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RIGID PLATE ACCRETION IN AN INTER-ARC BASIN: MARIANA TROUGH†

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It is verified that an oblique rigid opening results in good fit of the rifted portions of arc on each side of the Mariana trough. The good fit suggests that there has been rigid plate accretion and that a plate 200 km wide and 1500 km long can stay undeformed between active consuming and accreting plate boundaries.

Small ocean basins, which often exist behind island arcs, have been called "marginal basins." KARIG (1970, 1971b) showed that the Lau-Havre trough between the Tonga-Kermadec ridge (frontal arc) and the Lau-Colville ridge (third arc), and the Mariana trough between the Mariana ridge (frontal arc) and the West Mariana ridge (third arc) are the sites of active extension. Using Karig's terminology, a new inter-arc basin is formed by relative migration of the third arc (an inactive rifted portion of the frontal arc) away from the frontal arc-trench system. Some authors such as VAN DER LINDEN (1969) and MILSOM (1970) have implied that the extension results from rigid plate accretion, as on mid-ocean ridges. However, it is now often assumed, following KARIG (1971a) that the process of rifting and creation of new lithosphere in marginal basins is different from the process of rigid plate accretion at mid-ocean ridge crests (PACKHAM and FALVEY, 1971). The actual process of opening is not clearly defined but is assumed by Karig to result from the rise of a hot diapir from the asthenosphere. It is also assumed that, during the opening of the marginal basin, the frontal arc did not remain rigid but was deformed, probably through block faulting, along a series of faults both parallel and perpendicular to the arc (KARIG, 1970; 1971a and b)

Westward from the Mariana trench, there is a poorly developed mid-slope basement-high on the eastern flank of the frontal arc (Mariana ridge) which carries the raised limestone islands: Guam, Saipan (Fig. 1). The back of the frontal arc is defined by a westward facing scarp with 2–3 km of relief

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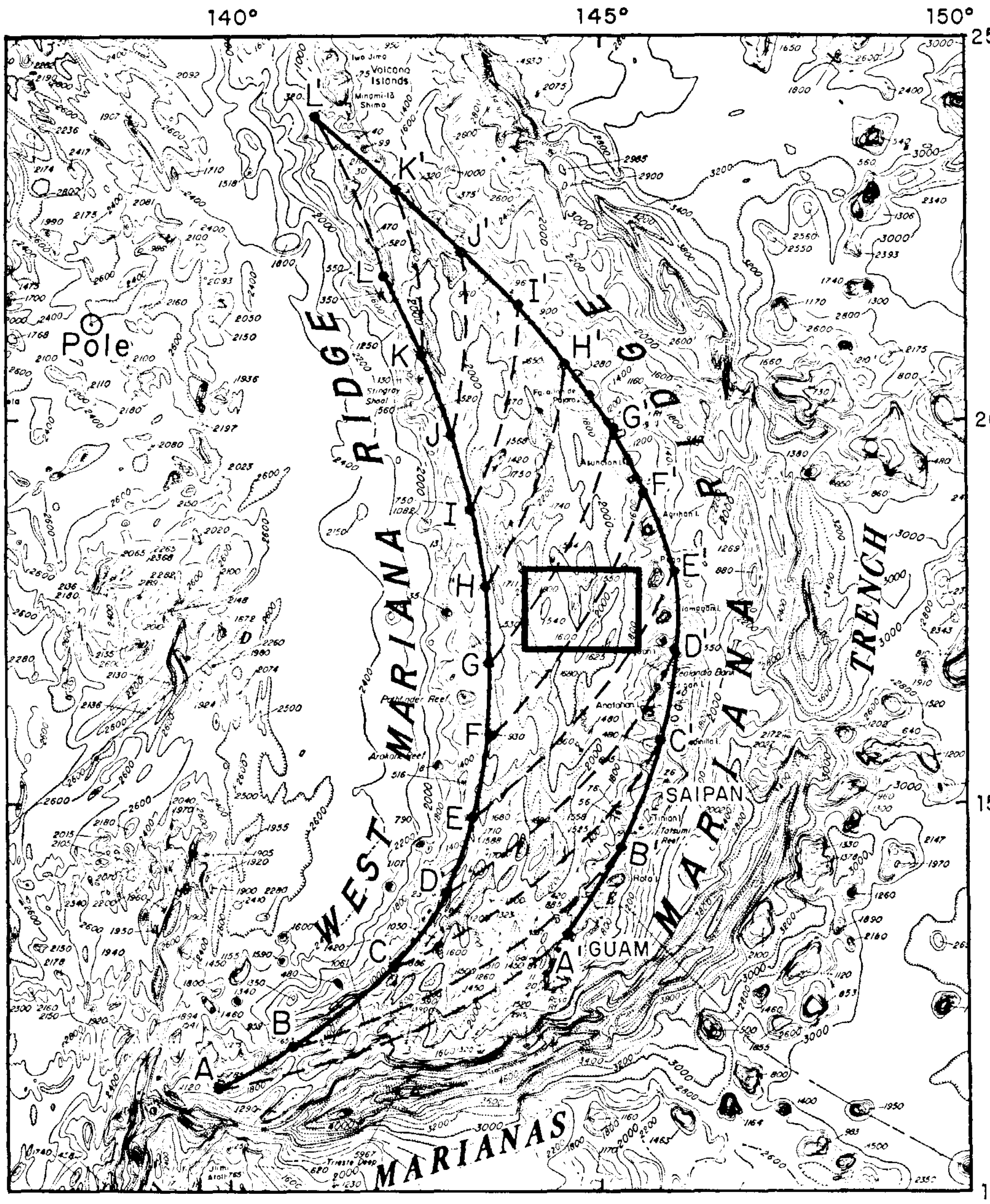

Fig. 1. Bathymetric map of the Mariana Island Arc System (from bathymetric map of the North Pacific compiled in Scripps Institution of Oceanography by T. E. Chase, H. W. Menard and J. Mammerickx). Heavy solid lines A′–L′ (frontal arc) and A–L (third arc) follow the two rifted scarps of the Mariana Inter-Arc Basin. Thinner, dashed lines (A through L) represent small circles between couples of points that are homologous in the fit using eulerian pole (circle on map) at 21.4°N, 138.1°E.

(line A′L′ on Fig. 1) which, following Karig's interpretation, is the original line of rifting. The scarp has been modified by volcanic activity between B′ and G′. On the westward side of the Mariana inter-arc basin, the third arc (West Mariana ridge) is limited on the east by a prominent scarp which has 2–3 km of relief and is therefore well defined morphologically (line AL on Fig. 1). Karig argues that, with opening roughly perpendicular to the arc, the two rifted portions do not match because the radius of curvature of the frontal arc is smaller than the radius of the third arc. He concludes that the frontal arc has been warped during the opening of the inter-arc basin. However, unlike the arc, the deep earthquake zone is planar (P. Molnar, personal communication, 1974), implying that it was not bent by this supposed warping. In this paper, we show that there is an excellent fit between the two rifted scarps, and we argue that, as in the case of the South Atlantic (BULLARD *et al.*, 1965), this favors rigid plate accretion. We show further that the general morphological pattern within the inter-arc basin is in good agreement with the trends predicted by the finite rotation which describe this fit.

A computer fit between the two rifted scarps AL and A′L′ minimizes the sum of the squares of the distances of overlap or underlap on given small circles. Figure 1 shows the twelve couples of points (A through L) which are homologous in the best fit. The eulerian pole of rotation is at 21.4°N and 138.1°E, the angle of rotation is 29.5°, and the standard deviation is 15 km. The fit is considered good, taking into account the present precision of definition of the scarps and considering that the lines which are fitted are 1500 km long and show a continuous decrease in their radii of curvature from south to north. Figure 1 also shows small circles about the eulerian pole, which should be fossil trajectories if the movement occurred about the same pole throughout the opening. Because the pole is close to the northern end of the inter-arc basin, the direction and amount of opening change very rapidly from south to north. In the south, the direction is approximately SW–NE and the amount of opening is 500 km. In the north, the direction of opening is S–N and the amount of opening is only 200 km. An examination of Fig. 1 shows that the morphological pattern can be interpreted as consisting of two trends. One trend parallels the small circles and may thus correspond to fossil transform faults directions. The other is oblique to the small circles and may correspond to the trend of accreting plate boundaries. Note also that, at the latitude of Guam, the chain of active volcanoes which lies to the west of the frontal arc crest does not curve around the southern end of the Mariana ridge but stops against the trench which is, in this area, a transform fault, according to our interpretation.

Figure 2 shows a detailed bathymetric map within the inter-arc basin in the region where a N–S "axial high" is well defined (KARIG, 1971b). We have shown, on this map, a portion of a small circle about the computed pole in order to illustrate that it is possible to interpret the series of N–S trending features as ending against a SW–NE fossil transform fault oblique to the general topography. This interpretation differs from the one given by Karig who considered that the major transverse feature of the map is a WSW–ENE trending trough just north of 17°30′N.

If the trough opened in the oblique fashion we suggest, the opening may have resulted in the development of closely spaced fossil transform faults of the type recognized by BAYER *et al.* (1973) on the basis of a very detailed and precise magnetic anomaly map of the western Mediterranean, an inactive marginal basin. Closely spaced transforms would make the magnetic pattern

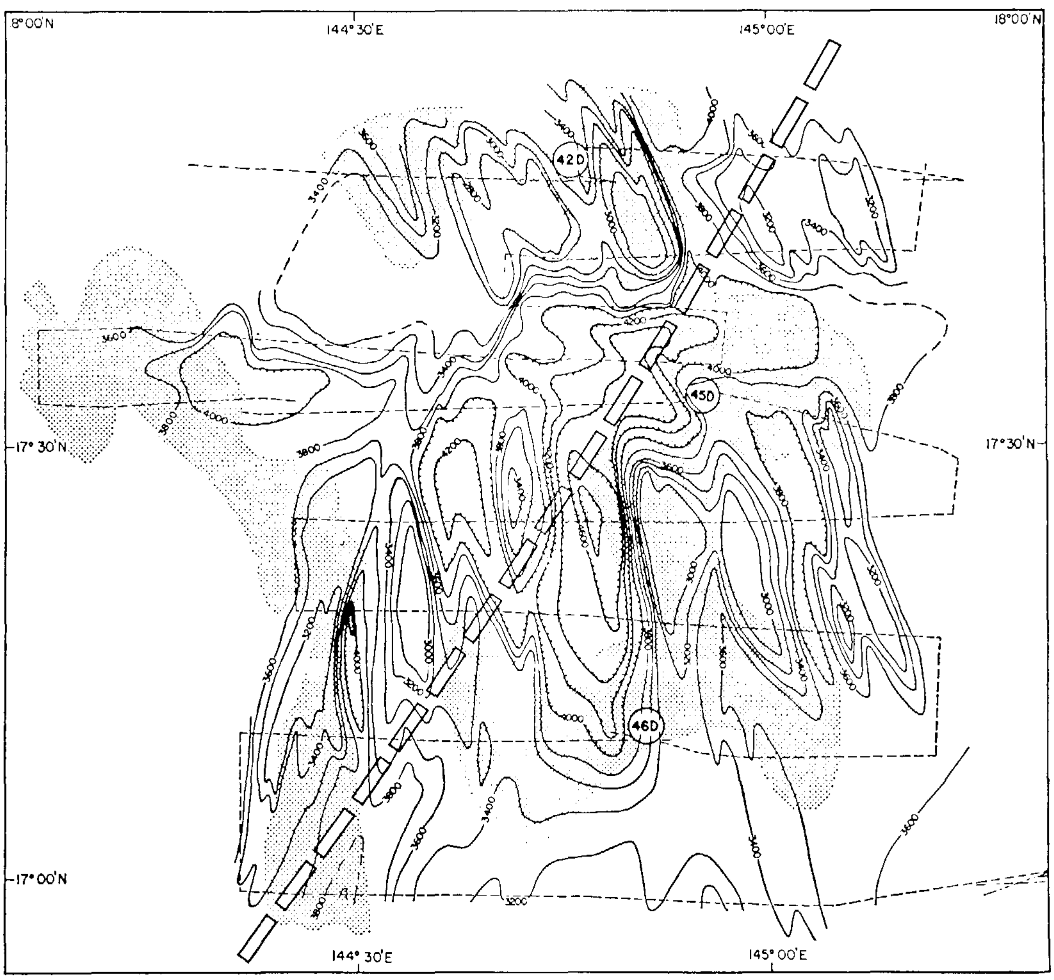

Fig. 2. Bathymetry of boxed area shown in Fig. 1 with superimposed areas of positive magnetic anomalies (shaded) and positions of rock samples (from KARIG, 1971). Rock samples, 1971: 42 D, fresh, Mn-coated basalt; 45 D, meta-basalt, meta-tuff, pieces of diabase, fresh basalt; 46 D, very fresh basalts without Mn-coating. Open-boxed line indicates SW–NE trend of possible fracture zone.

difficult to identify. An oblique opening cannot proceed for long distances without geometrical adjustment and this may explain the existence of shifts from one marginal basin opening to the next one. Alternatively, the shift may be due to some geometrical relationship with the downgoing slab.

We have verified that oblique rigid opening results in good fits on the rifted portions of arc not only behind the Mariana trench but also behind the Tonga and Kermadec trenches. However, these fits are less significant than those for the Mariana arc because the rifted scarps are rectilinear and because, if the interpretation of SCLATER *et al.* (1972) is correct, the present pattern of opening is different from the one obtained using the total finite rotation.

We recognize that the geometrical exercise outlined in this paper does not prove that the frontal arc of the Mariana has behaved as an undeformed plate. Similarly, as pointed out by BULLARD *et al.* (1965), the morphological fit of the African and South American continental edges does not prove that there has been rigid plate accretion. However, the good fit of the rifted scarps in the Mariana area strongly suggests that there has been rigid plate accretion here, and that for long periods, plates only 200 km wide and 1500 km long can stay undeformed between active consuming and accreting plate boundaries. The exercise also provides important guidelines to confirm or deny the hypothesis of rigid opening of inter-arc basins.

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