Papers

Part 2

Younger Pacific Arcs and the Eastern Marginal Seas

RIFTING AND SEAFLOOR SPREADING IN MARGINAL BASINS: SHIKOKU BASIN

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Marginal basins of the western Pacific Ocean comprise the small semi-enclosed seas which occur behind most island arc-trench systems. Seismic refraction measurements and petrology of dredged samples indicate that the crust of marginal basins is oceanic in type. Two hypotheses are currently held regarding the origin of these features. Karig, and Packham and Falvey have proposed that marginal basins are formed during episodes of extension behind island arcs. Sequential intervals of extension during the Cenozoic have caused the series of marginal basins and aseismic ridges (remnant portions of the island arc) to the west of the Izu-Bonin-Mariana and the Tonga-Kermadec island arc-trench systems. Crustal extension behind island arcs may not, however, explain the formation of all marginal basins. Magnetic lineations which trend at high angles to active or remnant island arcs in the West Philippine basin and the Aleutian basin have led to the suggestion that these marginal basins formed by entrapment of oceanic crust when an island-arc trench system developed *in situ.*

In this paper we will present magnetic anomaly and other geophysical data from the Shikoku basin (south of Japan, west of the Bonin Arc), classified by Karig as an "inactive" marginal basin formed behind the Izu-Bonin island arc during Middle Tertiary or younger times.

Studies of marine magnetic anomaly data from the Shikoku basin reveal magnetic lineations which strike north north-west almost parallel to the trend of the Palau-Kyushu ridge. The lineation pattern is best developed in the western part of the basin and we can confidently identify a sequence of anomalies 7 through 5E between the base of the Palau-Kyushu ridge and the center of the basin.

JOIDES Site 296 on the Palau-Kyushu ridge indicated that island arc volcanism on the Palau-Kyushu ridge terminated in the Late Oligocene. The lineation pattern is slightly discordant to the trend of the Palau-Kyushu ridge and anomalies 7 through 6C (27 - 25 m.y.b.p.) pinch out in succession along the margin of the ridge. The location of anomaly 5E, the most easterly of the confidently identified magnetic anomalies in the western part of the Shikoku basin marks a distinct change in the character of the basement morphology between the east and west parts of the basin. While the uniformly sloping west side has small amplitude, short wavelength basement relief, the eastern part shows larger, more blocky relief.

In the eastern part of the basin where the basement morphology is rough and complex, the magnetic anomalies can not be identified unequivocally. The unidentified eastern anomalies could therefore indicate 1) a continuous magnetic anomaly sequence so that the crust continues to get younger to the east (one limb); 2) that crust was generated at a two-limbed system by symmetric or asymmetric spreading. Subsequent to the formation of the basin the eastern part was disrupted by renewed tectonic activity so that the original magnetic pattern and basement morphology are only presently preserved in the western part of the basin. Note that while the seafloor apparently slopes uniformly downward from east to west, extensive volcaniclastic aprons behind the Iwo-Jima ridge obscure the true basement morphology in the east. Depths derived from the empirical global depth vs. age relation indicate that crust in the Shikoku basin is at least 200-300 meters deeper than expected.

When the observed magnetics data are compared to a seafloor spreading-plate tectonics model for the basin, no symmetric pattern may be discerned by inspection of the data, and thus we tentatively assumed that a continuous sequence of anomalies is present across the basin. Overall, the magnetics data can be satisfied by this model; but the "goodness of fit" varies dramatically across the basin. In the west anomalies 7 through 5E are considered well-identified. The model fits anomalies in the eastern part quite poorly, suggesting that a one-limb model may be incorrect. If our tentative one-limb assumption *was* correct, anomalies 5D to almost 5A (18 - 12 m.y.b.p.) would be present from the center of the basin to the margin of the Iwo-Jima ridge. Because of this poorness of fit, the rough basement morphology associated with these eastern anomalies, and known tectonic events in the adjacent Japanese region (discussed below), the generation of the Shikoku basin by a one-limb style of accretion is considered highly unlikely.

The following tectonic events from the area around Japan influence our interpretation of the geophysical data from the Shikoku basin. Karig and Moore mapped NE-SW trending structural ridges and troughs beneath partly sedimented areas of the Iwo-Jima ridge. These features are interpreted as en echelon shear fractures formed due to collision between the Iwo-Jima ridge and Japan in the Early-Middle Miocene in response to the overall convergence between the Asian and Philippine Sea plates. A continuing state of N-S compression presently exists in the Izu peninsula and the northern Iwo-Jima ridge as inferred from micro-earthquake studies of Huzita *et al.* Further, geological evidence such as the folding of Early Miocene sediments and later thrusting in the South Fossa Magna area described by Matsuda, and the geomorphological evidence presented by Hoshino for the post-Lower Miocene formation of the Suruga Bay supports the proposal of this collision and continuing state of compression in the northern Iwo-Jima ridge.

With such geological evidence in mind, the observed pattern of magnetic lineations and the different basement morphologic fabrics in the east and west parts of this basin can be best explained if a two-limb system generated the Shikoku basin beginning with an interval of rapid separation (4.2 cm yr^{-1}) from 26 to 22.5 m.y.b.p. Significant deformation of the eastern part of the basin subsequently occurred due to the collision and continuing state of compression existing between the Japanese islands and the Iwo-Jima ridge. Significant "intra-plate" deformation has occurred in the basin contrary to what is observed (or assumed) for ridge flanks in the major ocean basins of the world.

From the correlatability, width and amplitude relations of observed magnetic anomalies, we conclude that the width of the accretion zone in the basin was less than several km, very similar to that inferred for mid-ocean ridges. In other words, the accretionary process which formed the crust of the Shikoku basin appears similar to that operating at mid-ocean ridges of the world.

ARC REVERSALS, AND A TECTONIC MODEL FOR THE NORTH FIJI BASIN

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The North Fiji Basin (or "Plateau") is a morphologically complex marginal basin lying between the New Hebrides arc and Fiji. According to the normally accepted view of basin-island arc polarity, it is a reversed marginal basin. The North Fiji Basin is a part of the Pacific plate which overrides the India plate along the New Hebrides arc. Conversely, the adjacent South Fiji Basin (Packham, this volume) is part of the India (Australia) plate which overrides the Pacific plate along the Tonga-Kermadec arc.

The regional seismicity presented by Chase (1971) reflects this tectonic situation. Epicentres occur beneath both trench-arc systems, and show a west dipping slab beneath the Tonga-Kermadec arc, and an east dipping slab beneath the New Hebrides arc. Other distinct lineations of epicentres occur along the Fiji Fracture Zone (north of Fiji) and the Hunter Fracture Zone (southwest of Fiji). Left lateral first motions have been computed for the Fiji Fracture Zone indicating transform motion between the Pacific and India plates. No earthquake epicentres occur anywhere along the Vityaz Trench – the region of ridge and trough topography along the northern margin of the North Fiji Basin. A few earthquakes occur mid basin. It is suggested that the Vityaz Trench is an old trench-arc system long since active.

Previous tectonic reconstructions of the basin have been instructive, but not definitive. Packham and Falvey (1971) and Karig (1971) recognized the region as a marginal basin in which some kind of seafloor spreading had occurred behind an island arc (Watts and Weissel, this volume). Packham (1973) proposed clockwise rotation of the New Hebrides arc about the northern end of the chain commencing just before the Upper Miocene. Chase (1971) correlated seafloor spreading magnetic anomalies trending north and NNE such as to suggest a number of triple junctions and subplates in a complicated, but stable pattern. His reconstructed outer Melanesian arc was dated as Upper Eocene to Middle Miocene. Luyendyk *et al* (1974) suggested that magnetic anomalies in the western part of the basin trended north but did not attempt a kinematic solution. Colley and Warden (1974) presented petrological evidence from the New Hebrides arc which suggested normal subduction of the Pacific plate pre-Upper Miocene. This would be achieved by reconstruction of the Outer Melanesian arc and subduction along the Vityaz Trench as suggested by previous authors.

The kinematic solution of Chase (1971) seems to be unnecessarily constrained by his choice of the pole describing the Pacific-India plate convergence. Magnetic anomalies did not, in this author's opinion, give strongly convincing correlations with the reversal time scale. The complexity of triple junctions and subplates proposed by Chase is largely due to the fact that the Fiji Fracture Zone is *not* a natural transform of the Le Pichon (1968) Pacific -India pole. I also believe that the density of magnetic data in the basin (that was available to both Chase and this author) is insufficient to provide a conclusive kinematic solution or even unambiguous magnetic trends. I have thus attempted a simpler solution which must be prefaced by an acknowledgement of a great degree of uncertainty.

The probable transform nature of the Fiji Fracture Zone is suggested by the earthquake first motions. A synthetic transform which best fits the epicentres and morphology of this feature has been computed from a proposed Pacific-India pole at 60°S, 157°W. An identical pole position with an angular rate of 1.35 degrees/m.y. may be calculated for the India-Pacific rotation using 0-10 m.yrs. b.p. stage poles: Weissel & Hayes (1972) for India-Antarctica 12°S, 145°W, 0.675°/m.y.; Christoffel (1971) for Pacific-Antarctica 82°S, 120°E, 1.04°/m.yrs. Thus one may infer a velocity vector for the India-Pacific convergence about Fiji of about 11 cm. $yr.^{-1}$ on bearing 075°. It is also interesting to note that this Pacific-India pole (60°S, 157°W, 1.35 degrees /m.y.) results in largely transform motion on the Alpine Fault, in contradiction to Christoffel's inference (this volume). While the Fiji Fracture Zone may be an extensional ("leaky") transform in the case where the Pacific-India pole was located nearer to Falconer's (1974) position (56°S, 176°E), his assumptions in obtaining this pole position are not necessarily preferable to those presented here. Thus, pure Pacific-India transform motion will be assumed for the Fiji Fracture Zone, and the kinematic consequences examined.

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