# APPENDIX II. THE CRUSTAL AGE AND TECTONIC FABRIC AT THE LEG 73 SITES[1]

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## INTRODUCTION

The opening of the South Atlantic is described to an accuracy of better than ±100 km by the relative rotation poles for the African and South American tectonic plates (Ladd, 1974; Rabinowitz and LaBrecque, 1979). The poles of relative rotation for the Cenozoic and Late Cretaceous have been determined by the best fit of the magnetic anomaly lineations from both plates. Small offset fracture zones provide more reliable information on the direction of relative motion of two tectonic plates as a function of time and therefore could provide a check on the validity of these poles. However, the only fracture zones that have been mapped well enough to constrain the opening poles of the South Atlantic have been the Agulhas and the Falkland fracture zones of the southern South Atlantic; these fracture zones have been used to constrain the Mesozoic opening of the South Atlantic Basin. The Falkland and Agulhas fracture zones are large offset fracture zones that tend to average the changes in relative motion by deformation along the transform fault portion of the fracture zone.

Poles of rotation were used by Ladd (1974) to describe flow lines or theoretical fracture zones of minor offset for the South Atlantic. These flow lines define the paleodirection of seafloor spreading for segments of the African and South American plates and should describe the fracture zone pattern or tectonic fabric of the South Atlantic. In the Ladd study few data were available with which to compare the locations and directions of these flow lines with well identified fracture zones. The bathymetric expression of fracture zone offsets for the South Atlantic is minimal because of the relatively small offsets of most fracture zones and the moderate rate of seafloor spreading (2–3 cm/yr).

In preparation for Leg 73, site surveys conducted by the R/V *Moore* greatly expanded the available geophysical data set in the southern Angola Basin. These data and those of the subsequent *Glomar Challenger* legs have been combined with previously gathered data from random ship and aeromagnetic tracks to provide a relatively dense coverage. We will use these data to define the age of the oceanic crust in the region and to delineate the regional fracture zone pattern. The poles of rotation discussed above will be applied in conjunction with the available magnetic and bathymetric data to define the age of the crust and to describe the tectonic fabric of the African Plate in the region of the Leg 73 sites.

## INTERPRETATION OF THE DATA

Figure 1 displays the location of the six Leg 73 sites with respect to the bathymetry of Heezen and Tharp (1978). Five of the sites (519 through 523) are located in the southwestern Angola Basin west of the Walvis Ridge, and Site 524 is located on the eastern margin of the Walvis Ridge within the northern Cape Basin. The relief in the region is minimal, with no known seamounts within the southwestern Angola Basin. The major bathymetric feature of the region is the Walvis Ridge. The Walvis Ridge is a northeast-striking aseismic ridge that extends from a seamount chain near the Mid-Atlantic Ridge at 38°S to a continuous 3.3-km–high ridge at its intersection with the African margin at 20°S.

The sparse bathymetric data are not sufficient to define the fracture zone locations. This can be seen from the rather conceptual nature of the contours in Figure 1. The magnetic anomaly data set, on the other hand, provides a strong constraint on the spreading direction, fracture zone trends, and the age of the crust. The anomalies of the region are well developed and easily identified. In Figure 2, we display the regional magnetic anomaly correlations for the southwest Angola Basin. Seven fracture zones have been identified in this region from the offsets in the magnetic anomaly pattern. We have interpreted offsets in the magnetic anomaly lineation between tracks as evidence of fracture zone locations. These offsets define points through which the synthetic fracture zones must pass. In all cases, we have used the South Atlantic rotation poles to define the synthetic fracture zone trends. In some cases minor discrepancies are observed between the observed location of magnetic anomaly offsets and the predicted flow lines such as for the late Eocene location of the Moore Fracture Zone (F.Z.), where the predicted location of the Moore F.Z. is approximately 10 km north of an observed offset in Anomaly 19. In such areas we have followed the theoretical flow lines as defined by the stage poles to illuminate the discrepancies. Navigational errors also contribute a substantial error (it may be as large as 25–50 km). Navigational errors are minimized in areas that are well surveyed, such as the Leg 73 sites, but may be substantial in the southwestern portions of Figure 2, where the data are rather old and widely scattered. The varying magnetic lineation directions in this region are most likely due to navigational errors.

[1] Hsü, K. J., LaBrecque, J. L., et al., *Init. Repts. DSDP*, 73: Washington (U.S. Govt. Printing Office). LVTO Contribution No. 3515 and University of Texas Institute for Geophysics Contribution No. 562.

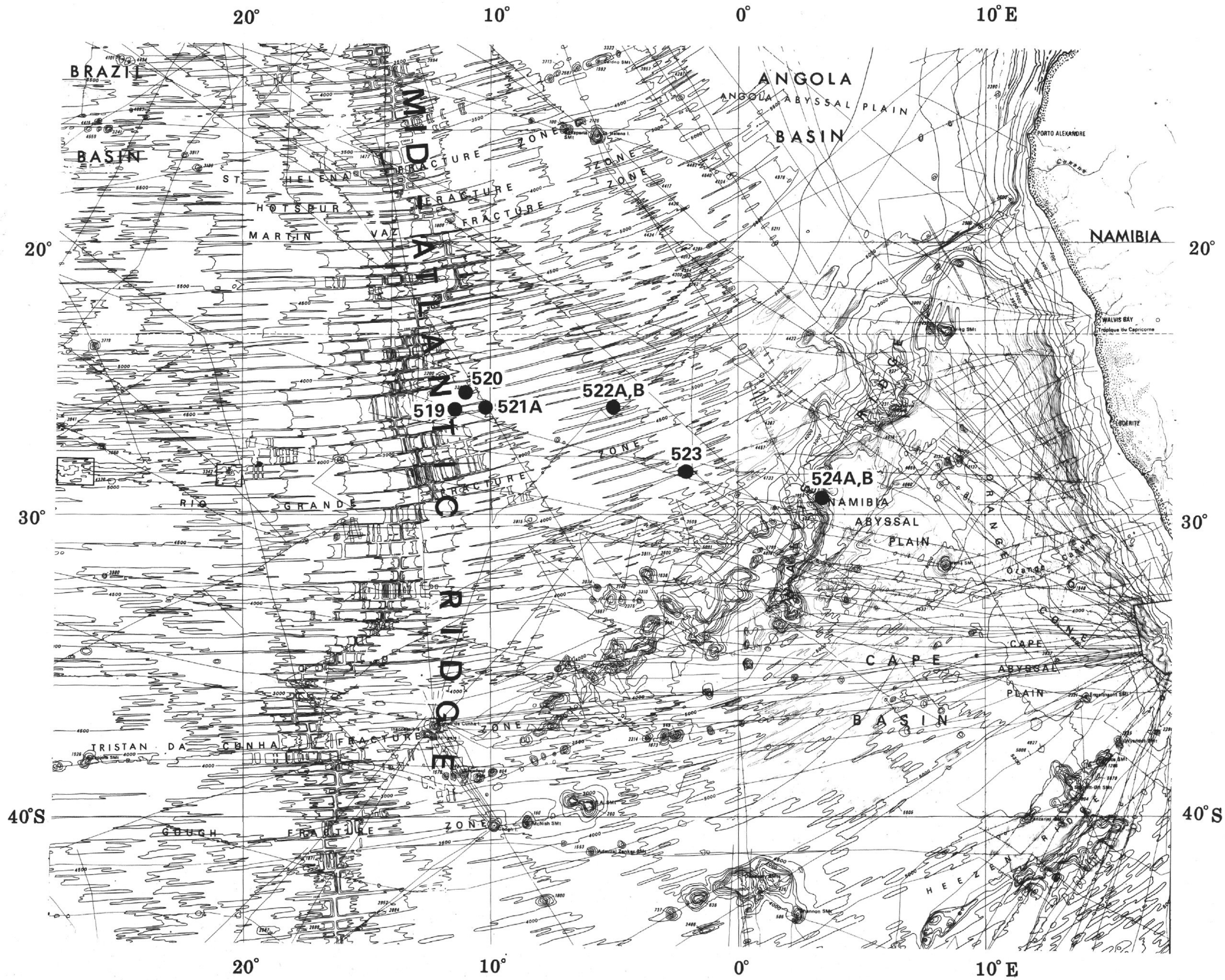


Figure 1. Bathymetry and site locations for Leg 73. Bathymetry is from Heezen and Tharp (1978).

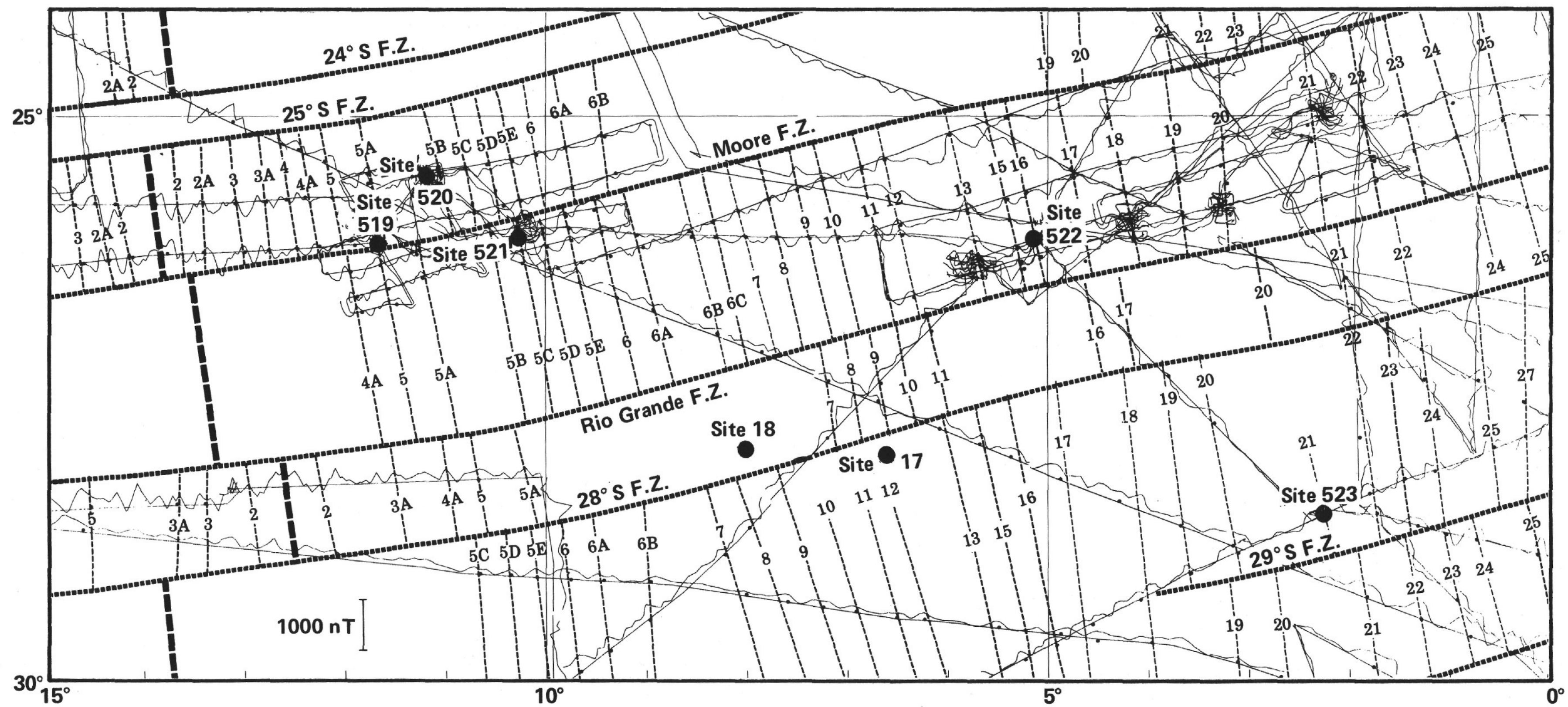


Figure 2. Magnetic anomaly correlations with respect to the available magnetic anomaly data. The fracture zone locations are determined from rotations about the poles of rotation for the South Atlantic as discussed in the text. Locations of Leg 3 and Leg 73 sites are also displayed.

The Rio Grande Fracture Zone is the most prominent fracture zone of the region and is identified in both Figures 1 and 2. The offset in the Rio Grande Fracture Zone appears to have increased from a nearly zero offset in the early Cenozoic (Chron C-24) to a 20-km left lateral offset at the present-day spreading center. During the survey by the R/V *Moore* a minor fracture zone was located approximately 1° north of the Rio Grande Fracture Zone. This fracture zone, which has been named the Moore F.Z. after the R/V *Moore*, offsets the Neogene magnetic anomaly pattern by 18 km in a left lateral sense. We have continued the Moore F.Z. toward the East using synthetic flow lines which were validated by the Rio Grande Fracture Zone. Near 5°W the offset across the Moore F.Z. is observed to be nearly 130 km (also in a left lateral sense). We are not certain as to the timing or the manner in which this offset was reduced. From Figure 2, we can bracket this reduction somewhere between Anomaly 19 and Anomaly 6B, or late Eocene to the latest Oligocene. Uncertain identifications of the anomaly sequences near 7°W and 24.5°S suggest that this reduction in offset occurred at or near Chron C-13 or the Oligocene/Eocene boundary.

The other five fracture zones in the illustration are not as well documented as the Moore and the Rio Grande fracture zones. The 29°S F.Z. appears to terminate on crust younger than late Eocene age.

The change in spreading center offsets observed on the Moore and 29°S fracture zones during Oligocene or late Eocene time broadly correlates with a change in the regional seafloor spreading direction that also occurred between the late Eocene and Oligocene. The precise timing of this change is not known, although the poles of rotation do show a large excursion during the period from C-20 to C-13. The change in seafloor spreading direction is shown in the variation of direction within the Rio Grande and Moore fracture zones, which were drawn from these poles of rotation.

Figure 3 is an enlargement of the region of the Moore F.Z., where DSDP Sites 519, 520, and 521 are located

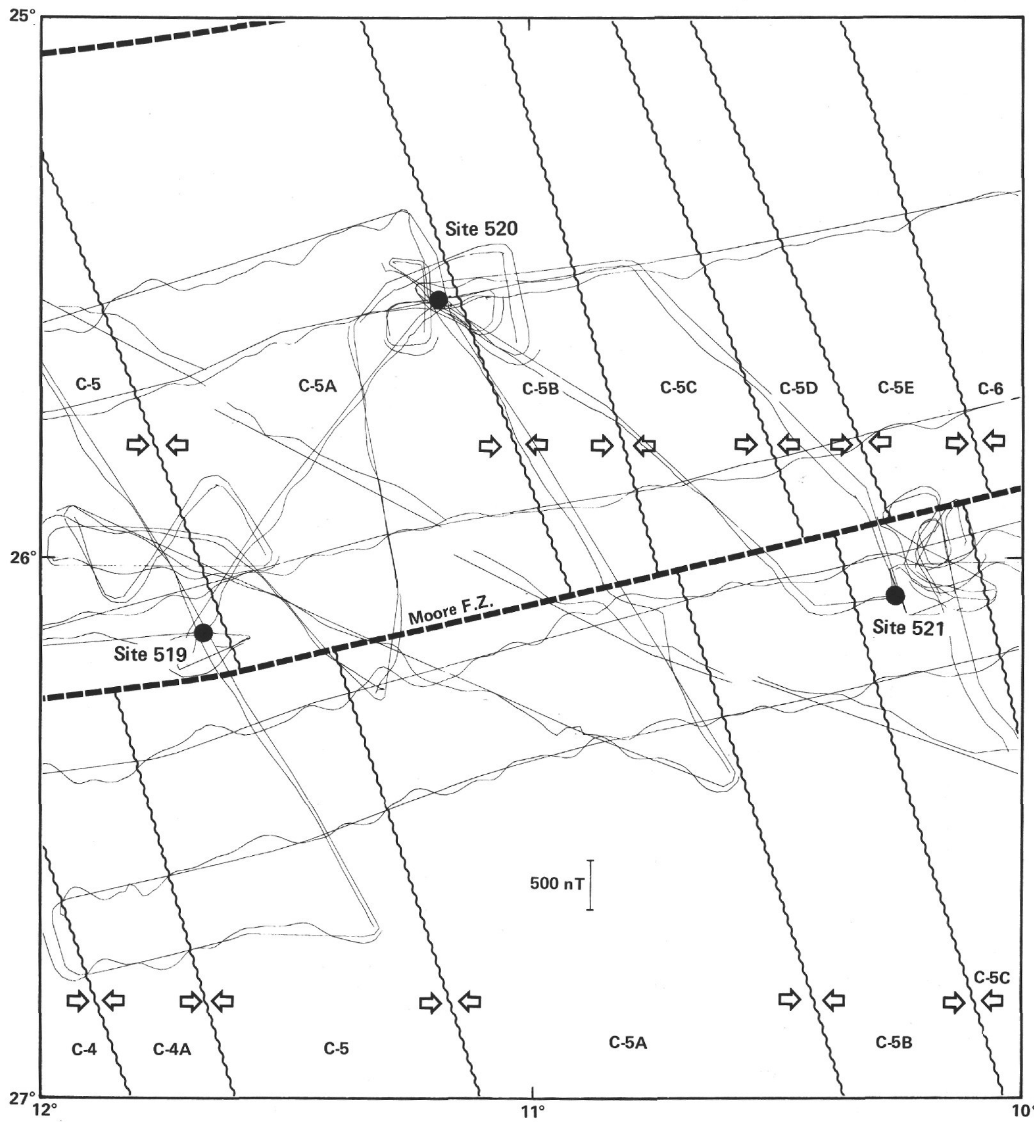


Figure 3. The age of the crust in the region of DSDP Sites 519, 520, and 521. The available magnetic anomaly data are also plotted in the figure.

on Miocene crust. Expressed in chrons, the magnetic crustal ages of Sites 519, 520, and 521 are C-5-82R, C-5A-95R, and C-5C-31N, respectively. (The reader is referred to the introduction to the volume and the site chapters for a discussion of absolute age.) The seafloor spreading half rate in this area is approximately 1.7 cm/yr. Sites 519 and 520 are located within 20 km of the Moore F.Z. Figure 4 displays a single-channel seismic section over Site 519. The Moore F.Z. is visible in Figure 4 as a small basin south of Site 519. It would be good to remember in analyzing the paleoenvironmental record at Site 519 that the spreading center to the south of the Moore F.Z. passed within 10 km south of Site 519 approximately 2.1 m.y. after the first sediments were laid down at Site 519 because the offset across the Moore F. Z. is left lateral. The passing spreading center may have affected the local environment, causing such phenomena as variations in local circulation patterns, an increase in volcanogenic sediments, or increased earthquake activity.

In Figure 5 we display the location of Site 522 with respect to the Rio Grande F.Z. and the magnetic age estimates of the crust. Site 522 is located 45 km north of the Rio Grande F.Z. on crust of age C-16-22R. The seafloor spreading rate is approximately 1.7 cm/yr in this region. Because the offset is left lateral across the Rio Grande Fracture Zone, Site 522 passed within 45 km of the spreading center south of the Rio Grande F.Z. approximately 1.5 to 2.0 m.y. after the first sediments were deposited. The effects of the left lateral transform motion south of Site 522 should have begun to diminish at this point.

Figure 6 displays the magnetic anomaly correlations in the region of the Walvis Ridge. The locations of Sites 523 and 524 are also illustrated in this figure. Site 523 is located on oceanic crust of geomagnetic age C-21-25N. The 29°S fracture zone is located approximately 40 km to the south of Site 523. Since this fracture zone is also a left lateral offset, the spreading center south of the 29°S F.Z. passed south of Site 523 a few hundred thousand years after the first sediments were laid down at Site 523.

The age of the crust at Site 524, on the other hand, is less clear. The Walvis Ridge has been interpreted as the expression of a pseudofault formed at the eastern margin of the Walvis propagator (see Hey et al., 1980). This geometry is shown in Figure 7 and is discussed in more detail by LaBrecque and Rabinowitz (in prep.). The important point to note here is that the Walvis Ridge delineates an age discontinuity in the oceanic crust. Figure 8 displays the anomaly lineation pattern of Figure 6 with respect to the regional bathymetry. Note that the anomaly lineations for Anomalies 27 to 32 intersect and can be traced onto the Walvis Ridge. To the east of the Walvis Ridge, no correlatable magnetic anomalies can be observed until the margin of the African continent, where we observe the Mesozoic sequence of anomalies (Rabinowitz, 1976). Therefore we conclude that the crust directly to the east of the Walvis Ridge was formed during the Cretaceous Normal period, or Chron C-34.

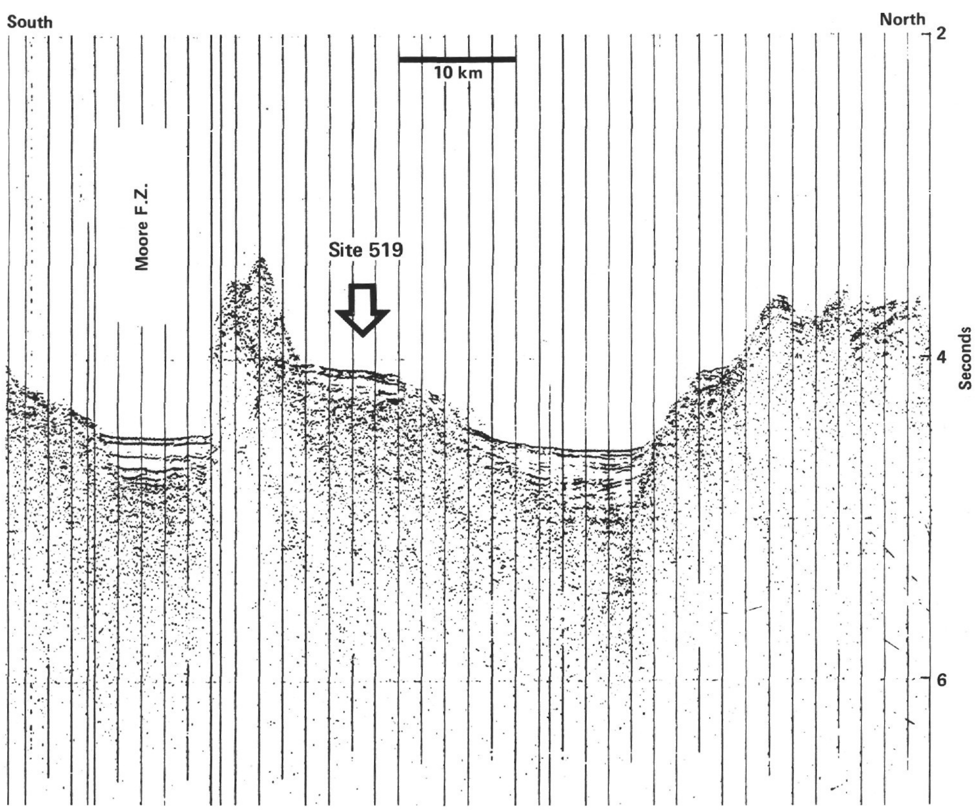


Figure 4. Single channel seismic profile from south to north over Site 519. The Moore F.Z. appears as a minor basin in the figure.

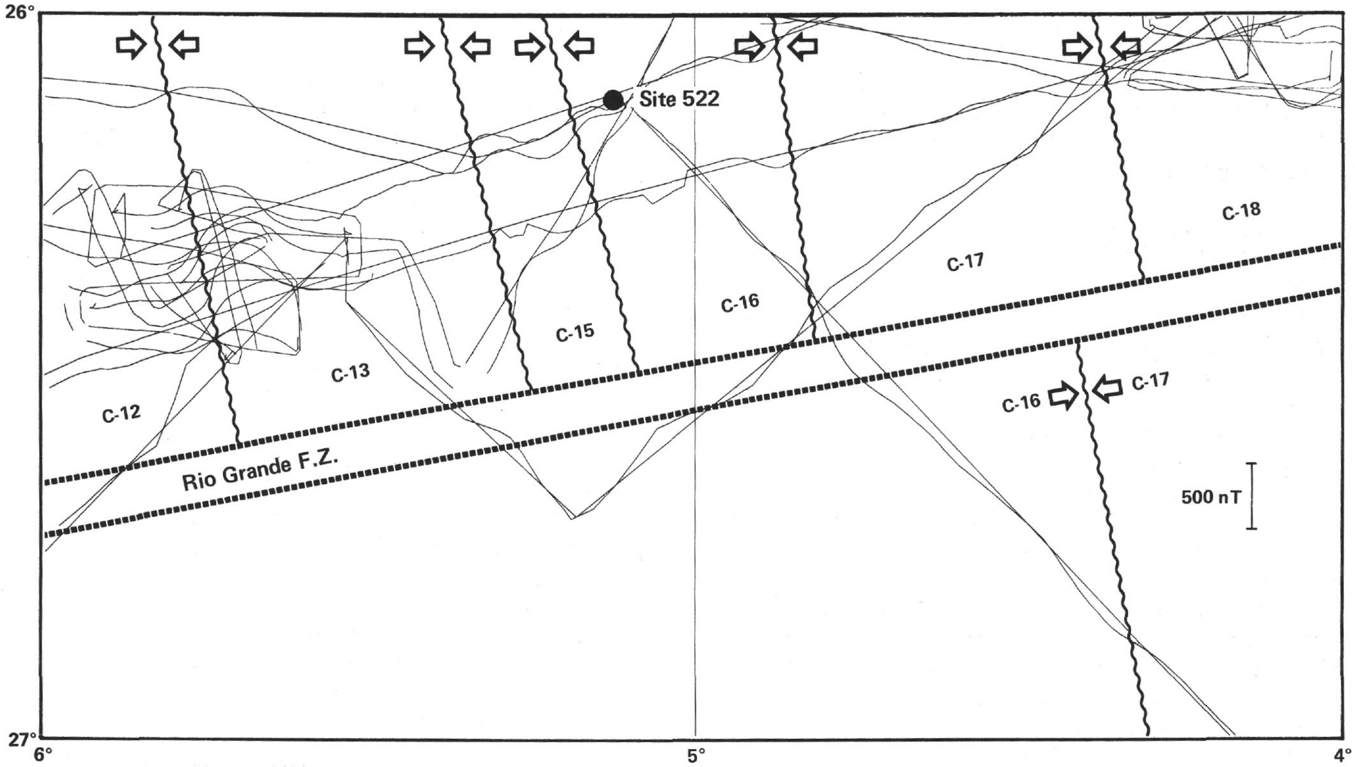


Figure 5. The location of Site 522 with respect to crustal age and the location of the Rio Grande Fracture Zone.

In order to predict the age of the crust to the west of the Walvis Ridge with more precision we have rotated the 1000-m isobath along the poles of rotation for the Mesozoic reconstructions. As can be seen in Figures 6 and 8, the crust immediately east of the Walvis Ridge in the vicinity of Site 524 is approximately 87 m.y. old. Just to the west of Site 524, we can trace the Anomaly 32 isochron of age 70 m.y. up onto the Walvis Ridge. Therefore an apparent age discontinuity of 17 m.y. exists across the eastern margin of the Walvis Ridge. This age discontinuity, coupled with the oblique strike of the Walvis Ridge with respect to the spreading anomalies and the lineation of the anomaly pattern up onto the Walvis Ridge, supports the rift propagation model for the Walvis Ridge. The observed basaltic sills at Site 524 were encountered within Maestrichtian sediments and were radiometrically dated at 67 m.y. by Dietrich et al. (this vol.). The propagating rift model suggests that these sills were emplaced on older crust at the time the tip of the propagating rift passed a few kilometers to the west of Site 524 during late Maestrichtian time.

## CONCLUSIONS

By using the available marine magnetic anomaly data we can define the age of the crust and the fracture locations near the six sites of Leg 73. Sites 519 and 520 are located within 20 km of the Moore F.Z. The South Atlantic spreading center underwent a reorganization in this region during the late Eocene and early Oligocene which can be correlated to the change in the pole of rotation for Africa–South America. Lastly, Site 524 is located on Turonian crust and experienced a volcanic episode as the Walvis propagator rifted the adjacent crust southward during Maestrichtian time. The volcanic sills recovered during Leg 73 were emplaced during this rifting episode and the formation of the Walvis Ridge.

## REFERENCES

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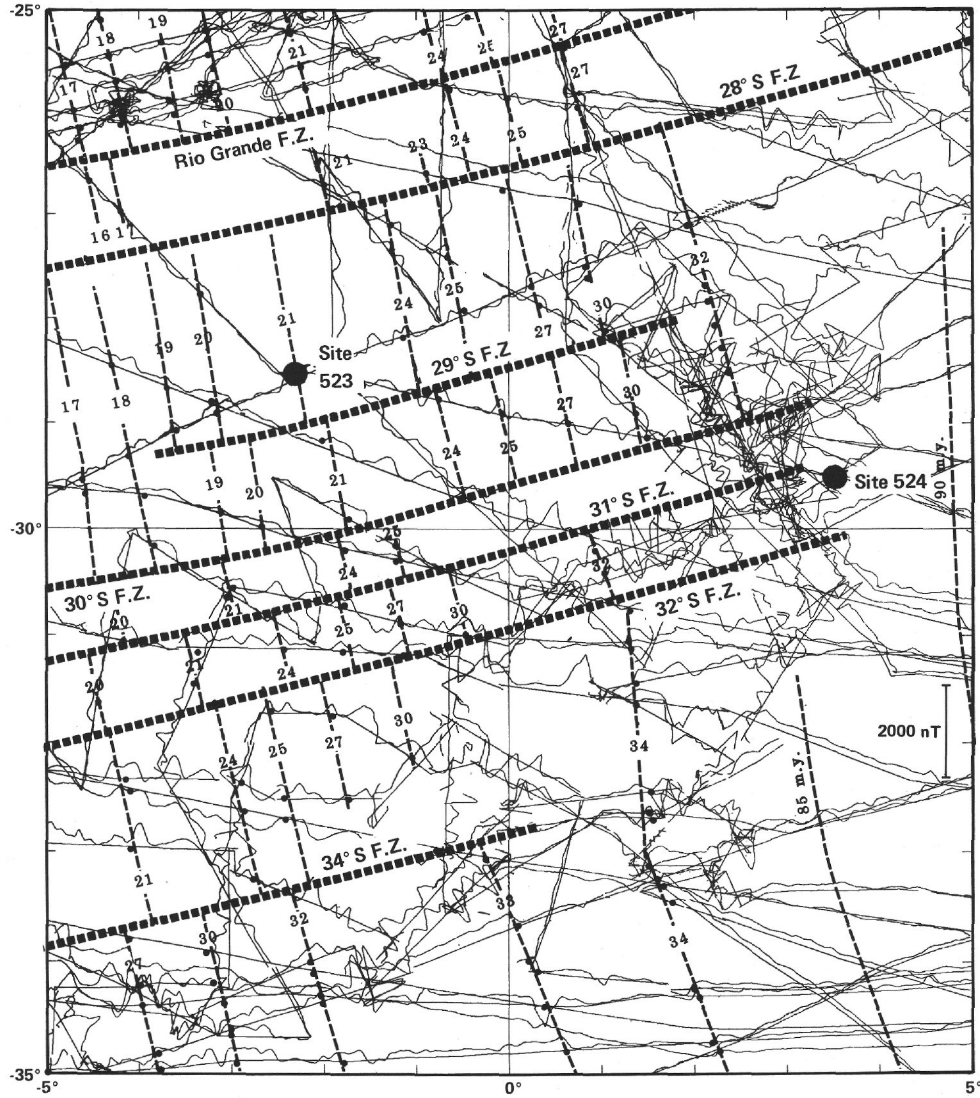


Figure 6. Magnetic anomaly correlations in the vicinity of the Walvis Ridge.

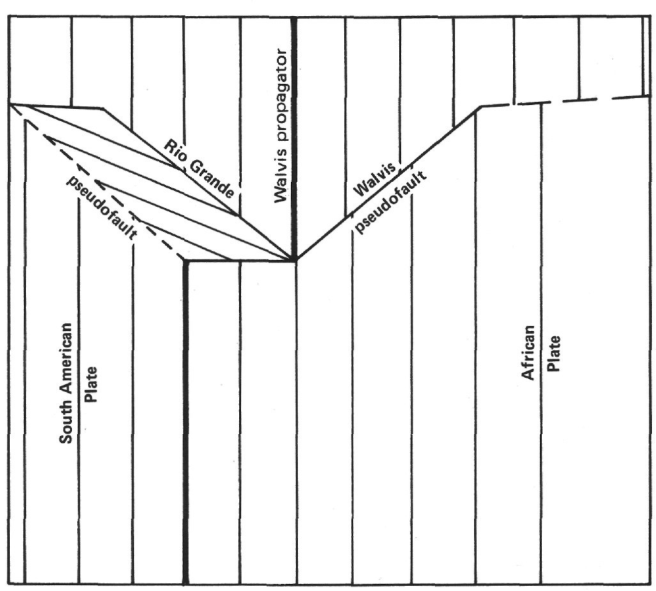


Figure 7. A schematic illustration of the Walvis propagator. The rifting of the African plate by the Walvis propagator in the region of Site 524 occurred during Maestrichtian time.

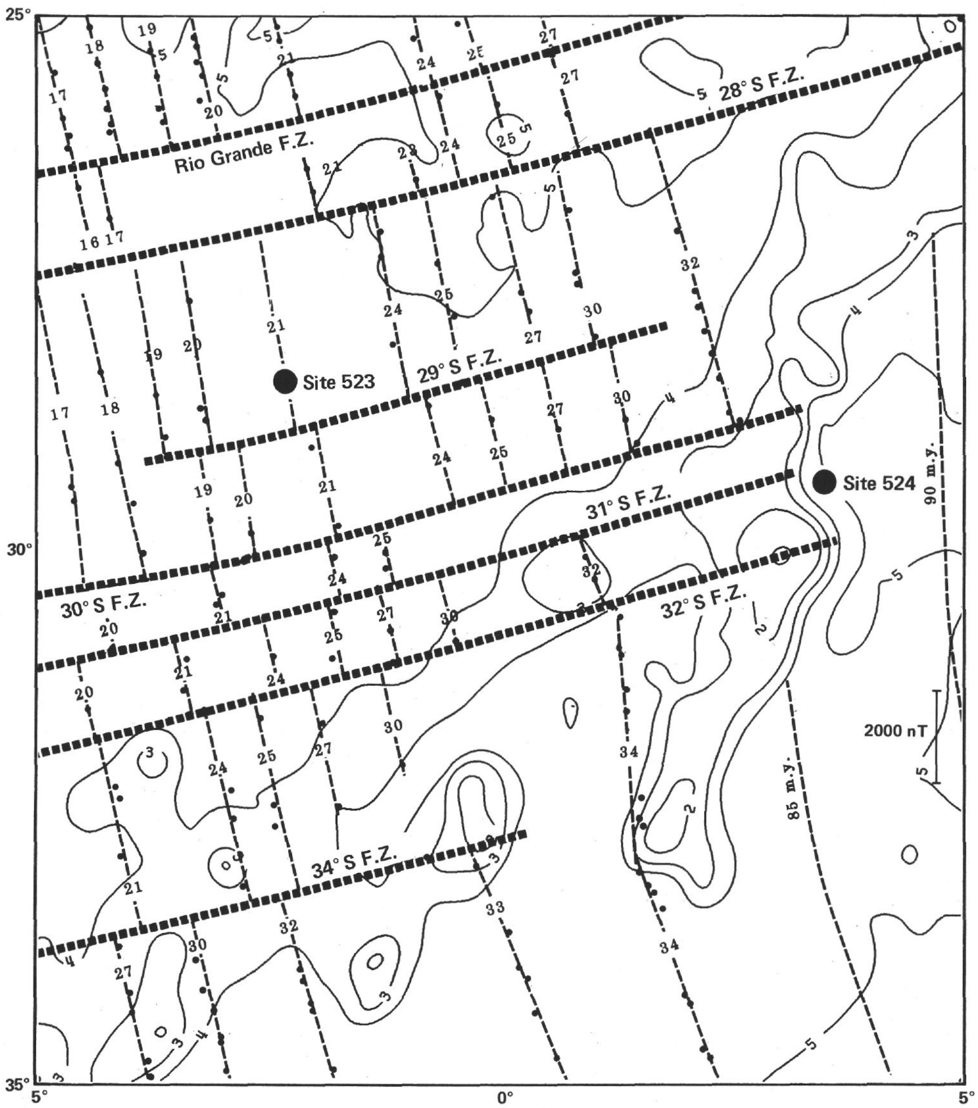


Figure 8. Magnetic lineation diagram of Figure 6 with respect to the regional bathymetry at Sites 523 and 524. Note that the anomaly isochrons intersect the Walvis Ridge at an oblique angle and can be traced onto the ridge.