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TECTONIC COMPLEXITIES IN THE SOUTH FIJI MARGINAL BASIN *

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Two magnetic lineation patterns occur in the South Fiji marginal basin. North–south lineation, which are parallel to the Lau-Colville ridge, are identified as anomalies 8 through 12 (29–35 m.y. B.P.). The inferred age of the basin increases eastward to the ridge. These identifications are consistent with DSDP drilling results and suggest that at least part of the basin formed in the Oligocene. These results, together with our previous study of magnetic lineations in the Shikoku basin south of Japan, also imply that the mechanism of crustal accretion in marginal basins is similar to that at mid-ocean ridges. Unidentified east–west-trending lineations west of the north–south pattern suggest a complicated tectonic history for the South Fiji basin. It seems that the evolution of the basin involved more than just one simple two-limb spreading system.

1. Introduction

Marginal basins comprise the small, semi-enclosed seas underlain by oceanic crust that occur behind most island arc–trench systems of the world. There are two currently accepted hypotheses for the origin of these basins.

(a) Marginal basins form by rifting of island arcs and the subsequent generation of new oceanic material between the rifted fragments [1, 2]. In this case the basin postdates the oldest island arc rocks.

(b) Marginal basins are areas of oceanic crust which are trapped when an island arc–trench system develops in situ [3,4]. In this case the basin predates the associated island arc.

Magnetic lineations that reflect the reversal history of the geomagnetic field are of fundamental importance for determining the age and manner of accretion of oceanic lithosphere. In some marginal basins of the western Pacific magnetic lineations have been mapped [4–7] but until recently correlation with the geomagnetic time scale has proved difficult. Nevertheless, magnetic fabrics can be used to discriminate between the above two hypotheses for the origin of these basins.

We recently identified magnetic anomalies 7 through 5E (27–19 m.y. B.P.) in the western part of the Shikoku basin, south of Japan [5]. These lineations, which trend almost parallel to the Palau-Kyushu ridge, suggest that the basin formed by separation of the Iwo-Jima ridge and the Palau-Kyushu ridge in the Late Oligocene/Early Miocene according to mechanism (a). Cooper et al. [4] mapped a north–south lineation pattern which they identified as anomalies M1–M13 (117–132 m.y. B.P.) in the Bering Sea basin oblique to the Aleutian arc. They proposed that part of the Mesozoic Pacific ocean crust was trapped after the Aleutian arc–trench system was initiated according to mechanism (b). A similar style of evolution has been proposed for the West Philippine basin, west of the Palau-Kyushu ridge (3).

The South Fiji basin is a marginal basin underlain by oceanic crust [8] to the north of New Zealand. It is separated from the Tonga-Kermadec island arc–trench system by the presently active Lau-Havre marginal basin and the Lau-Colville ridge, a remnant island arc [9]. On their global magnetic lineation chart, Pitman et al. [10] show a tentative pattern of

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magnetic lineations in the South Fiji basin almost parallel to the Lau-Colville ridge. Using an independent data set, Foreman [11] recognized part of the same lineation pattern although he did not attempt to identify the anomalies. We have re-examined all available data and are now able to correlate these lineations with the geomagnetic reversal time scale. The purpose of this paper is to present our anomaly identifications and to use this information to help understand the tectonic history of this marginal basin.

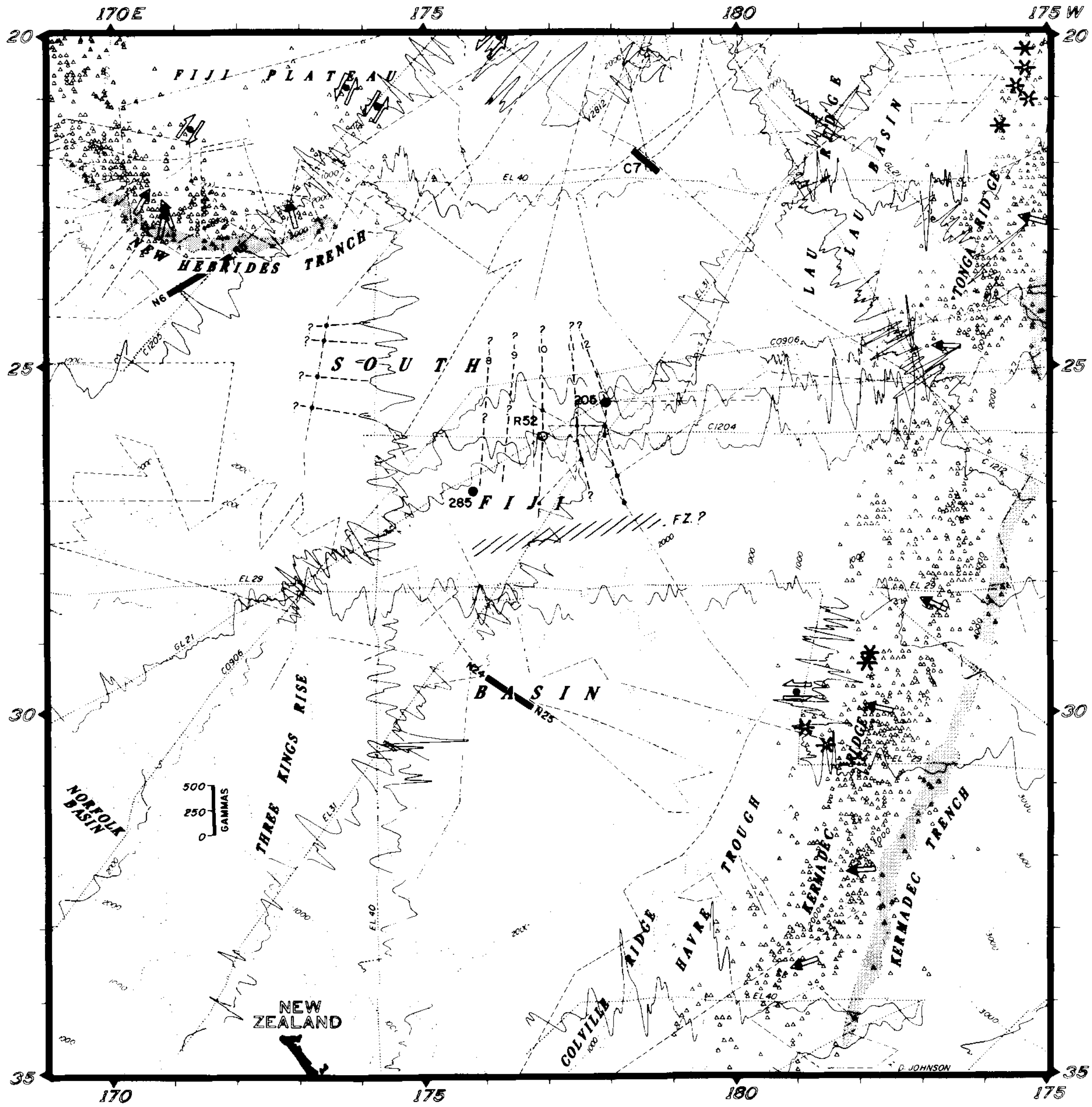

Fig. 1. Marine magnetic anomalies along ship tracks in the South Fiji marginal basin. Dotted lines are ship tracks of Lamont-Doherty Geological Observatory and the Deep-Sea Drilling Project and dashed lines are tracks from other sources. Bathymetry [20] is shown at 100-fm contour intervals. Historically active volcanoes are indicated by asterisks and earthquake epicenters with focal depths less than 100 km by open triangles. Hollow arrows indicate focal mechanism solutions of selected shallow earthquakes [21]. Solid circles indicate DSDP sites [15,17], solid bars indicate seismic refraction profiles [8], and the open circle is sonobuoy refraction station R52.

2. Magnetic anomaly data

In Fig. 1 we present magnetics data from the Lamont-Doherty Geological Observatory and the Deep Sea Drilling Project (Leg 21) as magnetic anomalies plotted along ship tracks. Also shown are tracks from University of Hawaii [11], Scripps Institution of Oceanography [12], and the New Zealand Department of Scientific and Industrial Research [13]. These combined data sets now better define the previously mapped magnetic lineation pattern in the east-central part of the basin. This area is reproduced at a larger scale in Fig. 2 which shows that individual anomalies (such as anomaly 10) can be confidently correlated for distances of up to 200 km. Although the anomalies generally trend north–south, small variations from this trend are detected where track density is greatest. There is some evidence that the lineation pattern fans to the south. The fracture zone tentatively identified in Figs. 1 and 2 approximately defines the southern termination of the lineation pattern. South of where the inferred fracture zone crosses the EL31 track acoustic basement becomes abruptly shallower by 750 m and rougher in character (Fig. 3). In Fig. 2, large-amplitude short-wavelength anomalies occur to the east of the north–south lineation pattern on track KK. These anomalies are inconsistent with a north–south direction of lineation and therefore have a different origin to the anomalies comprising the lineation pattern. Rough basement morphology might contribute

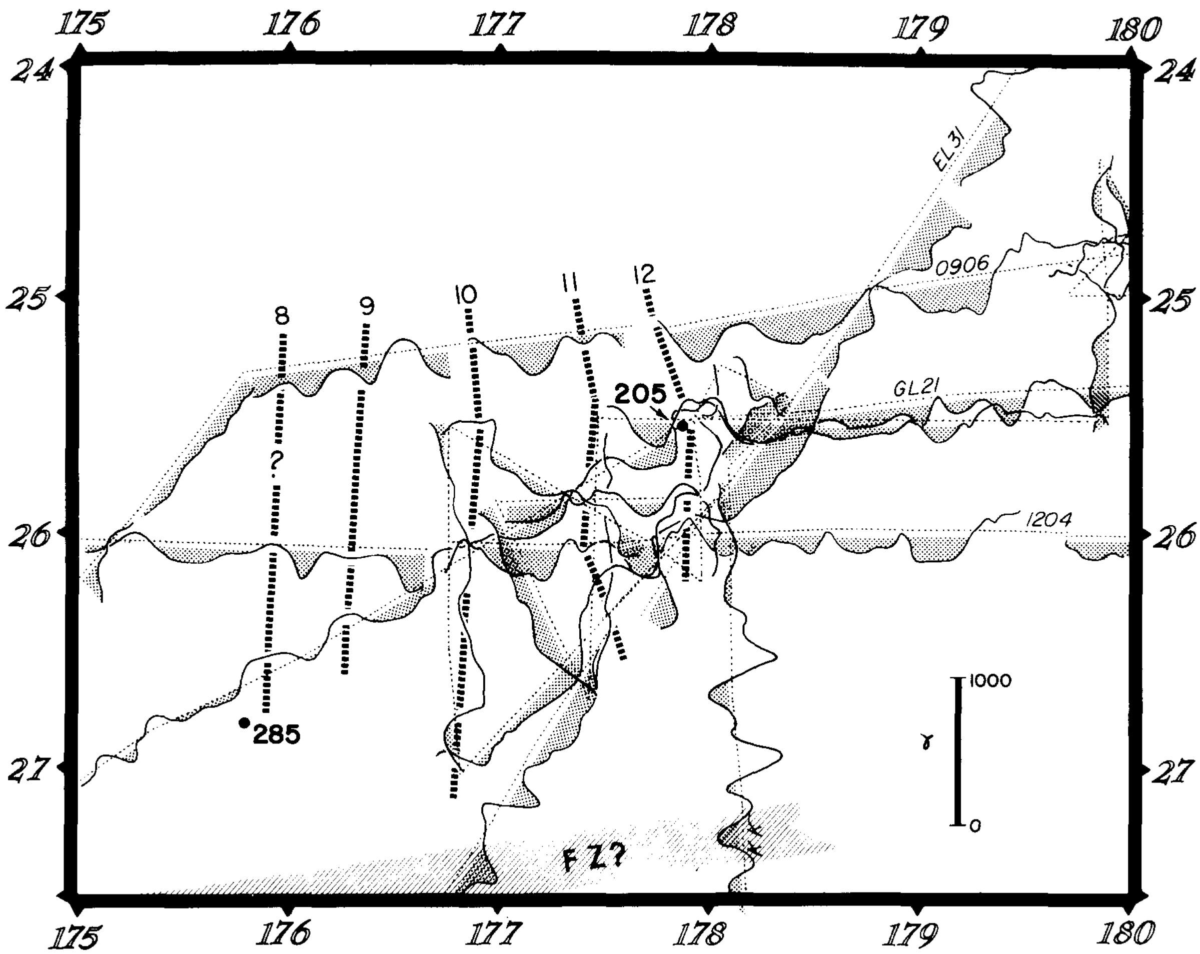

Fig. 2. Detailed map of the north–south magnetic lineations in the east-central part of the South Fiji basin. Magnetic anomaly "lows" are shaded.

to the anomalies observed on track KK but we have not had the opportunity to examine seismic reflection data from this segment of the track which was run by the University of Hawaii. However, Hussong [14], using wide-angle seismic reflection/refraction information, described the crustal structure as very irregular.

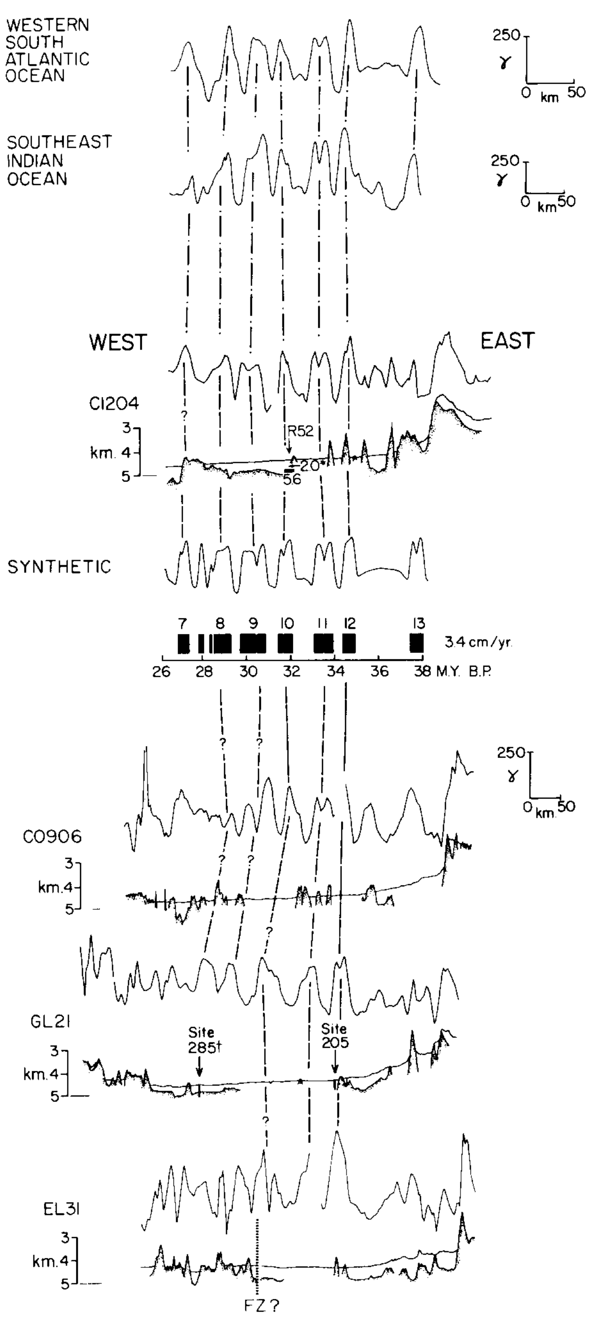

Fig. 3. Comparison of projected magnetic anomaly profiles with a computed profile and profiles from major ocean basins. The South Fiji basin magnetics and line drawings of seismic reflection profiles have been projected normal to the lineation direction. The computed profile assumes a depth to upper surface of the block model of 4.9 km, a layer thickness of 0.5 km and a uniform magnetization contrast of 0.005 emu/cm^3. The profiles from other ocean basins have been phase-shifted by 10° and plotted at horizontal and vertical scales to match observed anomalies in the South Fiji basin. The dagger adjacent to 285 indicates that the position of this site has been projected on to the GL21 profile, whereas it really lies about 25 km south of this track (Fig. 2).

We suggest that anomalies 8 through 12 (29–35 m.y. B.P.) constitute the north–south magnetic lineation pattern indicating that at least this portion of the basin formed during the Oliogocene. The inferred age of crust in the east-central part of the basin is within the Early to Middle Tertiary range suggested by Karig [9] from geological evidence. DSDP site 205 (Figs. 1 and 2) is located on a magnetic lineation that we identify as anomaly 12 (35 m.y. B.P., Early/Middle Oligocene). The oldest sediment encountered at this site is of late Middle Oligocene age [15] which agrees well with our predicted basement age. These sediments, which are predominantly limestone, overlie extrusive basalt in which drilling terminated. It is not known with certainty if these basalts represent the top of oceanic layer 2 [16] although the close agreement between the drilling results and our inferred basement age is persuasive affirmative evidence. At DSDP site 285 (Figs. 1 and 2) the oldest sediment encountered is of early Middle Miocene age [17]. Drilling terminated in intrusive diabase which is probably not the top of oceanic layer 2. Although the drilling results at site 285 are inconclusive they are not inconsistent with our anomaly identifications.

To further test the validity of our anomaly identifications we compared observed data with computed anomaly profiles and with profiles from well-known areas of the major ocean basins (Fig. 3). The synthetic profile was computed by standard Fourier techniques [18] and a constant half-spreading rate of 3.4 cm/yr obtained from the lineation pattern was used.

A quantitative measure of magnetic anomaly shape or skewness, θ, depends on the azimuth of the magnetic lineations and the present and paleo-geomagnetic field parameters [18]. θ values of 0° and 180° correspond to symmetric anomaly shapes; values of 90° and 270° to purely antisymmetric shapes. Our best fitting synthetic profile has $\theta = 350°$ and this agrees well with $\theta = 341°$ obtained using an Oligocene paleomagnetic pole for Australia [19]. This similarity between θ values is consistent with the South Fiji basin being part of the Indian plate since its formation. The synthetic profile is in reasonably good agreement with the observed data (Fig. 3). However, differences between observed and computed profiles occur in the shapes of anomalies 8–10 and for the portions of profiles C1204 and C0906 east of anomaly 12 where basement morphology is rough. Profile C1204 agrees more closely with the two profiles over oceanic crust formed by sea-floor spreading processes than with the computed profile.

We believe that the striking similarity between observed magnetic anomalies from widely separated and different tectonic provinces of the world's ocean basins supports our anomaly identifications and suggests that the mechanism of crustal accretion in marginal basins is similar to that which occurs at mid-ocean ridges.

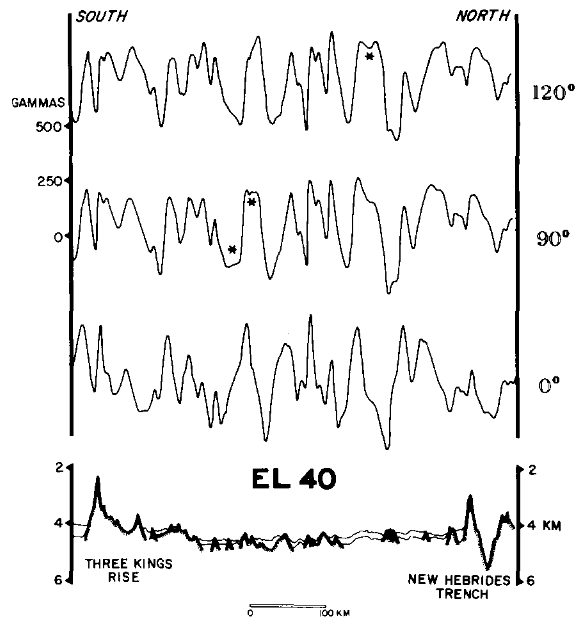

Fig. 4. EL40 magnetic anomaly profile (Fig. 1) phase-shifted by 120°, 90°, and 0° (top three profiles). Although most anomaly shapes passed through symmetry after 90° to 120° of phase-shifting, asterisks denote the prominent magnetic anomalies which have been brought to symmetry. The bottom profile is a line drawing of the corresponding EL40 seismic reflection profile.

3. Discussion

Although anomalies 8 and 9 are only well identified on profile C1204 (Fig. 3), our interpretation implies that crustal age increases *eastward* across the east-central part of the basin to the base of the Lau-Colville ridge. In contrast, the well-identified anomalies in the western part of the Shikoku basin increase in age *westward* to the base of the Palau-Kyushu ridge [5]. For both marginal basins, if crustal accretion occurred at a simple two-limb spreading system, the apparent absence of a repeated lineation pattern about an extinct axis is difficult to explain. In the Shikoku basin, however, by considering the nature of the magnetic and basement morphologic fabrics and contemporaneous regional tectonic events in nearby Japan, we explained this apparent absence by extensive subsequent deformation of the eastern part of the basin due to major modification of adjacent plate boundaries. A similar explanation cannot be made at present for the lineation pattern in the South Fiji basin.

An interesting feature is the presence, along the north–south EL40 track (Fig. 1), of large-amplitude, short-wavelength magnetic anomalies that are inconsistent with the north–south lineation pattern mapped to the east. Crustal depths are similar in both areas (Figs. 3 and 4) and similar crustal ages would therefore normally be inferred. Although we cannot identify the anomalies along the EL40 track, we believe they represent part of an east–west-trending lineation pattern for two reasons. First, to produce symmetric anomaly shapes, we phase-shifted the EL40 profile by 90° to 120° (Fig. 4). In contrast, a change in θ of about 10° restores anomalies in the north–south pattern to symmetry. The difference of approximately 90° in θ values for anomalies in the two areas combined with the similar inferred crustal ages and the known track azimuths, indicates that the anomalies along the EL40 track are part of a lineation pattern which trends at about 90° to the north–south pattern in the east-central part of the basin. Second, an adjacent track from Hochstein and Reilly [13] shows anomalies similar to those along the EL40 track allowing tentative east–west correlation between tracks (Fig. 1). Thus the evolution of the South Fiji basin seems to have involved more than just one simple two-limb spreading system.

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