the former Tethys zone a struggle for space resulted in the formation of the Tibetan Plateau, pushed up by the convergence of the northward drift of India and the southward moving lithospheric units generated by the spreading of the 'Chinese' mega-undation. From this high plateau, the so-called 'roof of the Earth', micro-plates are carried westward and eastward like floes of drifting ice on the back of an undercurrent in the mantle. The westward drift is attracted by the foundering column in the mantle underneath the North-Atlantic and Western Europe. This family of micro-plates is characterized by right-lateral shear faults at their northern (starboard) side such as the North Anatolian Fault and the Vardar Fault in the Mediterranean area.

From the Tibetan Plateau another family of micro-plates is drifting eastward towards the free-board area in the western Pacific and the NE-Indian ocean, attracted towards the foundering flow in the mantle underneath the moribund Melanesian mega-undation. This eastbound family of micro-plates is characterized by left-lateral shear faults at their northern (port-)side. The Semangko Fault of Sumatra at the starboard side shows right-lateral shear. The Melanesian region in the western Pacific, which extends from the Philippine Islands to the North Fiji Basin, is characterized by positive gravity anomalies. Its elliptical outline measures about 6000 km ESE-WNW and about 3000 km SSW-NNE. At the surface it is an oceanic basin, characterized by atolls and guyots. Its floor is formed by Middle to Late Oligocene sediments on basalts. It has been a shallow or partly emerging part of the Pacific ocean about 30-35 million years ago, from which the name 'Darwin Rise' island arcs immigrated southwestward towards the Australian shield. This is in contrast to the eastward migrating East-Asiatic island arcs to the north of it, which are emigrating towards the inner Pacific. The southwestward immigrating arc-systems (New Hebrides, New Caledonia, Solomon Islands, Bismarck arch, North Coast of Irian) indicate that the Darwin Rise had the character of a mega-undatory centre of spreading diastrophism. This geodynamic situation fits well in the context of the global synthesis of the undation theory (see Van Bemmelen, 1976, p. 168). On the other hand the fact that over a distance of about 6000 km island arc systems are immigrating toward the Australian shield is not easily explained by the model of 'plate tectonics'.

In my paper of 1976 I suggested that the Darwin Rise might be a fossil, or 'moribund', mega-undation, which started its life-cycle in Jurassic time in the eastern Pacific. From there the crest of mantle upwelling with negative gravity anomalies migrated westward, leaving in its trail some extended, more or less straight submarine ridges, such as the Tuamoto and Austral chains. These can be called 'nemataths', and they might be compared with the Ninety-east Ridge and the Maldive-Laccadive Ridge in the northern part of the Indian Ocean. After about 100 million years the buoyancy of the Darwin Rise mantle upwelling was exhausted, cooling near the surface prevailed, and a downward foundering of its crest started. It is still an obstacle, however, for the family of micro-plates which is drifting from the Tibetan Highland toward the freeboard of the West Pacific (Van Bemmelen, 1976, p. 169-170, and 1978, p. 270-271). This remarkable megatectonic picture of a zone with interrelated geodynamic processes stretching between 80° and 180° E longitude provides an excellent setting for the geodynamics of the archipelagoes between SE-Asia and the Australian-New Guinea shield.

The great Sunda Arc forms the southern front; it begins west of the Andaman Sea and cuts obliquely across the palaeomagnetic lineations in the floor of the Northern Indian Ocean. According to the new tectonic map of Indonesia by Warren Hamilton (1978) the lineation of 41 million years age is situated at one degree southern latitude and 94 degrees eastern longitude, trending E-W. It is cut by the NW-SE trending outcrop of the 'subduction zone' off Sumatra. In the Wharton Basin at 16°S latitude the age of the lineations is about 65-70 million years. The original spreading centre has apparently to be sought in the North and it has been covered by western part of the Indonesian archipelago.

The relative displacement was evidently not the subducting Indian Ocean 'plate', but the actively southward spreading of the Sunda Archipelago. The same picture is repeated farther to the East, where in the Argo abyssal plain at 118°E long. and about 12°S lat. lineations of about 150 million years ago occur, trending SW-NE. They have been identified as the M-10 to M-25 Mesozoic anomalies by Heirtzler et al., 1978. These are also cut obliquely by the trace of the subduction zone at the easternmost end of the Java trench, south of Sumba.

Lineations of the same direction as those in the Argo abyssal plain are reported by the Bowin et al. MS in the South Banda Basin. Their age is unknown. The Bowin et al. MS says that it is only the similarity in trend of two sets of magnetic anomalies that suggests their relationship. In view of the counterclockwise rotation of Seram (to be discussed hereafter), I doubt this correlation. The floor of the South Banda Basin may have rotated also. It could be the product of tectonic 'denudation' at the rear of the spreading sectors of the Banda Arcs System, whilst rotations may have occurred in this Banda centre of diastrophism.

For the formation of the Banda Arcs the following alternative geodynamic synthesis might be suggested:

(1) Northeast of Sumatra no active Benioff is observed. The active right-lateral shear movements of the longitudinal Semangko fault evidently did stop in the present time the passive subduction of the floor of the Indian Ocean. The trace of the outcrop of a subduction zone indicated by Warren Hamilton (1978) in the fore-deep of the weternmost part of the Sunda Arc System can be interpreted as the front of upthrusts of imbricated mélange-wedges which have been rafted outward, now forming the non-volcanic outer arc of the Sunda Arc System (see my remark in Testcase II, 1973, first paragraph of p. 77, and figure 14 on p. 113 in Testcase III, 1974).

(2) The Semangko fault terminates in the Sunda Strait between Sumatra and Java, which is a very young 'sphenochasm' (Van Bemmelen, 1949, p. 635). In its stead a seismic Benioff Zone sets in, which can be traced eastward to the North of Wetar-Romang, that is from 105° to 120°E long. The submarine non-volcanic outer arc presumably consists of mélange wedges which hide the real trace of the passively subducted floor of the Indian Ocean. From Sewu through Timor to Sermata the non-volcanic outer arc contains imbricated units derived from the Australian fore-land (Sahul Shelf). This convergence between the southward migrating Sunda Arc System and the Australian 'plate' is very young. According to the Bowin et al. MS the age of the junction increases eastward to a maximum of 5 million years. This Timor sector is called in their manuscript the A-sector of the Banda Arcs System. It belongs evidently to the great Sunda Arc, which actively spread southward over floor of the Indian Ocean.

The position of Sumba is still unsolved. Warren Hamilton indicates it on his map as a continental micro-plate (1978), and BRUNN & BUROLLET (1979, this issue) characterize it as a northwestward-directed horst-like promontary of the Australian foreland which is actively pushing and underthrusting into that direction.

(3) The S-N trending frontal sector of the Banda arc is a very young addition to the Sunda arc, stretching N-S from 4° to 8½°S lat., that is a length of about 550 km. It is actively migrating eastward in the wake of the eastward retreating Arafura-Irian fore-land (see sub 8). The very young volcanic inner arc extends perhaps from Gunung Api by way of Damar to the Banda group of islets. It consists of volcanic cones which rise directly from the abyssal oceanic floor of the Banda Basin. The Weber trough belongs structurally to the South Banda Basin; both have an oceanic crustal floor. The non-volcanic outer arc of this sector (called the B-sector by the Bowin et al. MS) extends from the Tanimbar islands by way of the Kai group to Pulu Pandjang and Pulu Gorong.

I have the impression that this eastward migrating B-sector is separated by an ESE trending right-lateral shear fault at its southern or starboard side, which might be traced from Gunung Api through the strait between Romang and Damar of the inner arc and the strait between Sermata and Babar-Masela of the outer arc. The Babar group occupies an intermediate position, being separated from the fore-mentioned fault by a NW-SE trending right-lateral shear fault which extends from Dai along Dawera and Daweloör, passing south of the Tanimbor Ridge (Selaru) and joining the main shear fault South of P. Selaru, at 131°E long.

At its northern (port-)side the eastward migrating B-sector is separated from the Seram (or C-)sector by a left-lateral shear fault, which trends almost west to east at 3½°S lat. It might begin in the NE trending Luymes and Siboga Ridges (horsts) which separate the southern and northern part of the Banda Basin *sensu lato;* it then can be traced south of Ambon (the Uliasser Group) eastward to the strait between P. Seramlaut at the easternmost tip of Seram, finally linking on to the left-lateral shear fault which forms the boundary between the 'Birds Head' of the Irian Jaya (western New-Guinea) and the Aru Basin (see Warren Hamilton's map, 1978).

(4) The very young volcanicity of the inner arc of the B-sector might be related to the ascending volatile constituents of a passively subducted slab of the eastward retreating Arafura shelf. This Benioff zone shows N-S trending isobaths of seismic centres reaching down to intermediate depths. The increasing pressure and temperature liberates the volatile constituents of the passively subducted shelf margin (in the same way as indicated in Fig. 14 on p. 113 in Van Bemmelen's Testcase III, 1974). These ascending volatiles generate the calc-alkaline magma suites of the volcanic inner arc of the B-sector.

(5) We come also to the conclusion, that the Tanimbar-Kai part of the Banda system is a very young addition to the present Banda orocline, now forming a link between the southern part (the Timor- or A-sector which belongs to the great Sunda arc) and the northern part (the Seram- or C-sector) and the Buru (or D-) sector. As will be discussed hereafter (sub 6 and 7) the C- and D-sectors do not belong to the great Sunda Arc system. They are foreign elements which have been added to the Banda Arc in late Cenozoic time. But there is one feature which the W-E trending Lesser Sunda Islands and the W-E trending Buru-Seram sector have in common, namely the tendency for an eastward extension, so that they now form 'nemataths'.

The eastward extension of the Sunda inner arc results into a thinning of the sialic-crust and strong volcanicity. It begins already in the Sunda Strait, which collapsed after catastrophic, voluminous pumice eruptions in late Quaternary time (the Lampong- and Bantam-pumiceous tuffs). The

Krakatoa-eruption of 1883 is merely a late 'hang-fire'. The evolution of the N-S range of the Ungaran-Merbabu-Merapi volcanoes represents a crustal fissure which initiates the separation of East-Java from Central Java. The lesser Sunda islands extend farther eastward, being separated by transverse straits which are bordered by normal (i.e. extensional) faults.

The character of extension of the Buru-Seram sector is manifested by the Appe-Kajeli graben between central and eastern Buru, the Boano Strait, the Hoalmoal horst of westernmost Seram, the Piru graben, the main part of Seram.

The mechanics of this west-to-east extension can be understood when this geodynamic process is placed in its megatectonic context, as exposed as the second main principle. It represents namely a family of micro-plates (floes) which is drifting eastward from the Tibetan area of confluence of lithospheric units between the actively rising Ceylon- and Chinese mega-undations towards the subsiding Melanesian mega-undation. Crustal floes are carried on the back of the sub-lithospheric current in the mantle, which connects the ascending columns of matter in the mantle underneath Central Asia and the descending current underneath the maximum of positive gravity anomalies in the western Pacific.

The moribund Melanesian mega-undation is, however, still an obstacle for this eastward-bound sublithospheric mantle current. The family of eastward drifting micro-plates and island arcs bifurcates into two groups when it reaches the western margin of the area with positive gravity anomalies in the western part of the Pacific. This is manifested by the fact that the island arcs between Japan and about 10°N lat. migrate far eastward into the Pacific (Marianas), whereas a southern branch carries archipelagoes and island arcs (Philippines, Indonesia) along the western and southwestern side of the area of the positive gravity anomalies. The northern portion of the Australia-Irian shield (Torres Strait – Irian) is drifting eastward along a system of left-lateral shear faults, called the Sorong fault system s.l. They are followed in their wake by the eastward extending Banda Arc system.

(6) In his paper on palaeomagnetic evidence for the rotation of Seram, Indonesia (J. Phys. Earth, in press) Haile found a 98° counterclockwise rotation of Seram since the late Triassic, and a pole position for a pillow basalt from Kelang (off the westend of Seram) suggests a counterclockwise rotation of 74° since the Late Miocene (Bowin et al. MS). This rotation of the C-sector of the Banda Arc system is comparable with the counterclockwise rotation of Corsica in the Mediterranean area. Seram probably occupied parts of the area where now the abyssal southern part of the Banda Basin is found. Likewise, Corsica was originally situated in the area of the Balearic basin. The South Banda Basin and the Balearic basin were both centres of diastrophism, which were originally emergent continental regions (Van Bemmelen, 1969, 1973). In the Bowin et al. MS is suggested that Seram has been subducted in a WSW direction by the Australian foreland (cq. the 'Birds Head' of Irian Jaya). In the discussion of the foreland (sub 8) it will be shown that the Birds Head is an extensional feature which retreats eastward so that the mechanical situation of this area is quite the reverse: the Seram sector actively overrides the retreating margin of the foreland, in ENE direction. This contention is a prognostic conclusion of my model which was published in Van Bemmelen, 1978, p. 271, 4th par. This prediction is now confirmed by the new diagnostic data provided by the palaeomagnetic researches of Haile.

(7) The island of Buru, called D-sector of the Banda Arcs system in the Bowin et al. MS, is a detached fragment of the Sula Spur *sensu stricto,* which extends westward to the Banggai group of Islands. Sulawesi (Celebes) shows a curious, inverted arc-structure which is concave towards its front, because the non-volcanic outer arc curves around the Banggai group of the Sula spur. Buru was originally situated in the area now occupied by the northern part of the Banda Basin, whilst the Tukangbesi horst is another remnant of the former east front of the Australian foreland, situated at the southern side of the North Banda Basin. The island of Seram may have formed a connection link between the present Sula spur and the Tukangbesi continental fragment, before its counterclockwise rotation around a hinge point, which was presumably situated in the deep Manipa Strait. Ambelau and the Uliassers (Ambon-Haruku-Saparua) represent an extinct volcanic belt at the rear of the ENE-ward retreating island of Seram. I do not think that this volcanic belt was ever connected to the volcanic inner arc of the great Sunda arc through the Weber Deep and by way of the gabbro-exposure on Dai, north of Babar, as is suggested in the Bowin et al. MS. Buru is a new acquisition of the Banda arcs. It now forms with Seram the northern limb of the Banda Arc System.

(8) The foreland of the Banda Arc System. The Sahul Shelf forms the foreland at its southern side. Convergence with the outer arc of the great Sunda Arc began about 5 million years ago according to the Bowin et al. MS. This geodynamic process might be progressing up to the present, as is suggested by the presence of an active Benioff zone north of Timor (the A-sector of the Banda System). As has been exposed earlier in this letter, the relative movement is a passive subduction of the Sahul margin of Australia caused by an active outward spreading of the Sunda Arc.

The Arafura Shelf forms the eastern foreland of the Banda Arcs. Between the Aru Islands on its western margin and the Kai Islands of the Banda outer arc, the Aru Basin occupies the position of a foredeep; but it has a tectonic character which deviates from the structural character of foredeeps normally found in front of migrating orogenic mountain or island arcs by the fact that it is obviously formed by (E-W) extensional crustal movements. This diagnostic fact is not conform but contrary, however, to the expectations of the model of plate tectonics, which suggests a westward compressive (active) subduction of the Australian shield.

On the other hand, these extensional movements of the western margin of the Arafura Shelf are a fine confirmation for my model of passive subduction, resulting from the eastward retreat of the foreland and the eastward advancing B-sector in its wake. The reality of this picture can be elucidated by a closer analysis of the tectonic structure and the morphology of this area.

The Kai Islands and the Aru Basin form together a triangular area, which is limited at its northern side by a left-lateral, W-E trending shear fault (see Warren Hamilton's map, 1978). Its eastern side is formed by a set of SW-NE trending normal (extensional) faults which form the transition between the Aru Basin and the platform of the Aru Islands on the Arafura Shelf. Its western side is slightly concave to the West, extending northward from the apex of the triangle (which is situated at about 7°S lat. and about 132½°E long.). It trends first northward, then more and more NW-ward towards P. Gorong. The sides of this triangle are about 350 km long. Structurally and morphologically it is a typical 'sphenochasm', with horst-and-graben structures arranged fan-wise, the hinge-point being situated in the apex at the southern side:

Hual Island trends SSE-NNW, Nuhutjut SSW-NNE, the eastern margin of the Aru Basin trends almost SW-NE (see also Bowin c.s. MS, Fig. 16).

At its northern side the Aru sphenochasm is limited by the above mentioned, W-E trending, sinistral shear fault.

The northern foreland of the Banda Arcs is situated between this fault (which belongs to the Sorong Fault system *sensu lato)* and another sinistral, W-E trending shear fault, the Sorong Fault *sensu stricto,* which cuts across the northern part of the 'Birds Head' (Jazirah Doberai). Between these two left-lateral faults at the southern and northern side of the Birds Head a repetition of the W-E extension of the Aru sphenochasm occurs, however, at about a two-times larger scale. The eastern side of the Aru triangle finds its repetition in the SW-NE axis of the youngest sediment-filled Basin at the eastern side of the Geelvink Bay (Teluk Sarera), into which some 8000 m of Quaternary sediments have been dumped. The western limit is formed by the WNW-ESE trending Seram Trough, which forms the westward extension of the Aru Basin. Between these two limits again a fan-like opening of horst-and-graben structures can be observed with clockwise rotations of the elements.

(1) The Misool-Onin-Kumawa Ridge (Trend WNW to NW).
(2) The Sulawati Basin (more than 7000 m of Mesozoic and Cenozoic strata) – Bintuni Basin (more than 8000 m of Tertiary and Quaternary strata) (Trend WNW to NW).
(3) The Lina Range (WNW) and the unnamed ranges east of the Bintuni Basin (NNW).
(4) Wandamen Graben (NNW).
(5) Wondiwoi Horst (N).
(6) Umar Bay (N).
(7) Waroromi-Angrameos Horst (N to NNE).
(8) Teluk Sarera or Geelvink Bay (N to NNE), which is a repetition in size and age of the Aru Basin (sphenochasm).

The length of this foreland belt of differentially eastward extension is about 900 km at its northern side (the Sorong Fault *sensu stricto),* and 400 km at its southern side. Its width ranges from 200 to 400 km. The zone of E-W crustal extension at the northern side of the Australian shield increases in length from zero in the hinge of the Aru sphenochasm to about 1000 km at the northern side of Irian Jaya. In the wake of this retreating foreland the B-, C-, and D-sectors of the Banda System have migrated eastward, and the abyssal South Banda Basin opened up in their rear.

This geodynamic concept can be tested by a comprehensive palaeomagnetic research program in the eastern part of Indonesia. The deductions from this alternative model of 'centrifugal' island-arc spreading (in contrast to the 'centripetal' active underthrusting of the forelands, as suggested by the paradigma of plate-tectonics) prognosticate that the island of Seram rotated some 90 degrees counterclockwise, whilst the horst-and-graben structures of the eastern and northern foreland rotated clockwise (up to a maximum of about 90 degrees between the Teluk Sarera Bay and the Bintuni Basin).

Diagnostic, independent data of palaeomagnetism can confirm or refute the functional correctness of this alternative model. As an example of the possibilities of palaeomagnetic researches with more advanced techniques, combined with palaeontological and radiometrical age determinations, we might mention the papers by J. VandenBerg (this issue).

The Bowin et al. MS is a valuable peace of scientific work, which presents a great number of new basic facts of observation concerning the Banda Region in Indonesia.

I do agree, of course, with the majority of these diagnostic facts. But my inductive interpretation of the available data into a synthesis differs from the current model (paradigma) of 'plate tectonics', which is the premise for the interpretations in the manuscript of Bowin et al. Of course, still other models of interpretation on the geodynamics of the Banda Arcs can and will be conceived in the future.

It is my opinion that a comprehensive program of palaeomagnetic researches in the eastern part of Indonesia should be executed, in order to obtain independent (diagnostic) facts of observation, which can test the functional correctness of these alternative models by comparing their logical deductions (prognoses) with new diagnostic data.

Yours sincerely,

Rein van Bemmelen