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EVIDENCE FOR LATE PALEOCENE TO LATE EOCENE SEAFLOOR IN THE SOUTHERN NEW HEBRIDES BASIN *

J.K. WEISSEL [1], A.B. WATTS [1,2] and A. LAPOUILLE [3]

[1] *Lamont-Doherty Geological Observatory of Columbia University, Palisades, N.Y. 10964 (U.S.A.)*
[2] *Also at Department of Geological Sciences, Columbia University, New York, N.Y. 10027 (U.S.A.)*
[3] *Office de la Recherche Scientifique et Technique Outre-Mer, B.P.A5, Noumea Cedex (New Caledonia)*

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ABSTRACT

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We interpret marine magnetic anomaly data from the southern part of the New Hebrides basin as showing that a fragment of Late Paleocene–Late Eocene oceanic crust is preserved between the New Caledonia–Loyalty Islands platform and the New Hebrides island arc–trench system. The magnetic lineations which trend about NE–SW, are interpreted as anomalies 18 through 23 (42–55 m.y. B.P.) with the inferred crustal ages increasing to the north. Drilling at DSDP site 286, which is located on oceanic crust slightly older than 55 m.y. according to our magnetic anomaly identifications, revealed mid-Eocene sediments overlying igneous basement.

INTRODUCTION

In this note we consider the age of the southern part of the New Hebrides basin, a roughly triangular piece of seafloor bounded on the north by the Entrecasteaux ridge, on the east by the presently active New Hebrides island arc–trench system, and on the west by the platform containing the Loyalty Islands ridge and New Caledonia (Figs. 1 and 2). Knowledge of the age of this basin is important because it is probably a last remnant of a much larger basin generated in the Early Tertiary most of which has been subducted beneath the New Hebrides island arc during the past 5–10 m.y. Our basic approach is to examine available marine magnetic anomaly information from the basin (Fig. 2) in an attempt to correlate the observed lineated

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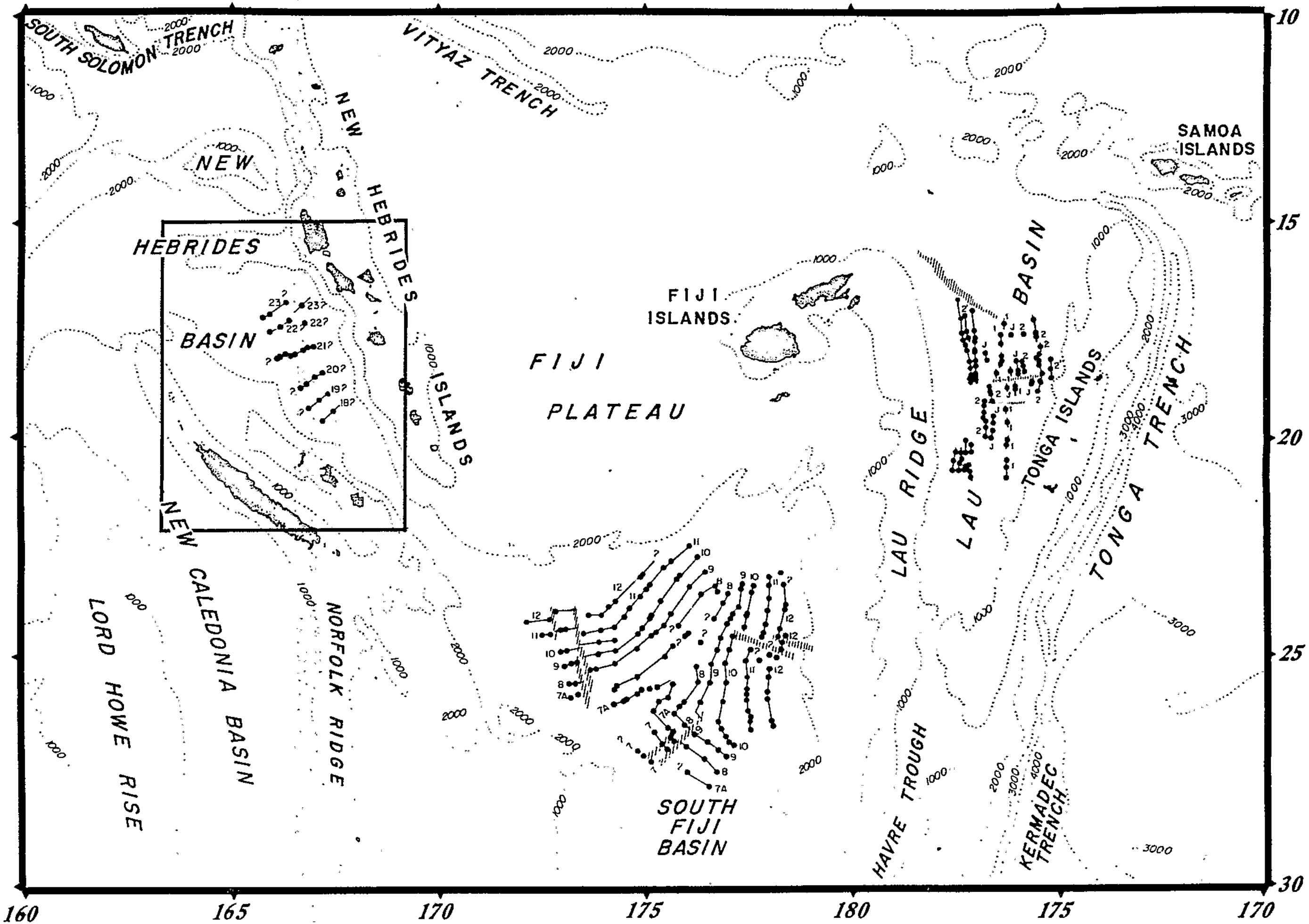

Fig. 1. Tectonic setting showing marginal basins of the southwestern Pacific Ocean (from Weissel, 1981). Study area is denoted by the box. Bathymetry is in

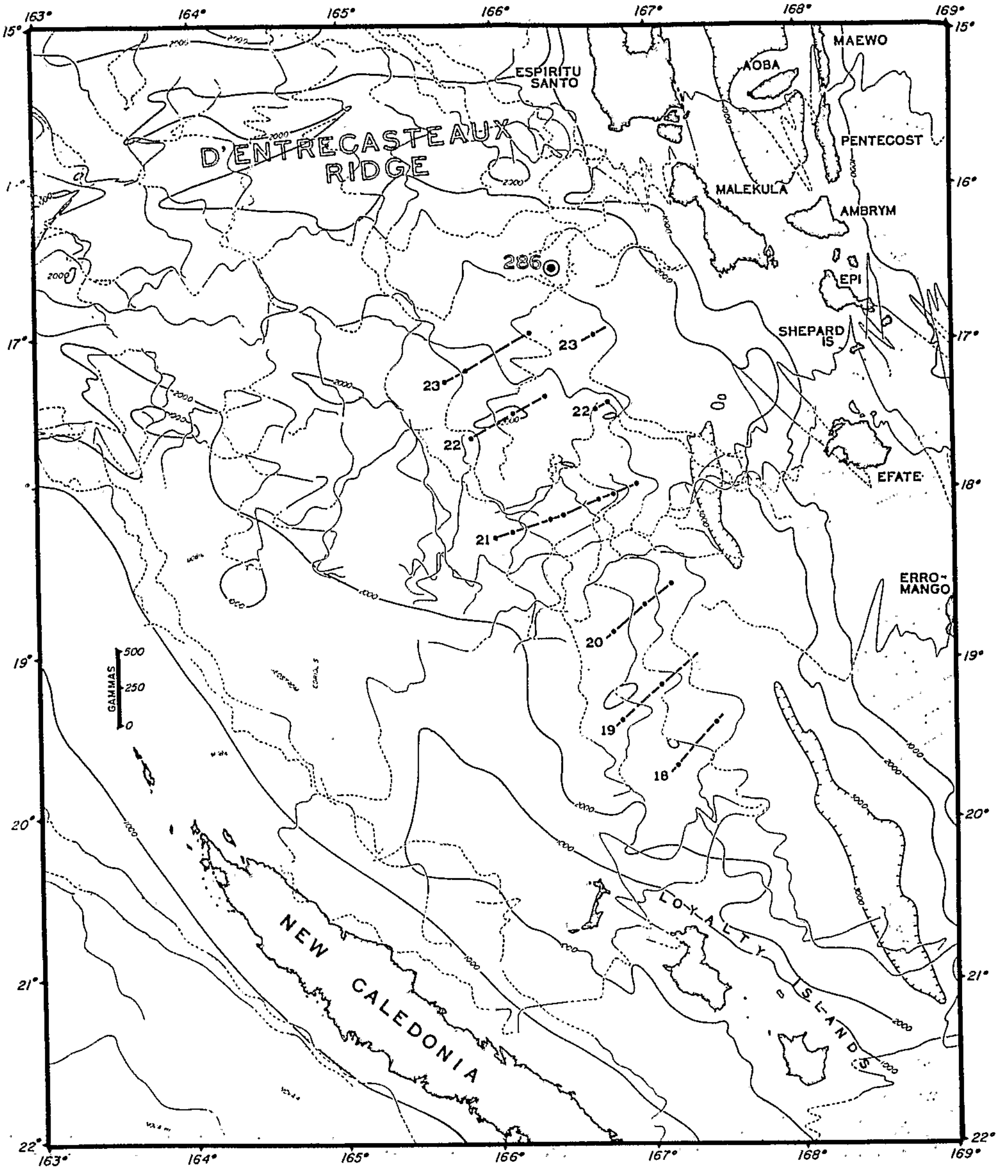

Fig. 2. Magnetic anomalies plotted along ships' tracks (dotted lines). Positive anomalies are solid lines, negative anomalies are broken lines. Magnetic lineations are denoted by the heavy broken lines and the numbers correspond to the geomagnetic reversal time scale of LaBrecque et al. (1977). Enclosed circle is DSDP site 286. Bathymetry is in fathoms.

magnetic anomalies with the geomagnetic reversal time scale (e.g. LaBrecque et al., 1977). We are aided in the southern New Hebrides basin by DSDP site 286 (Fig. 2) which penetrated igneous basement below vitric sandstones and siltstones of mid-

Eocene age (Andrews et al., 1975). The drilling results thus provide a *minimum* age for the oceanic crust at that site.

MAGNETIC ANOMALY DATA

In Fig. 2 we show marine magnetic anomalies plotted along ships' tracks. Most of these data were obtained by Lamont–Doherty Geological Observatory and Centre ORSTOM de Noumea, New Caledonia, and supplementary information was supplied by the National Geophysical and Solar-Terrestrial Data Center in Boulder, Colorado. The magnetics data in the southern New Hebrides basin clearly define a set of lineations whose general NE–SW trends appear to vary smoothly with latitude in the basin (Fig. 2). We suspect from the rugged appearance of acoustic basement in seismic reflection records that small fracture zone offsets influence the observed lineation trends. However, we have not shown any fracture zones in Fig. 2 because these cannot be accurately mapped by the present distribution of ship tracks. We tentatively correlate the lineated magnetic anomaly sequence in this basin with anomalies 18–23 which formed approximately 42–55 m.y. ago (LaBrecque et al., 1977). The major reason for this interpretation (in addition to DSDP evidence) is that anomalies 19, 20 and 21 are a distinctive anomaly sequence whose shape is easily recognized in the world's major oceans.

The anomaly identifications are illustrated in Fig. 3 where we compare observed magnetic anomaly profiles from the southern New Hebrides basin with a theoretical magnetic anomaly profile based on the geomagnetic reversal time scale. In order to match the spacings of the observed anomalies interpreted as anomalies 18–23, a change in half-spreading rate from about 1.7 cm/yr prior to 47 m.y. B.P. (about anomaly 20-time) to about 3.4 cm/yr after 47 m.y. B.P. is required in the magnetic model. The anomaly identifications shown in Figs. 2 and 3 imply that DSDP site 286 was drilled on crust formed during the latest Paleocene or earliest Eocene, about 5–10 m.y. before deposition of the mid-Eocene sediments which overlie basement (Andrews et al., 1975). Overall, we believe that although magnetic lineations trending generally NE–SW are clearly present in the southern New Hebrides basin, their correlation with anomalies 18–23 of the geomagnetic reversal time scale should be regarded as tentative.

DISCUSSION

Because we regard the magnetic anomaly identifications discussed above as uncertain, we considered other geological and geophysical data (in addition to DSDP evidence) which might help constrain the age of the southern New Hebrides basin.

Oceanic basement depths are generally useful indicators of crustal ages in the major ocean basins (Sclater et al., 1971; Parsons and Sclater, 1977), but are less useful for predicting ages for the abnormally deep marginal basins on the Philippine plate (Sclater et al., 1976). However, normal to less than normal seismic crustal thicknesses are observed over the Philippine plate which might explain the anomalously deep crustal depths (Sclater et al., 1976). In contrast, limited seismic refraction measurements suggest that slightly thicker than normal oceanic crust underlies the southern New Hebrides basin (Ibrahim et al., 1980). We examined available seismic reflection data to obtain average depths to oceanic crust in the basin, taking into account the effects of sediment loading. In arriving at an average crustal depth of 4750 ± 250 m we observed several disturbing factors. In some parts of the basin, acoustic basement on single-channel seismic reflection records often appears too smooth to represent the surface of oceanic crust (which may therefore lie at greater depths). In other parts of the basin, we observed apparent tensional fractures in the oceanic crust (see Fig. 3 and Andrews et al., 1975). The depth of oceanic crust associated with the observed lineations (Fig. 2) might be slightly shallower than expected because most of this crust is negotiating the bulge seaward of the New Hebrides Trench (see Dubois et al., 1974). Although we believe that these three factors make us question the validity of using basement depths to predict crustal ages for the southern New Hebrides basin, we note that in the major ocean basins depths of 4750 ± 250 m are generally associated with crustal ages ranging from Late Oligocene to Early Paleocene (Parsons and Sclater, 1977), which includes the ages inferred from magnetic anomaly data in the southern New Hebrides basin (Fig. 3).

Heat flow is another geophysical parameter which is a potentially useful indicator of crustal age (e.g. Anderson and Hobart, 1976; Parsons and Sclater, 1977). For the 42–55 m.y. age range inferred for the crust of the southern New Hebrides basin from our magnetic anomaly identifications (Figs. 2 and 3), the cooling half-space model for oceanic lithosphere predicts heat flow between 64 and 73 mW m^{-2} (Parsons and Sclater, 1977). MacDonald et al. (1973) found that heat flow in the southern New Hebrides basin was unexpectedly high and would suggest crustal formation as recently as Early Pliocene. In a more recent survey of heat flow in the southwestern Pacific, M. Langseth and H.-C. Shen (unpublished map, 1980) evaluated the reliability of individual measurements and found that only four measurements in the basin could be considered "high quality". Of these, two (159 and 116 mW m^{-2}) are much higher than expected and two (73 and 50 mW m^{-2}) are closer to the expected range of heat flow. Thus, the primary results of MacDonald et al. (1973) that heat flow is abnormally high in the basin might still hold even with only four reliable values.

From a study of transmission qualities of S waves from shallow and intermediate depth earthquakes in the New Hebrides to Charters Towers, Australia, Molnar and Oliver (1969) suggested that a zone of high attenuation was present in the upper mantle west of the New Hebrides island arc. However, Barazangi et al. (1974) showed that S-wave propagation from shallow New Hebrides events to Noumea, New Caledonia was efficient. They suggested that the earlier results of Molnar and

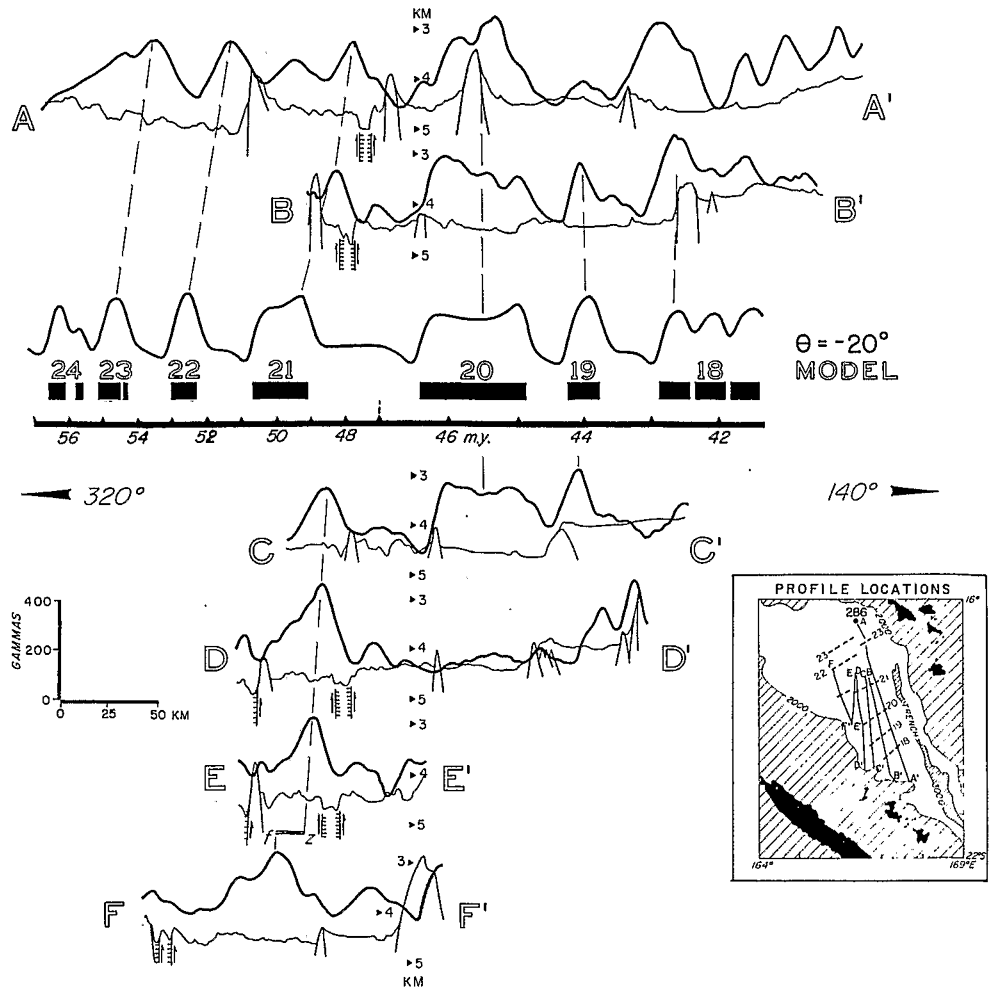

Fig. 3. Observed magnetic anomaly profiles (heavy curves) from the southern part of the New Hebrides basin compared to a magnetic profile based on the geomagnetic reversal time scale (LaBrecque et al., 1977). The profiles, which are located in the inset, have been projected along azimuth 320°–140°. In the model calculation, depth to the magnetic source layer is 4700 m, its thickness is 500 m, and strength of magnetization is 0.005 emu. Bathymetric profiles are shown with their corresponding magnetic anomaly profiles. Seamounts and prominent basement pinnacles observed in reflection records are shaded. Graben and half-graben structures are shown by vertical ticked lines. Note that a graben is consistently observed parallel to lineation trends in crust slightly younger than anomaly 21-time.

Oliver (1969) could perhaps be due to a zone of attenuation in the mantle between the coast of Australia and the New Hebrides island arc, located at least 400 km west of the New Hebrides Trench. In a more recent study of S-wave transmission, Goula (1978) suggested that two local zones of high attenuation exist in the upper mantle beneath the New Hebrides basin. One zone is located west of the trench between about 14^0 and 16°S in the vicinity of the Entrecasteaux ridge. The other zone is associated with the Loyalty Islands ridge where volcanism has occurred in Late Miocene time (see below). Zones of high attenuation in the upper mantle on the 'convex' side of the island arcs are rare; such zones are normally associated with active or recently active areas of back-arc extension on the "concave" side of arcs. In such back-arc areas, high heat flow would normally be expected. However, it is surprising to see both abnormally high heat flow values (MacDonald et al., 1973) and zones of high attenuation in the upper mantle (Goula, 1978) in the New Hebrides basin on the convex side of the New Hebrides arc where other geophysical and DSDP evidence would suggest that seafloor spreading has been inactive for more than 40 m.y.

The Late Paleocene to Late Eocene crustal ages for the southern New Hebrides basin inferred from the magnetic anomaly identifications and DSDP results (Figs. 2 and 3) bear an interesting relation to the timing of a major tectonic event on adjacent New Caledonia and to the Oligocene oceanic crust of the South Fiji basin to the southeast (Fig. 1). Figure 2 shows that the magnetic lineations in the southern New Hebrides basin trend at high angles to the general trend of the New Caledonia–Loyalty Islands platform. This relationship suggests that the original tectonic contact between these features was characterized by strike slip or compression (or a combination). Also, it should be noted that the inferred age of the seafloor in the southern New Hebrides basin is slightly older than the Late Eocene–Early Oligocene age generally given for the east to west overthrusting of the ultramafic sheet on to New Caledonia (e.g. Brothers and Blake, 1973; Paris and Lille, 1977). On the other hand, basaltic volcanism on the Loyalty Islands is known to post-date the sea floor of the southern New Hebrides basin. For example, Dubois (1971) cites a 29 ± 4 m.y. age for lava flows on Mare Island in the Loyalty chain and Baubron et al. (1976) obtained ages of 9–11 m.y. from the same island. Thus the tectonic relationship between the southern New Hebrides basin and the New Caledonia–Loyalty Islands platform is still poorly known.

Figure 2 shows that inferred crustal ages in the southern New Hebrides basin get younger towards the south and it is possible that magnetic lineations in this basin once formed a continuous sequence with the Oligocene lineations in the South Fiji basin (Fig. 1, Weissel and Watts, 1975; Watts et al., 1977; Davey, 1982). Unfortunately, oceanic crust which might substantiate this suggestion has been subducted at the New Hebrides trench over the last 5–10 m.y. However, if the crust of the two basins constituted one flank of a spreading system, the absence of anomalies 18–23 lying *east* of the South Fiji lineations is not easily explained by any simple tectonic model. Moreover, the large distance between anomaly 18 in the southern New Hebrides basin and anomaly 12 in the South Fiji basin implies that generation of the "missing" section of ridge flank between the southern New Hebrides basin and the South Fiji basin occurred at a half-rate > 6.5 cm/yr which appears unreasonably high since half-spreading rates for the bounding lineation sequences are about half this value (Fig. 3; Watts et al., 1977; Davey, 1982).

The apparent tectonic relationships between the fragment of Early Tertiary crust preserved in the southern New Hebrides basin and its margins can be summarized as follows:

(a) The trends of the magnetic lineations suggest that the Entrecasteaux Ridge is the northern half of a block rifted apart and subsequently isolated by seafloor spreading activity in the southern New Hebrides basin. The southern counterpart to the Entrecasteaux ridge cannot be recognized at present, nor can we locate an extinct spreading center or south flank counterparts of the magnetic anomaly sequence in the basin. We cannot determine whether the southern New Hebrides basin formed in a "back-arc" setting (c.f. the Lau basin or the Mariana Trough). However, at DSDP site 286 rapid accumulation of sediments containing andesitic detritus occurred during middle and late Eocene time, suggesting to Andrews et al. (1975) that island arc volcanism occurred in proximity to the basin during its early stages of formation.

(b) The Indo-Australian plate has been subducted at the New Hebrides trench for the last 5–10 m.y. resulting in the loss of a considerable part of the New Hebrides basin.

(c) The relationship between the southern New Hebrides basin and the New Caledonia–Loyalty Islands platform is still enigmatic as discussed above.

CONCLUSIONS

Generally NE–SW trending magnetic lineations are observed in the part of the New Hebrides basin bounded by the Entrecasteaux ridge, the New Hebrides island arc–trench system, and the New Caledonia–Loyalty Islands platform. We tentatively correlate these magnetic anomalies with anomalies 18 through 23 of the geomagnetic reversal scale, implying that the fragment of seafloor ranges in age from more than 55 m.y. in the north to about 42 m.y. in the south where the basin is now closed between the Loyalty Islands and the New Hebrides island arc. The inferred crustal ages are consistent with drilling resuls at DSDP site 286 which encountered mid-Eocene sediments overlying igneous basement.

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Department of Geology and Geophysics, University of Sydney, Sydney, N.S.W. 2006 (Australia)

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