COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1970 / 35

Seismicity in the Bismarck Volcanic Arc

by

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SUMMARY

On the basis of the distribution of earthquakes during the period April, 1958, to June, 1969, the Bismarck Volcanic Arc can be divided into two sections, each with a distinctive seismic regime. The eastern, or New Britain, section is underlain by a well-defined seismic, or Benioff, zone which dips northwards at 70°. In contrast, earthquakes in the western part of the Arc (between Umboi Island and the Schouten Islands) appear to have a scattered distribution, and no seismic zone dipping beneath mainland New Guinea can be delineated.

If the generation of magmas in circumoceanic regions is related to seismic events, and if the compositions of magmas are governed by the depths at which earthquakes take place below the volcanoes, then significant differences in composition can be anticipated between volcanoes in the eastern part of the Bismarck Volcanic Arc, and those in the western part.

SEISMICITY IN THE BISMARCK VOLCANIC ARC

Introduction

Current petrological research on the volcanoes of island arc regions attempts to relate the composition of lavas to the depth of the seismic (or Benioff) zone beneath the volcanic areas. In Japan, for example, a zonation of magma series has been established across the island arc, and compositional variations have been ascribed to the depth at which magma was generated at the seismic plane which dips westwards, beneath the continental margin (see, for example, Sugimura, 1968).

The petrology of volcanoes comprising the Bismarck Volcanic Arc is being investigated by the Bureau of Mineral Resources, and in order to test the hypothesis that seismicity and magma generation are related, a map of earthquake epicentres and seismic cross-sections have been constructed. In this Record the seismic map and sections are presented and briefly described. The volcanological implications of the data will be discussed in a separate report.

In a recent study of seismicity in the New Guinea-Solomon Islands region, Denham (1969) analysed the distribution of earthquakes in the Bismarck Volcanic Arc. He plotted the epicentres of earthquakes of magnitude 5 or greater (and recorded by more than 15 stations) for the period 1958-1966, and constructed three seismic cross-sections at right-angles to the volcanic arc. The present study is a more detailed extension of Denham's work. Its purpose is two-fold: (1) to plot all earthquakes for the period 1958-1969, with magnitude 4.5 or greater, and recorded by 10 or more stations; (2) to divide the Bismarck Volcanic Arc into sections whose limits are defined by the distribution of volcanic areas and distinctive seismic patterns, and to construct seismic profiles for each of these sections.

The seismic data for the period April, 1958, to June, 1969, were obtained from the computer Storage and Retrieval System of Seismic Data, operated by the Geophysical Observatory, Port Moresby. On the print-out sheets supplied by the Observatory, co-ordinates of all plotted epicentres of earthquakes up to December 31st, 1966, were recorded to a tenth of a degree, and those for earthquakes after January 1st, 1967, were given to the nearest hundredth of a degree.

For the purposes of this report, it is convenient to consider the Bismarck Volcanic Arc in two parts: (1) New Britain Island, to the south of which lies a submarine trench, over 8000 m deep; (2) the section between Umboi Island (in the east) and the Schouten Islands (in the west), off the north coast of New Guinea (figure 1); in contrast to the New Britain section, no trench is associated with this part of the volcanic arc. The present study demonstrates that each of these areas is characterised by distinctive seismic regimes.

Seismicity in New Britain

Earthquake epicentres for New Britain are divided into the following three categories, and plotted in figure 2: (1) earthquakes down to a depth of 70 km; (2) those 71-150 km deep; (3) earthquakes deeper than 150 km.

Epicentres of the shallow earthquakes occupy a broad zone that covers the southern part of New Britain island, and extends southwards into the trench area of the Solomon Sea. The intermediate-depth earthquakes define a zone that spreads across the entire width of New Britain. The deep earthquake epicentres plot along the north coast of the island and northwards into the Bismarck Sea area.

The most active seismic area in New Britain is the central-eastern part, near Jacquinot Bay (Denham, 1969), and the least active part is in the centre of the island, south of Kimbe Bay. Figure 2 also defines the "seismic lineament" that crosses the Bismarck Sea from the Schouten Islands in the west to the northern tip of the Gazelle Peninsula, in the east (Denham, 1969).

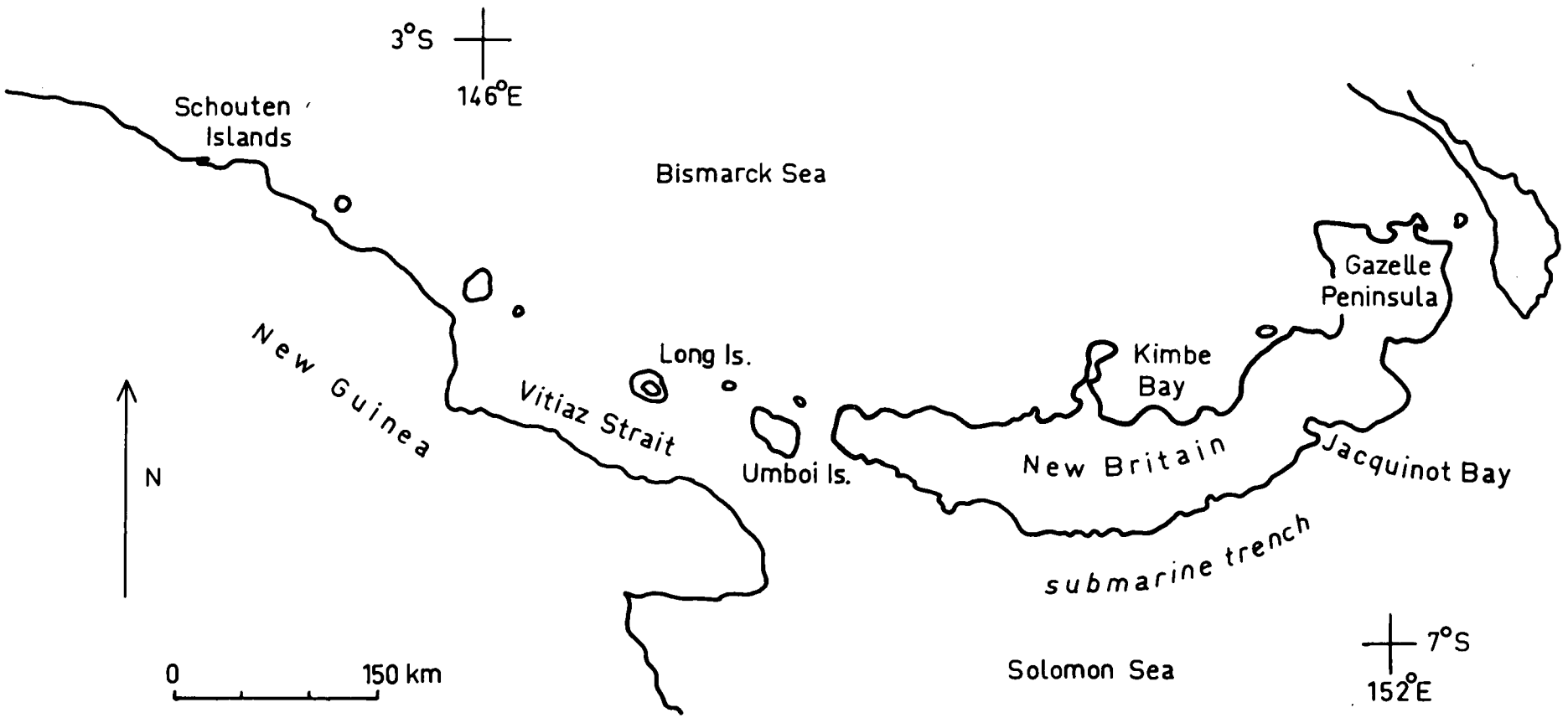

Figure I. Locality Map

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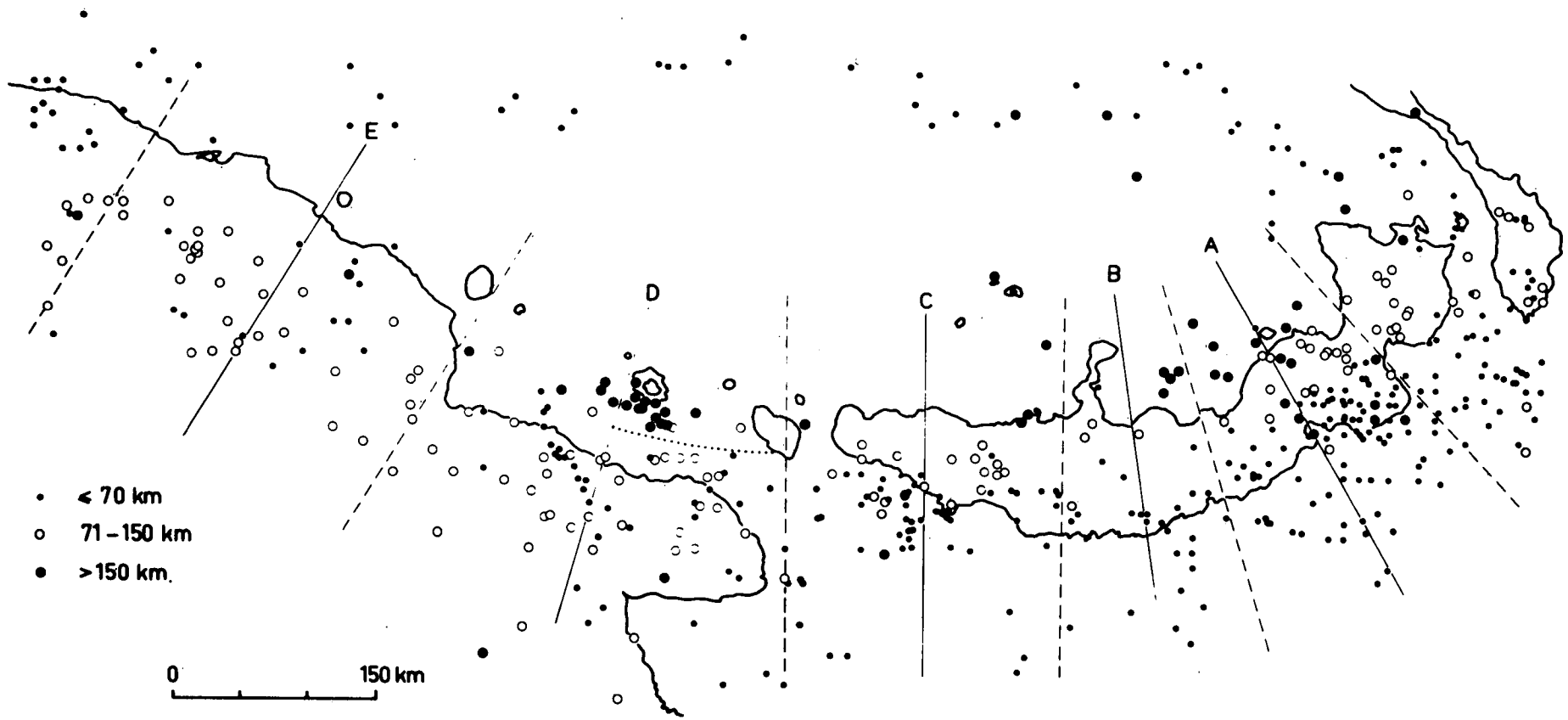

Figure 2. Map of the Bismarck Volcanic Arc showing epicentres for earthquakes of magnitude 4·5 or greater, and recorded by 10 or more stations, during the period April, 1958, to June, 1969. The Arc is divided into five sectors whose limits are shown by the dashed lines. The solid lines, A to E, are traces of vertical planes onto which earthquakes for each sector were projected to give the seismic cross-sections in Figures 3 and 4.

In figure 2, New Britain is divided into three sections (excluding the Gazelle Peninsula) for which seismic profiles have been constructed (A, B, and C in figure 3). The profiles of each section show similar features: (1) a more-or-less flat-lying zone of shallow earthquakes (less than about 70 km deep) beneath the Solomon Sea trench and the south coast of New Britain; (2) a steep zone of deeper earthquakes dipping northwards at about 70° beneath the island (see also Denham, 1969; his figure 8, section 6); (3) a concentration of shallow earthquakes at the junction of zones (1) and (2).

The seismic zone beneath New Britain is geometrically similar to the seismic, or Benioff zones of many other "island arcs" (see, for comparison, Sykes, 1966). According to one interpretation (Oliver and Isacks, 1967), the seismic zones represent the upper surfaces of thick slabs of oceanic crust and upper mantle which have been downthrust beneath the island arcs. If this interpretation is extended to the New Britain area, northward movement of oceanic crust and upper mantle from the Solomon Sea area must be visualised.

Seismicity in New Guinea north coast section

The New Guinea north coast section of the Bismarck Volcanic Arc differs from that of New Britain, not only by the absence of an associated submarine trench, but also by its distinctive seismic regime. In contrast to the New Britain section, shallow earthquakes (70 km deep or less) are much less common than those of intermediate depth (71 to 150 km deep). Furthermore, most of the deep-focus earthquakes (deeper than 150 km) are restricted to a small area south of Long Island in Vitiaz Strait, and contrast with the belt of deep foci along the north coast of New Britain (figure 2).

The seismic cross-sections, D and E in figure 4, also reveal pronounced differences from the New Britain sections. The most obvious difference is the absence of any well-defined planar structure, or seismic zone. There is a tendency in section D for deeper earthquakes to be more common in the south, and for foci east of plane D to be shallower than those to the west (see figure 2), but in general the distribution of foci is seen to be scattered (see also Denham, 1969; his figure 8, sections 4 and 5).

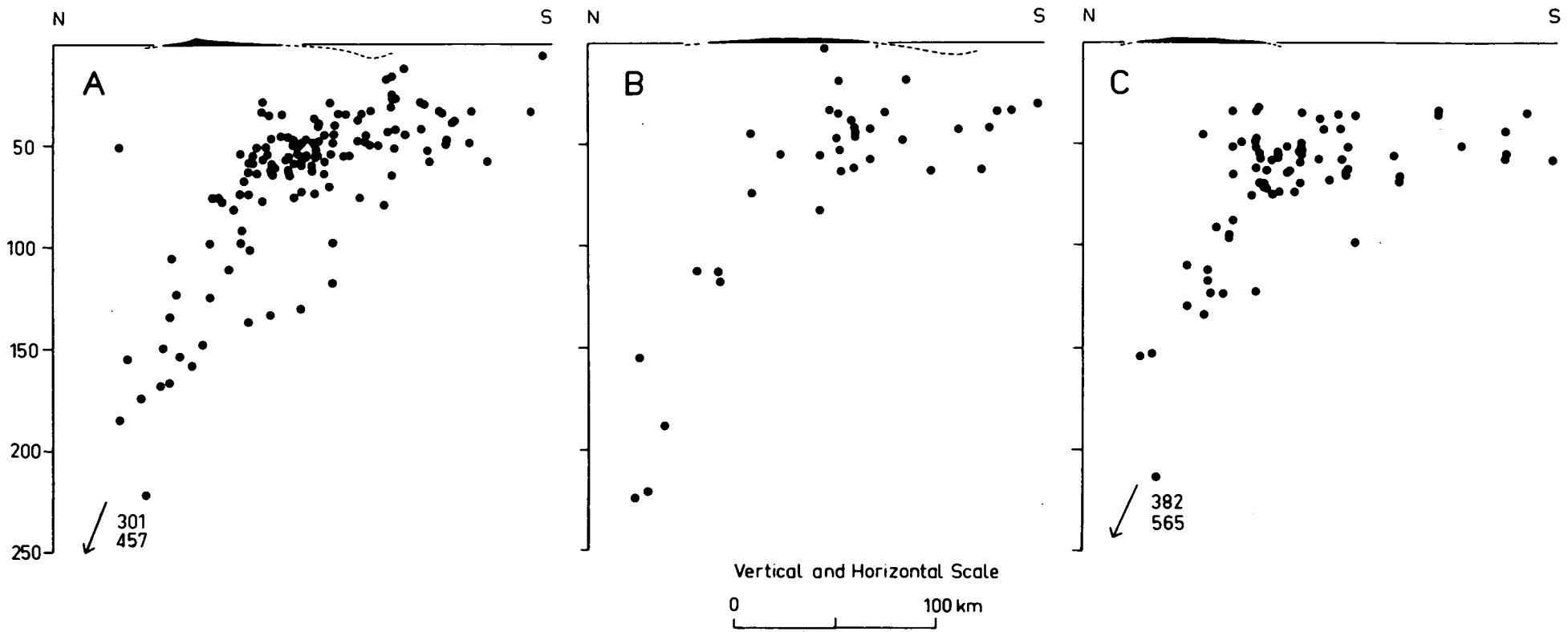

Figure 3. Seismic cross-sections, A, B and C, for New Britain island (compare with Figure 2). In sections A and B, the submarine trench south of the island is shown by the dashed line. The depths in kilometres of four foci deeper than 250 kilometres are shown in sections A and C.

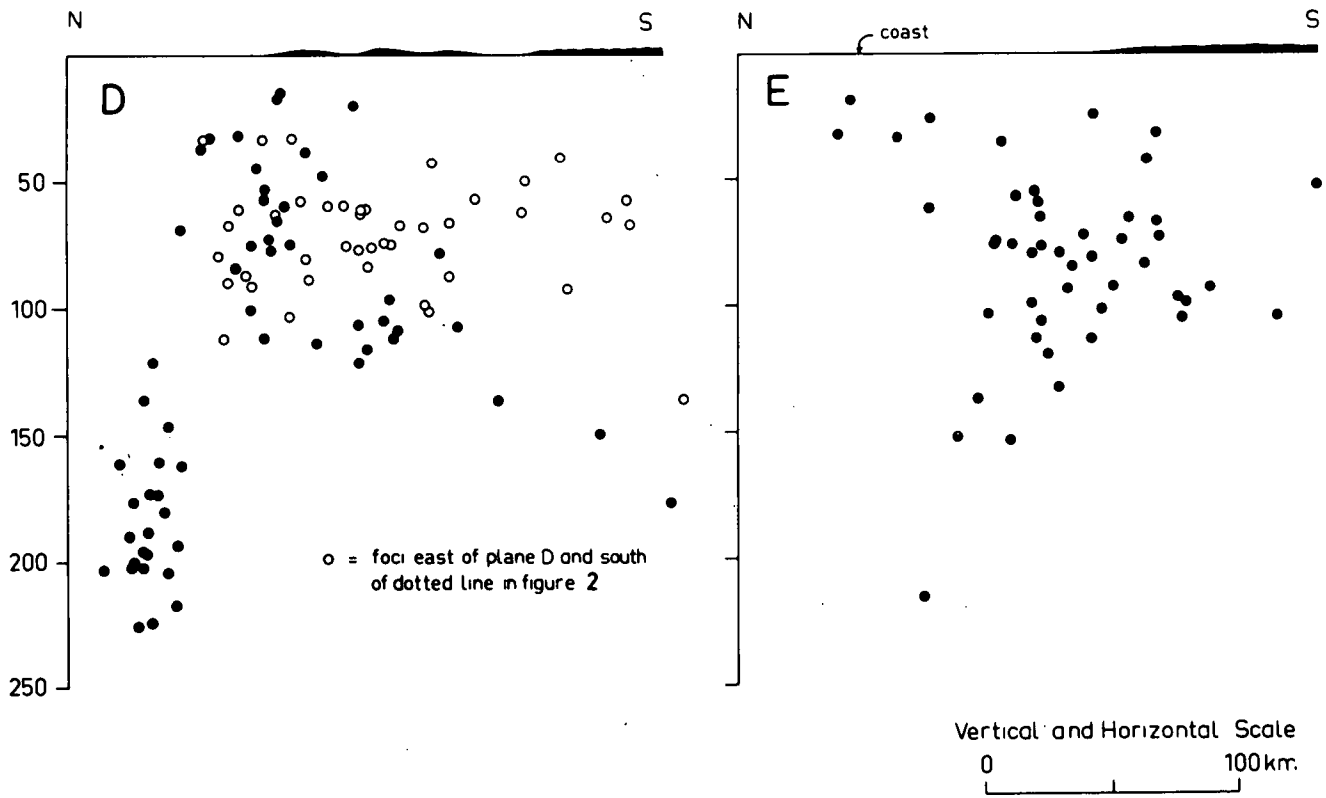

Figure 4. Seismic cross-sections, D and E, for the New Guinea north coast section (compare with Figure 2)

Section D also reveals the vertical zone of deep-focus earthquakes in the Vitiaz Strait, south of Long Island (figure 4). These earthquakes appear to be contained in a vertical "seismic cylinder", separated from both the intermediate-focus earthquakes of the mainland, and the deep-focus earthquakes of the New Britain Benioff zone. It is possible, however, that this "separation" is only an apparent feature, due merely to a lack of deep-focus seismic events in this area during the 1958-69 period. If this is so, then the deep foci in Vitiaz Strait could be interpreted as a steeper, western extension of the deep part of the New Britain Benioff zone.

Conclusion

The map of earthquake epicentres (figure 2) and the five seismic cross-sections (figures 3 and 4) show that the Bismarck Volcanic Arc may be divided into two parts. The eastern, or New Britain, section is associated with a submarine trench and a well-defined Benioff zone, and it therefore shows a geotectonic configuration similar to that of several "island arc" regions (for example, Japan, Tonga, and the Aleutian Islands). In contrast, the volcanoes of the western part of the Bismarck Volcanic Arc, between Umboi Island and the Schouten Islands, are associated with neither a Benioff zone nor a submarine trench, and therefore, in the strict geophysical sense, they cannot be considered as belonging to a true "island arc" environment.

If it is true that the generation of magmas in circumoceanic regions is related to seismic events, and that the compositions of magmas are governed by the depths at which earthquakes take place below the volcanoes, then significant differences in composition can be anticipated between volcanoes in the eastern part of the Bismarck Volcanic Arc, and those in the western part. Conversely, if no significant differences in composition are revealed, then doubt may be cast on the validity of attempting to relate magma compositions to the depth of seismic events in island arc areas.

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