1986

Fast Rift Propagation along the East Pacific Rise near Easter Island

David F. Naar
Scripps Institution of Oceanography, naar@usf.edu

R. N. Hey

Follow this and additional works at: https://digitalcommons.usf.edu/msc_facpub

Part of the [Life Sciences Commons](#)

Scholar Commons Citation

Naar, David F. and Hey, R. N., "Fast Rift Propagation along the East Pacific Rise near Easter Island" (1986).
Marine Science Faculty Publications. 2243.
https://digitalcommons.usf.edu/msc_facpub/2243

This Article is brought to you for free and open access by the College of Marine Science at Digital Commons @ University of South Florida. It has been accepted for inclusion in Marine Science Faculty Publications by an authorized administrator of Digital Commons @ University of South Florida. For more information, please contact digitalcommons@usf.edu.

Fast Rift Propagation Along the East Pacific Rise Near Easter Island

DAVID F. NAAR AND R. N. HEY

Scripps Institution of Oceanography, La Jolla, California

During a 1983 Seabeam cruise, we surveyed the Easter-Nazca spreading center which forms the eastern boundary of the Easter microplate. We have analyzed all available bathymetry and magnetic anomaly data to determine the present fine-scale tectonic configuration and recent tectonic evolution of this spreading center. The narrowing of the axial (Brunhes) anomaly is best explained by a young propagating rift growing northward at an average rate of 150 mm/yr assuming an average spreading rate of 120 mm/yr. There are indications of a short episode of faster propagation (350 mm/yr) prior to 0.4 Ma. These are the fastest rates of rift propagation yet documented. The tip of the propagating rift is at about 25°S, 112°25'W, ~180 km south of the previously hypothesized position. The recent spreading direction is N85°W. A large well-defined "sheared zone" to the west of the western pseudofault bounding the crust formed by the propagating rift suggests that the Easter-Pacific spreading center (360 km to the west) is being replaced by the fast propagator.

INTRODUCTION

The existence of the Easter microplate, surrounded by the Nazca and Pacific plates (Figure 1), was initially proposed by Herron [1972] because of the ring-shaped epicentral pattern and her analysis of the bathymetric and magnetic data, which suggested that dual spreading centers were generating a small growing plate. Forsyth [1972] corroborated this interpretation by showing that the first motions of two strike-slip earthquakes in this area were anomalous with respect to the normal Nazca-Pacific transform direction. Anderson *et al.* [1974] organized these observations with all the available bathymetric, magnetic, and focal mechanism data into a coherent plate boundary configuration with two spreading centers and two transform faults bounding a growing plate.

Hey and Vogt [1977] and Hey *et al.* [1980] briefly noted that a propagating rift model (Figure 2a) could provide a possible alternative explanation for the Easter microplate in which the plate would only exist instantaneously during the time it takes for the failing western spreading center (West Rift) to completely stop spreading and the new eastern spreading center (East Rift) to accelerate to the full Pacific-Nazca rate. Thus the size of the plate depends on how fast the new East Rift is propagating, how long the old West Rift takes to stop spreading, and the distance between the two ridges. These geometric details were explored by Engeln and Stein [1984].

Handschomacher *et al.* [1981] proposed a propagating rift model for the East Rift and noted that the size of the Easter microplate may make it too complicated to correspond to the simple propagating rift model [Hey, 1977]. Their tectonic interpretation (Figure 3) shows a northward propagating rift with a fanning of the older magnetic anomalies, especially to the southwest. Engeln and Stein [1984] published a new tectonic model using the distribution of earthquakes, eleven new focal mechanisms,

the existing bathymetry, and the magnetic anomaly identifications of Handschomacher *et al.* [1981]. They used the interpreted magnetics to obtain spreading rates which they inverted [Minster and Jordan, 1978] for the Easter-Nazca rotation pole.

We show that the Handschomacher *et al.* [1981] magnetic model does not satisfy our new data on the East Rift and thus the tectonic model of Engeln and Stein [1984], which was based on the Handschomacher *et al.* [1981] magnetic model, should be altered. In this paper we present new data from an April 1983 cruise of the R/V *Thomas Washington* (PASCUA 04) and propose a different propagating rift model which does explain the magnetic anomaly, bathymetric, and petrologic patterns in a straightforward way.

BATHYMETRIC DATA

The bathymetric data are displayed in profile form (Figure 4) and contour form (Plate 1). (Plate 1 is shown here in black and white. The color version can be found in the separate color section in this issue.) The bathymetric data were contoured using Seabeam [Renard and Allenou, 1979; de Moustier and Kleinrock, this issue] computer-generated contours in conjunction with printed depth values from the older cruises. In places where two Seabeam tracks crossed, but their bathymetry did not match, the track with the poorest satellite navigation was adjusted to match the bathymetry. This was done by smoothly tapering the navigation correction out to the nearest dependable satellite fix. These adjustments were small, usually less than 400 m and never more than 750 m, which demonstrates the precision of our transit satellite navigation, even when some crossings were made more than 18 days apart. The navigation of the merged data tape containing the magnetics, gravity, and vertical beam Seabeam bathymetry was not modified because the changes were so small.

The Seabeam data were also used in a computer program that calculated the bathymetric gradients so that a plot of bathymetric gradients greater than or equal to a given slope could be generated. This was done by plotting a small cross each time a calculated gradient between two

Copyright 1986 by the American Geophysical Union.

Paper number 4B5349.
0148-0227/86/004B-5349\$05.00

Fig. 1. Location of the Easter microplate. Heavy lines are spreading centers, lighter connecting lines are transform faults. The 3 and 4 km isobaths are from *Mammerickx and Smith [1978]*.

data points exceeded or equaled the minimum slope parameter, which was set at 20° to emphasize abyssal hill trends. These crosses form linear clusters which were redrawn as lineations, which have been extrapolated out to a swath envelope which is three times the Seabeam swath width for better visibility in Figure 5. Two exceptions exist to this procedure. The first occurs when the orientation of the lineation is parallel to the ship track in which case the lineation is only drawn as far as the feature is observed. The second occurs when a volcanic feature produces curved lineations in which case the lineations are drawn as circles (or parts of circles) preserving their true radius of curvature. Thus the size of the circle represents the true size of the feature. Lack of lineations inside the swath envelope shows where gradients are less than 20° inside the area surveyed by Seabeam. This new objective method of displaying Seabeam lineation data can also be used to filter out smaller scarps by increasing the minimum slope parameter.

MAGNETIC ANOMALY DATA

The magnetic anomaly data are displayed in profile form (Figure 6) and in contour form (Plate 2). (Plate 2 is shown here in black and white. The color version can be found in the separate color section in this issue.) Accurate, detailed contouring of the magnetic anomaly values from the 15 cruises in the study area was difficult because the cruises span 17 years, which is enough time for secular variation to significantly alter the total field, and/or because of poor navigation. Therefore a 200-nT contour interval was used to determine the general trend of the magnetic anomalies. The -100-nT contour interval

corresponds to the value of most of the inflection points between normal and reversed magnetic events; therefore magnetic anomalies less than -100 nT have been darkly colored, and ones greater have been lightly colored (Plate 2). In places where magnetic data from older cruises disagreed with our new data, the older data were ignored because our dense intersecting Seabeam coverage allowed us to verify the precision of our navigation.

DATA ANALYSIS

Seabeam Lineations

The Seabeam lineations (Figure 5) can be grouped into four general orientations. In the northwest, the lineations have an orientation of about $N45^\circ E$. In the southwest they have an orientation of about $N20^\circ E$. The rest have an orientation of about $N05^\circ E$ except for a narrow band of lineations east of the spreading center which have an orientation of about $N30^\circ W$. The $N30^\circ W$ lineations form a distinctive band which is broader than the $N20^\circ E$ band. The $N20^\circ E$ lineations do not all line up, but instead are offset to the east at $25^\circ 40' S$ and are nonexistent on the two tracks just south of $25^\circ S$. The National Geophysical Data Center (NGDC) earthquake epicenters through 1981 are also displayed with the lineations to show that this area is not teleseismically very active. There were no earthquakes in this area with a body wave magnitude greater than 6.0. The larger earthquake (December 16, 1974; EQ in Figure 5) which was analyzed by *Engeln and Stein [1984]* as having a $N70^\circ E$ left-lateral strike-slip focal mechanism, is about 100 km southeast from the nearest $N70^\circ E$ lineations observed in the northwest corner of Fig-

Fig. 2. Three models of how the Easter microplate oblique magnetic anomalies could have been generated. (a) Continuous propagating rift model with rotation pole far away (no spreading rate changes). Modified from Hey *et al.* [1980]. (b) A combination of a nearby rotation pole and rift propagation. Modified from Engeln and Stein [1984]. (c) A nearby rotation pole without rift propagation (produces a "fanning" of the anomalies). PR, propagating rift; DR, doomed rift; AFR, actively failing rift; FR, failed rift; SZ, sheared zone; PF pseudofault; TZ, instantaneous transform zone; IS, isochron.

ure 5. Its alternative nodal plane solution is within 10° of the $N30^\circ W$ lineations.

Bathymetry

North of $25^\circ S$, the bathymetry is very rough with relief up to 1400 m for the scarps and 2300 m for the large 1460-m-deep seamount. To the far northwest there is a broad plateau, cross-cut by a 800-m-deep and 10-km-wide NE-SW trough (Plate 1). The northwest corner of this area is generally deeper than 3000 m, and contours trend mostly NE-SW. Most of the northeast corner is shallower than 3000 m except for three deep (>3400 m) valleys, and the contours trend mostly N-S. The bathymetric trends to the east of the spreading center are mostly N-S except for some minor NW-SE structures which are consistent with the $N30^\circ W$ lineations (Figure 5). In the south the bathymetry is smoother than in the north, and at $26^\circ S$ there is an overlapping spreading center [Macdonald and Fox, 1983; Lonsdale, 1983] which has the characteristic geometry and about a 200-m-deep, 25-km-long, and 10-km-wide overlap basin in between the two ridges. At $25^\circ S$, $112^\circ 25' W$ there is a broad 3300-m-deep basin which lies at the northern end of the spreading center and is about where the $N20^\circ E$ and $N30^\circ W$ lineation bands intersect. South from this deep

Fig. 3. Tectonic model of Handschumacher *et al.* [1981] in which dots represent pseudofaults. Rectangle represents our study area. Modified from Handschumacher *et al.* [1981].

Fig. 4. Bathymetric profiles from all E-W cruises projected N05°E from trackline with our tectonic interpretation superimposed. Bathymetry shallower than 3000 m is above trackline. Thick V-shaped lines represent pseudofaults. Remaining thick lines represent spreading centers.

basin the spreading axis shallows to a 2100-m well-developed axial ridge at 26°30'S (Plate 1 and Figure 7).

Magnetics

The magnetic anomalies (Figure 6) can be grouped into three orientations: N-S oriented magnetic anomalies in the east and south, converging magnetic anomalies which converge toward 24°50'S, 112°25'W, and NE-SW oriented anomalies in the northwest. Our new data between profiles B2 at 25°30'S and B1 at 25°S illustrate where the *Handschumacher et al.* [1981] model (shown as small circles in Figure 6) breaks down. The axial anomaly begins to narrow at 26°S and converges at 25°S. Profile B1 shows that the small axial anomaly at 25°S, 112°25'W was misinterpreted as the western edge of the Brunhes axial anomaly. Therefore two somewhat similar looking anomalies at 26°S (B3) and 25°S (B1) were connected across the

ambiguous data at 25°30'S (B2). Our new magnetic anomaly contour map (Plate 2) shows the same N-S, NE-SW, and convergent trends observed in the bathymetry map, lineation map, and magnetic profiles. At 25°S, 112°25'W there is a very distinctive large positive anomaly (Plate 2) well-centered over a deep axial valley (Plate 1). The axial magnetic anomaly narrows northward from 26°S to 24°55'S, enclosing the high-amplitude magnetic anomaly. There are also steep anomaly gradients along the flanks of the axial anomaly at 112°10'W and 112°40'W. The overlapping spreading centers at 26°S (Plate 1) have two corresponding magnetic highs (Plate 2).

INTERPRETATIONS

Not all of the lineation orientations (Figure 5) can be explained with simple orthogonal seafloor spreading because they are not all parallel to the spreading center,

Plate 1. New bathymetric contour map. (The color version and a complete description of this figure can be found in the separate color section in this issue.)

nor do they symmetrically "fan" about the spreading center in any clear manner and therefore they cannot be explained solely by a nearby pole of rotation (Figure 2c). Instead, there are mostly oblique lineations to the west

and rift-parallel lineations to the east, which can be better explained by the continuous propagating rift model [Hey *et al.*, 1980]. In this propagating rift model, the N05°E lineations inside the N20°E and N30°W lineations were

Fig. 5. Lineation map generated from Pascua (legs 2 and 4) Seabeam data, superimposed with NGDC earthquake epicenters. Lineations subparallel to ship tracks are drawn as far as observed. Details explained in key. EQ represents an earthquake discussed in text. Tectonic elements as in Figure 4.

Fig. 6. Magnetic anomaly profiles. Positive anomalies are projected up (N05°E) from trackline. Open circles denote the partially erroneous Brunhes identification of *Handschumacher et al.* [1981]. A, E, and J stand for the Axis, Emperor, and Jaramillo anomalies. M/B and B/M represent the Brunhes/Matuyama reversal boundary. Tectonic elements as in Figure 4. Most labeled tracks are modeled in Figures 9 and 11. W indicate our new data.

formed at the active East Rift. The N05°E lineations east of the N30°W lineations were presumably formed by the old Pacific-Nazca spreading center or more recently by a previous East Rift. The N20°E and N30°W lineations represent pseudofaults and the N45°E lineations represent the sheared zone (Figure 2a) consisting of lithosphere which has been transferred from one plate to another. The N45°E lineations in the extreme northwest could not have been sheared into their present orientations by the current propagator because these sheared structures are north of the propagating rift tip and therefore indicate previous rift propagation or some other kind of structural disturbance.

The spreading axis, which shallows 1200 m from the deep axial basin at 25°S to the axial ridge at 26°30'S (Figures 4 and 7 and Plate 1), is morphologically similar to the Galapagos 95.5°W propagating rift [Hey *et al.*, 1980, this issue; Christie and Sinton, 1981]. This shallowing away from a propagating rift tip is more pronounced than at a stationary ridge-transform intersection because of the larger cooling area at the rift tip and consequently greater viscous head loss. In addition, the possible interaction of a hotspot with the East Rift at 26°30'S would increase the shallowing. The high-amplitude magnetic anomaly (Plate 2) overlying the deep axial basin at 25°S (Plate 1) which is at the apex of converging lineations, bathymetric struc-

Plate 2. Magnetic anomaly contour map. (The color version and a complete description of this figure can be found in the separate color section in this issue.)

Fig. 7. Depth of the Easter-Nazca spreading center from 26°30'S to 25°S. Two depths at one location result from overlapping spreading centers. Notice increase of depth toward the 25°S propagating rift tip.

tures, and a narrowing axial anomaly, correlates well with what is observed at the Galapagos 95.5°W rift tip [Vogt and de Boer, 1976; Hey *et al.*, 1980, this issue; Christie and Sinton, 1981; Sinton *et al.*, 1983; Searle and Hey, 1983]. The steep anomaly gradients along the pseudofaults probably result from FeTi enrichment (as the propagator tip passed by) and/or propagation into reverse polarity crust.

Results from a dredging cruise on the R/V *Endeavor* support the propagating rift model in this area because of a distinct gradual increase of FeTi basalts from 26°S to 25°S [Schilling *et al.*, 1985], which is a characteristic signal observed along propagating rifts in the Galapagos region [Christie and Sinton, 1981; Sinton *et al.*, 1983]. Two analyzed dredge samples from our cruise also agree with this FeTi enrichment trend. One, just south of the propagator tip, shows a high Fe/Mg ratio of 2.41, 13.2% normalized Fe, and 2.5% normalized Ti; the other, 160 km south of the first, shows a lower Fe/Mg ratio of 1.68,

Fig. 8. Magnetic data and models across the EPR south of the Easter microplate. For each set, the top profile is actual data (in nanoteslas), the middle profile is the model, the lower profile is bathymetry (in meters), and the darkened blocks are normal magnetic polarity. Horizontal axis at bottom is kilometers from spreading axis. The Emperor reversed event is indicated by two dashes underneath the synthetic anomaly. Model A (74010903, 27.2°S) uses a full-rate of 174 mm/yr; model B (PASCO4WT, 28.9°S) 176 mm/yr; model C (ELT29, 28.3°S) 180 mm/yr. All models are generated using the bathymetry, a 1.7-km-thick magnetic layer, and effective susceptibility of 0.01.

Fig. 9. Magnetic data and models computed assuming narrowing central anomaly results exclusively from slow spreading. Each title includes the profile index (Figure 6), the full spreading rate and (when needed) the percent of asymmetric spreading to the west. Model parameters as in Figure 8. The Jaramillo is only well matched in profiles B3, B5, W1, and B4.

Fig. 10. Model parameters from Figure 9. (a) Spreading rate versus latitude. (b) Spreading asymmetry versus latitude. Notice inconsistent pattern of asymmetric spreading.

10.9% normalized Fe, and 2.0% normalized Ti [Macdougall and Tanzer, 1984]. These petrologic results are best explained by our propagating rift model.

Thus the Seabeam lineation, bathymetric, magnetic, and petrologic data can be better explained by a younger and different propagating rift than previously proposed. According to our new interpretation the convergent trends are pseudofaults, the N-S trends inside the pseudofaults were generated by the propagator, the N-S trends east of the eastern pseudofault were generated by a previous spreading center, the NE-SW trend is a sheared zone of transferred lithosphere, and the high-amplitude magnetic anomaly is a consequence of rift propagation. To further test the plausibility of the propagating rift model, we have modeled the magnetic anomaly data.

MAGNETIC MODELING

The main objective of this section is to test whether spreading rate changes (without rift propagation) or rift propagation (without spreading rate changes) better explains the detailed magnetic and bathymetric data in this area. These two plate motion models represent two extremes which can explain the narrowing of the axial anomaly from 26°S to 25°S. The first fits the narrowing by slower spreading rates to the north. The second fits the narrowing by two pseudofaults converging northward. Although it is possible to combine these two models (e.g.,

Figure 2b), we have not done so because we do not have any direct control on the spreading rate inside the narrowing axial anomaly.

Constraints

The magnetic anomaly data are forward modeled, using the bathymetry and specified input parameters to generate a synthetic magnetic anomaly. We used the Mankinen and Dalrymple [1979] recalculation of the La Brecque et al. [1977] time scale, modified to include the Emperor reversed event between 0.49 and 0.50 Ma [Wilson and Hey, 1981]. The most important constraints used in the modeling are the decreasing axial anomaly width to the north (Figure 6), the high-amplitude magnetic anomaly at 25°S (Plate 2) and the 180 mm/yr spreading rates of the East Pacific Rise (EPR) modeled to the south of the microplate (also proposed by Herron [1972]) (Figure 8). The 180 mm/yr spreading rate was used for the West Rift (probably the old EPR) prior to the onset of spreading at the East Rift. The East Rift is modeled to spread at 120 mm/yr (not 180) because the anomalies south of 26°30'S all match about 120 mm/yr out past the Jaramillo. This slower spreading rate [Hey et al., 1977; Minster and Jordan, 1978; Chase, 1978] is expected for the East Rift because of the current seafloor spreading at the West Rift as shown by magnetic anomaly data [Naar and Hey, 1983; Hey et al., 1983, 1985], seismic activity [Herron, 1972; Forsyth, 1972; Anderson et al., 1974; Handschumacher et al., 1981], and dredged fresh basalts [Schilling et al., 1985]. For computational convenience the dual spreading is approximated by assuming that the West Rift stops spreading when the East Rift starts spreading. The jump distance is adjusted until a best fit of the model to the data is obtained. The older seafloor magnetic anomaly into which the rift is propagating has not been unequivocally identified but is modeled as anomaly-3.

Slower Spreading Model

This model fits the narrowing of the axial anomaly by slower spreading to the north without any rift jumps or rift propagation, and so the Brunhes anomaly is well matched in all the profiles, (Figure 9). However, the next set of positive anomalies to the outside are only matched by the Jaramillo in the profiles south of 26°S (B3, B5, W1, and B4). To the north of 26°S, this model does not match any of the anomalies outside the Brunhes anomaly. The profiles between 25°S and 26°S show an increase in spreading rate, but the other profiles south of 26°S have nearly the same rate of 120 mm/yr (Figure 10a). This model only works with an unusually high degree of inconsistent asymmetric spreading (Figure 10b) between 25°S and 26°S and does not work very well south of 26°S because the spreading rates do not continue increasing at the same rate as they did north of 26°S (Figure 10a).

Propagating Rift Model

This model fits the narrowing of the axial anomaly by a propagating rift assuming an average spreading rate of 120 mm/yr. Figure 11 shows how the narrowing of the axial anomaly is modeled by rift propagation; the spreading rate is the same for all the profiles, but the jump ages become

Fig. 11. Magnetic data and models computed assuming narrowing central anomaly results exclusively from a propagating rift with a constant spreading rate of 120 mm/yr. Dashed lines represent pseudofaults (jump time). The profile label (Figure 6), jump time, and percent of westward asymmetric spreading (when needed) is in each title. Model parameters as in Figure 8. Notice the good fit of the Emperor event (the two dashed lines in profiles B3, B5, W1, B4) and the Brunhes and Jaramillo anomalies (profiles B5, W1, and B4).

Fig. 12. Model parameters from Figure 11. (a) Time of spreading center jump vs. latitude. The solid line represents a propagation rate of about 150 mm/yr; the dotted line represents a possible short-lived episode of very fast propagation (350 mm/yr). (b) Spreading asymmetry versus latitude. Notice minimal degree of asymmetric spreading.

progressively younger toward 25°S (Figure 12a). The inconsistent asymmetry from the previous model is no longer necessary to fit the Brunhes anomaly (Figure 12b), because the time of the ridge jump and the polarity of crust into which the ridge jumped can be adjusted to fit a lopsided axial anomaly. In Figure 11, profiles B5, W1, and B4 show three positive anomaly peaks which have been fit as the Brunhes and Jaramillo anomalies. Note the good fit to the Emperor reversed event [Wilson and Hey, 1981] as well. The Jaramillo disappears between profiles B5 and B3, as does the Emperor event between profiles B3 and W3, which means the rift started spreading at these latitudes after the magnetic reversals. We have de-emphasized profile B3 in locating the eastern pseudofault because of suspect navigation.

By using a linear approximation of the ridge jump times versus latitude (Figure 12a), the ridge has been propagating at an average rate of about 150 mm/yr during the past 1.2 Ma, which is 1.3 times faster than the spreading rate (120 mm/yr). Before 0.4 Ma the propagation rate could have been considerably faster, about 350 mm/yr, which is 2.9 times faster than the spreading rate. These two ratios of propagation to spreading rate are greater than the 0.85 ratio observed for the Galapagos 95.5°W propagating rift [Hey *et al.*, this issue]. Thus the propagation rate is not

directly proportional to spreading rate, but is most likely related [Hey *et al.*, this issue].

SPECULATIONS

The elevated rough bathymetry and earthquakes to the northeast of the propagator tip (Plate 1 and Figure 5) have led others [Handschomacher *et al.*, 1981] to postulate spreading in this area even though the magnetic anomalies are difficult to identify. Some of the anomalies to the east of their axis location have been matched with very slow spreading, but to the west, the smooth magnetic anomalies north of 25°S and west of 112°30'W are still unidentified (Figure 5). This region has been shown to be recently volcanically active by dredged fresh basalt [Schilling *et al.*, 1985].

If the northeast area (Plate 1) was generated by an older northward propagating rift, then this suggests that the growth of the eastern microplate boundary may be a result of a series of successive northward propagating rifts. If so, then it will be very difficult to model the interior of the microplate. This would further imply that this younger propagating rift is currently extending between two spreading centers, thus forming a new geometry for a propagating rift in which there are two sheared zones (or zones of transferred lithosphere) and two failed rifts surrounding the propagating rift. If there is not a spreading center to the northeast, then perhaps the shallow bathymetry is related to some kind of thermal uplift or is a failed rift segment of the old EPR that has just recently become volcanically active. North of 23°30'S it appears there is a large broad transform/deformation zone which connects with the EPR at 23°S, 114°30'W [Hey *et al.*, 1985].

The EPR south of the microplate is very complicated (Figure 8), possibly due to extensive broad-scale volcanic activity. At the present time it appears that the EPR axis is shifting to about 113°W, ~30 km west of where the older anomalies indicate the spreading axis should be [Herron, 1972]. This relocation may be a result of southward propagation of the new EPR which is also suggested by a slight FeTi enrichment trend south of 27°S [Schilling *et al.*, 1985].

The Easter hotspot has yet to be precisely located, but recent isotopic and chemical evidence [Craig *et al.*, 1984; Macdougall and Tanzer, 1984; Schilling *et al.*, 1985] suggest that it (or channeled flow from it) may lie at the spreading axis of the East Rift near 26°30'S (Plate 1). Whether the hotspot is under the East Rift, Easter Island, or Sala y Gomez Island, the northward propagation of the East Rift at 25°S and the possible southward propagation of the EPR at 29°S is similar to the Galapagos area where the rifts propagate away from the shallow region near the Galapagos hotspot [Hey *et al.*, 1980].

CONCLUSIONS

The Seabeam lineation, bathymetric, magnetic, and petrologic data are better explained by a younger and different propagating rift than previously proposed. The Seabeam lineations and magnetic anomalies indicate that the recent spreading direction is N85°W. Our preferred model of the magnetic anomaly data shows that the

Easter-Nazca spreading center (from 26°30'S to 25°S) has been propagating northward for at least the past million years at an average rate of about 150 mm/yr (assuming an average spreading rate of 120 mm/yr) and may have been propagating as fast as 350 mm/yr prior to 0.4 Ma. These propagation rates are the fastest yet documented by magnetic and bathymetric data. The microplate boundary configuration [Hey *et al.*, 1985] is being reorganized by this propagating rift, and there are indications of additional rift propagation in this area. A large well-defined "sheared zone" to the west of the western pseudofault bounding the crust formed by the propagating rift suggests that the Easter-Pacific spreading center (360 km to the west) is being replaced by the fast propagator. The magnetic anomalies that the East Rift is propagating into have not been identified but presumably were formed by the Pacific-Easter spreading center and/or an earlier northward propagating rift on the eastern margin of the microplate.

Acknowledgments. Unpublished Seabeam data were generously provided by P. J. Fox and H. Craig. J.-G. Schilling provided extensive bathymetry and magnetics data from his recent dredging cruise. M. Tanzer did the petrologic lab analysis on our dredges. Many thanks to Captain Johnson and the crew of the R/V *Thomas Washington*, our Chilean observer, E. Morales, and the many people at Scripps who helped in many ways, especially M. Kleinrock, M. Keeler, A. Bobbitt, U. Albright, W. Smith, J. Wilson, D. Caress, N. Ferguson, E. Portillo, L. Jackson, and M. Hiller. Supported by National Science Foundation grant OCE82-15396. For critical reviews we thank Marty Kleinrock, David Rea, and Joseph Engeln.

REFERENCES

- Anderson, R. N., D. W. Forsyth, P. Molnar, and J. Mammerickx, Fault plane solutions of earthquakes on the Nazca plate boundaries and the Easter plate, *Earth Planet. Sci. Lett.*, **24**, 188-202, 1974.
- Chase, C. G., Plate kinematics: The Americas, East Africa, and the rest of the world, *Earth Planet. Sci. Lett.*, **37**, 355-368, 1978.
- Christie, D. M., and J. M. Sinton, Evolution of abyssal lavas along propagating segments of the Galapagos spreading center, *Earth Planet. Sci. Lett.*, **56**, 321-335, 1981.
- Craig, H., K. R. Kim, and W. Rison, Easter Island hotspot, I, Bathymetry, helium isotopes, and hydrothermal methane and helium, *Eos Trans. AGU*, **65**, 1140, 1984.
- de Moustier, C., and M. C. Kleinrock, Bathymetric artifacts in Seabeam data: How to recognize them, what causes them, *J. Geophys. Res.*, this issue.
- Engeln, J. F., and S. Stein, Tectonics of the Easter plate, *Earth Planet. Sci. Lett.*, **68**, 259-270, 1984.
- Forsyth, D. W., Mechanisms of earthquakes and plate motions in the East Pacific, *Earth Planet. Sci. Lett.*, **17**, 189-193, 1972.
- Handschumacher, D. W., R. H. Pilger, J. A. Foreman, and J. R. Campbell, Structure and evolution of the Easter plate, *Mem. Geol. Soc. Am.*, **154**, 63-76, 1981.
- Herron, E. M., Two small crustal plates in the South Pacific near Easter Island, *Nature Phys. Sci.*, **240**, 35-37, 1972.
- Hey, R. N., A new class of pseudofaults and their bearing on plate tectonics: A propagating rift model, *Earth Planet. Sci. Lett.*, **37**, 321-325, 1977.
- Hey, R. N., and P. R. Vogt, Spreading center jumps and sub-axial asthenosphere flow near the Galapagos hotspot, *Tectonophysics*, **37**, 41-52, 1977.
- Hey, R. N., G. L. Johnson, and A. Lowrie, Recent tectonic evolution of the Galapagos area and plate motions in the East Pacific, *Geol. Soc. Am. Bull.*, **88**, 1385-1403, 1977.
- Hey, R. N., F. K. Duennebie, and W. J. Morgan, Propagating rifts on mid-ocean ridges, *J. Geophys. Res.*, **85**, 3647-3658, 1980.
- Hey, R. N., D. F. Naar, M. C. Kleinrock, W. J. Phipps Morgan, E. Morales, and L. Johnson, Microplate tectonics and fast rift propagation along the superfast spreading East Pacific Rise near Easter Island, *Eos Trans. AGU*, **64**, 855, 1983.
- Hey, R. N., D. F. Naar, M. C. Kleinrock, W. J. Phipps Morgan, E. Morales, and J.-G. Schilling, Microplate tectonics along a superfast seafloor spreading system near Easter Island, *Nature*, **317**, 320-325, 1985.
- Hey, R. N., M. C. Kleinrock, S. P. Miller, T. M. Atwater, and R. C. Searle, Seabeam/Deep-Tow investigation of an active oceanic propagating rift system, *J. Geophys. Res.*, this issue.
- La Brecque, J. L., D. V. Kent, and S. C. Cande, Revised magnetic polarity time scale for the late Cretaceous and Cenozoic, *Geology*, **5**, 330-335, 1977.
- Lonsdale, P. F., Overlapping rift zones at the 5.5° offset of the East Pacific Rise, *J. Geophys. Res.*, **88**, 9393-9406, 1983.
- Macdonald, K. C., and P. J. Fox, Overlapping spreading centers: A new kind of accretion geometry on the East Pacific Rise, *Nature*, **301**, 55-58, 1983.
- Macdougall, J. D., and M. O. Tanzer, Easter Island hotspot, II, Isotopic and chemical evidence of its influence on EPR basalts, *Eos Trans. AGU*, **65**, 1140, 1984.
- Mammerickx, J., and S. M. Smith, Bathymetry of the Southeast Pacific, *Geol. Soc. Am. Map Chart Ser.*, **MC-26**, 442, 1978.
- Mankinen, E. A., and G. B. Dalrymple, Revised geomagnetic polarity time scale for the interval 0-5 m.y. B.P., *J. Geophys. Res.*, **84**, 615-626, 1979.
- Minster, J. B., and T. H. Jordan, Present-day plate motions, *J. Geophys. Res.*, **83**, 5331-5354, 1978.
- Naar, D. F., and R. N. Hey, Preliminary analysis of Seabeam and magnetics data from the Easter microplate, *Eos Trans. AGU*, **64**, 855, 1983.
- Renard, V., and J. P. Allenou, SEA BEAM multi-beam echosounding in "Jean Charcot": Description evaluation and first results, *Int. Hydrol. Rev.*, **56**(1), 35-67, 1979.
- Schilling, J.-G., H. Sigurdsson, A. N. Davis, and R. N. Hey, Easter microplate evolution, *Nature*, **317**, 325-331, 1985.
- Searle, R. C., and R. N. Hey, Gloria observations of the propagating rift at 95°W on the Cocos-Nazca spreading center, *J. Geophys. Res.*, **88**, 6433-6447, 1983.
- Sinton, J. M., D. S. Wilson, D. M. Christie, R. N. Hey, and J. R. Delaney, Petrologic consequences of rift propagation on oceanic spreading ridges, *Earth Planet. Sci. Lett.*, **62**, 193-207, 1983.
- Vogt, P. R., and J. de Boer, Morphology, magnetic anomalies and basalt magnetization at the Galapagos high-amplitude zone, *Earth Planet. Sci. Lett.*, **33**, 145-163, 1976.
- Wilson, D. S., and R. N. Hey, The Galapagos axial magnetic anomaly: Evidence for the Emperor event within the Brunhes and for a two-layer magnetic source, *Geophys. Res. Lett.*, **8**, 1051-1054, 1981.

R. N. Hey and D. F. Naar, Scripps Institution of Oceanography, Geological Research Division, A-020, UCSD, La Jolla, CA 92093.

(Received November 16, 1984;
revised July 24, 1985;
accepted August 14, 1985.)

Plate 1 [Naar and Hey]. New bathymetric contour map with 100-m contour and 200-m color interval. The following cruises (from the Scripps Geologic Data Center) were used: 74010903, C1502, POL7101, POL7302, POL7303, 72110807, ARES1BWT, 73002311, PASC02WT, PASC03WT, PASC04WT, C1714, 80001711, and EN113. Tectonic elements as in Figure 4.

Plate 2 [Naar and Hey]. Magnetic anomaly contour map with 200-nT contour and color interval. Dotted lines represent ship tracks. The large 500-nT magnetic anomaly and surrounding V pattern indicate the propagating rift tip. Tectonic elements as in Figure 4.