DISCUSSIONS AND COMMUNICATIONS

GEOLOGIC INTERPRETATION OF THE BATHYMETRY OF THE EAST INDIAN ARCHIPELAGO.

The splendid oceanographic results described and fully mapped in Volumes II and V of the reports of the Snellius East Indian Expedition undertaken by the navy of the Netherlands in 1929-1930[1] are also of much interest to structural geologists. Of deep-sea wire soundings below 200 m. in the vast archipelago of the East Indies, there were up to 1929 not more than 3500, and now, thanks to the Snellius Expedition, no fewer than 32,000 echo soundings are added.

Very instructive for the geologist and paleogeographer are the chart on Van Riel's Plate V (our Fig. 1) and his discussion of it on pages 55 and 57. This plate shows in a striking way how the Asiatic and Australasian continental masses fray out toward one another in a most complicated, swirling manner. It suggests to the present writer that Asia and Australasia have been separated from one another by abyssal waters from the Pacific and Indian oceans probably since Precambrian times. The waters from the Pacific, entering between the Philippines and New Guinea, flow southwest into the vast Celebes basin and thence south into an irregular trough (Makassar) situated to the west of the great island of Celebes. Another stream from the Pacific goes south through Molucca Passage into the North Banda basins and thence widely into the greater South Banda basin, where the waters swirl around under pressure from the waters of the Indian Ocean. It was this second string of wide abyssal seas that made the biogeographic barrier known as "Wallace's Line," and it was these seas that prevented most of the Mesozoic-Cenozoic land life of Asia from reaching Australasia, or traveling in the reverse direction. This vast deep-water passage, with a sigmoidal curvature and situated between two continents, is truly a mediterranean: it is altogether too large to be classed as a geosyncline (unless the term is made meaningless by including mediterraneans and oceans) and is, moreover, wholly different structurally from a typical geosyncline like those of North America.

In more detail, the plate appears to show how Borneo, a part of Asia, once continued into the Philippines by way of the Palawan

[1] The Snellius-Expedition in the Eastern Part of the Netherlands East-Indies, 1929-1930, under leadership of P. M. Van Riel. Vol. II, Oceanographic Results, Part 2, Soundings and Bathymetric Charts, Chapter II, The Bottom Configuration in Relation to the Flow of the Bottom Water, by P. M. Van Riel, 1934. Vol. V, Geological Results, Part I, Geological Interpretation of the Bathymetrical Results, by Ph. H. Kuenen, 1935.

and Sulu ridges; how Borneo also continued at the southeast into Celebes, which great island, also of Asia, frays eastward into four fantastically shaped peninsulas; and how Asiatic Sumatra attenuates into Java and farther east into the scattered islands of this arc of the southern Banda Sea. On the other side of these

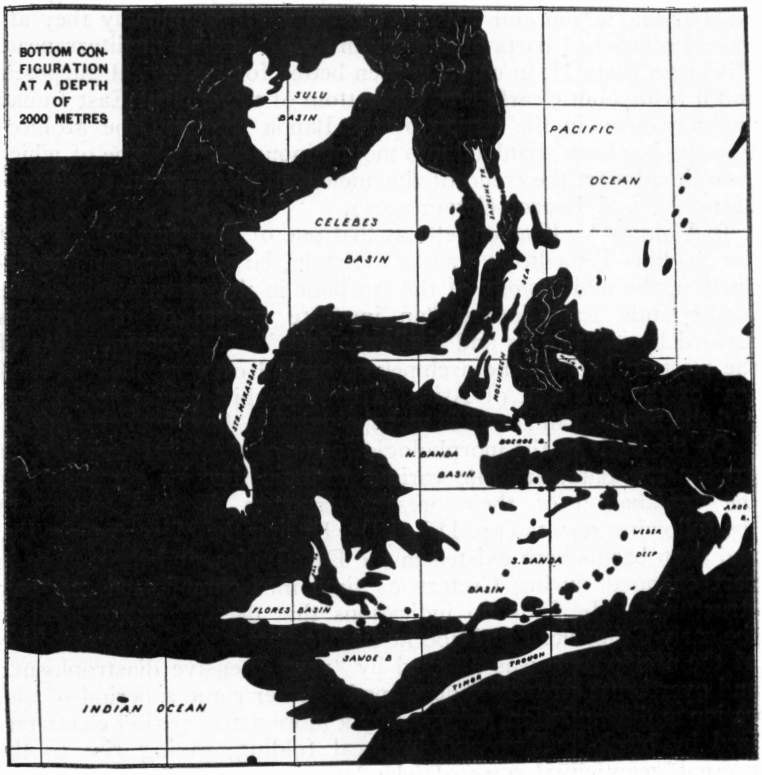

Fig. 1. Van Riel's Plate V, much reduced, showing the bottom configuration at a depth of 2000 m. Lands black, water areas white.

deep basins, which are now structurally much modified, lies Australia, with its northeastern continuation into continental New Guinea; here there is also much peninsulation of the last-named land, but now the fraying is toward the west into the Molucca Passage and the North Banda Sea. Timor and other islands of the outer Banda arc appear to be but thrust-up or arched parts of the northwestern marginal (or Sahul) part of Australia.

The deepest basins of the East Indian mediterranean are the Celebes (largest, with greatest depth at 20,215 feet), the North Banda (18,000 feet), the South Banda (17,550 feet) and the Webber deep (deepest of all, 24,180 feet). The greatest depth (30,550 feet), however, occurs as in the Mindano trough east of the Philippines in the Pacific Ocean. Van Riel's Plate VI, drawn at 4000 m. depth, shows that these basins are in the zone of greatest dynamic action and crustal deformation; presumably they are the overdeepened parts of the original East Indian mediterranean. His large Plate II, in color, is even better for geological purposes, and it brings out clearly how the bottom of the ancient East Indian mediterranean in the region of the Banda seas and the Molucca Passage has been wrinkled into mountainous ridges, some of which even lie athwart the trend of the ancient mediterranean (Taliaboe-Mangole, and Boeroe-Ceram arcs).

In Volume V, Kuenen tells us that one of the principal tasks of the Snellius Expedition was to ascertain, largely for geologic deduction, the morphology of the sea floor in the eastern half of the Netherlands East Indies, "an intricate system of deep basins divided by island arcs and shallow ridges." The marine areas of the western half of the archipelago are all of very shallow shelf seas of the continent of Asia. There are thirteen distinct basins, and the South Banda one is morphologically the most complex.

On the basis of the morphologic forms of the West Indies, their gravimetric data, and the various tectonic theories proposed for the explanation of their present structure, Kuenen arrives at the following results (pp. 113-118): During the Mesozoic, shallow and deep basins both existed in the East Indies, and these were in part changed during Cretaceous time into complicated orogenic structures. He finds no indications that deep basins existed in the early Cenozoic. In Miocene time, a part of the eastern section of the archipelago was affected by "very intensive diastrophism," and overthrust structures developed. Later came a period of elevation and denudation, followed by a more active period characterized by block-faulting and by local folding, giving rise to the present geanticlinal rows of islands.

Of the larger basins there are two main types, (a) the largest and deepest basins with flat and horizontal floors, and (b) those having narrow synclinal shapes, linked in long festoons, and with considerable variation in depth. These basins are illustrated and interpreted in Kuenen's Fig. 47 on page 114, reproduced in our Fig. 2. The basins of group (a) are believed to have come about through a regional downward force which caused them to sink *en bloc* along flexures or by stepped faults all around; nearly all the basins of this type are connected with the Cathaysian continent. The synclinal basins of group (b) are situated mainly on the Australia-New Guinea mass but some also are of the Philippines

and of southeastern Asia; these are believed to be parts of a former continent, now submerged, and to have arisen through "a

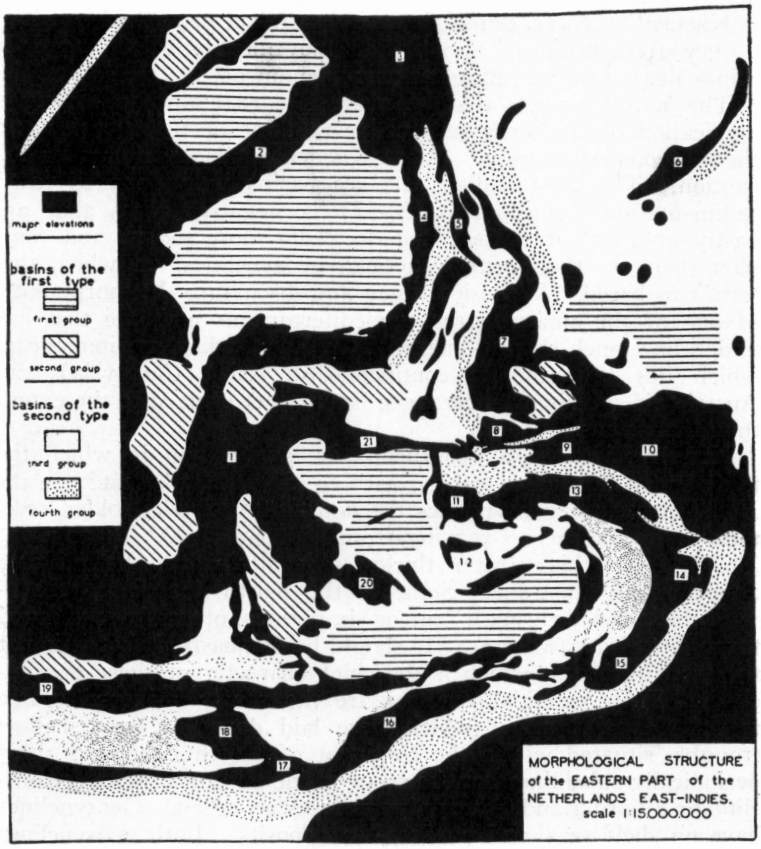

Fig. 2. Kuenen's Figure 47, much reduced, showing the "morphological structure" of the eastern part of the East Indies. 1, Celebes; 2, Sibutu-Basilan ridge; 3, Mindanao; 4, Sangihe ridge; 5, Talaud ridge; 6, Palao ridge; 7, Halmahera; 8, Obi; 9, Misool; 10, New Guinea; 11, Boeroe; 12, Luymes and Siboga ridges; 13, Ceram; 14, Kai; 15, Jamdena; 16, Timor; 17, Sawoe; 18, Soemba; 19, Bali; 20, Toekangbesi; 21, Soela islands. Newer data disprove the existence of the formerly assumed "Palawan trough."

horizontal compressive force in the mode of normal synclines." Kuenen postulates further "that the Asiatic and the Australian continents at one time formed a more or less continuous mass" (to which the writer would add, surely not since the Paleozoic).

Also, that the mobile belt has decreased considerably in breadth and has been pressed together. "The two continents in this way approached each other."

Kuenen, however, thinks that the Australian mass "did not drift a very great distance" and that its movement affected only in a minor degree the resulting tectonic phenomena.

The writer regrets that he must take exception to Kuenen's application of the term geosyncline to these deep-sea basins and the festoons of troughs. What Kuenen is discussing under the caption, "The East Indian deep-sea basins in relation to fossil sedimentation basins" (pp. 50-57) is negative areas that are vastly greater, far deeper, and decidedly more mobile and complex than are the North American geosynclines, on which this term was based. He is describing and discussing the morphology of one of the ancient, greater mediterraneans and one that has undergone much change—namely, the East Indian mediterranean, which lies between the continents of Asia (Cathaysia) and Australasia. This mediterranean has not yet evolved to the extent that Tethys has.

Kuenen's idea of a geosyncline is "any region in which the thickness of the sediments is great" (p. 51). How great? In the North American geosynclines the dominantly clastic, folded sediments have thicknesses varying from less than 10,000 feet to about 70,000 feet; this greater thickness is attained in both North America and Australia. Some of the North American geosynclines have lasted through four or six periods, others have endured through at least two eras. It should be emphasized that it is not the great thickness which is the chief character of these geosynclines. Their essential features are the nearly universal coarse marine deposits, all of which were laid down in very shallow troughs, situated within the continent of North America; these periodically subsiding troughs occur inside an outer, rising geanticline or a borderland, which always faces an ocean. Geosynclines have no shelf seas, and no deep-sea deposits. Both geosynclines and geanticlines are parts of a continent, and they are but complementary members of an orogenic belt. It is the geanticlines and borderlands that furnish nearly all the clastic sediments in the geosynclines. Structurally, geosynclines are relatively simple crustal affairs, when compared to mediterraneans.

A mediterranean, on the other hand, is a far greater, and a much deeper oceanic region, which is also far more active dynamically and has endured at least as long as the longest lived geosynclines of the continents. Moreover, mediterraneans are always situated between two (or more) continents.

The East Indian archipelago, with its several abyssal intermediate basins and its island festoons with troughs on either side of the lands, makes a highly variable morphologic complex that was

wrought out of the East Indian mediterranean chiefly through its inherent periodic dynamic action, assisted by the pressures generated by the approaching continents of Asia and Australasia. The result is a tangle of linear and criss-cross arcs, conditioned by the multiplicity of subsiding and interfering basins and troughs, whereas the mountains that result from geosynclines have long and sweeping lines of ranges in conformity with the grain of the continents, like the narrow and simple Appalachians or the wider and more complex Cordilleras of western North America.

The several strings of troughs of the East Indian archipelago, so clearly mapped on Kuenen's morphologic chart on page 114 (our Fig. 2), are narrow and more or less irregularly elongate waterways linked in festoons and having great variation in depth. These are not like North American geosynclines.

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