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Multibeam bathymetry and sidescan imaging of the Rivera Transform–Moctezuma Spreading Segment junction, northern East Pacific Rise: New constraints on Rivera–Pacific relative plate motion

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ABSTRACT

To better understand the recent motion of the Pacific plate relative to the Rivera plate and to better define the limitations of the existing Rivera–Pacific plate motion models for accurately predicting this motion, total-field magnetic data, multibeam bathymetric data and sidescan sonar images were collected during the BART and FAMEX campaigns of the N/O L'Atalante conducted in April and May 2002 in the area surrounding the Moctezuma Spreading Segment of the East Pacific Rise, located offshore of Manzanillo, Mexico, at 106°16′W, between 17.8°N and 18.5°N. Among the main results are: (1) the principle transform displacement zone of the Rivera Transform is narrow and well defined east of 107°15′W and these azimuths should be used preferentially when deriving new plate motion models, and (2) spreading rates along the Moctezuma Spreading Segment should not be used in plate motion studies as either seafloor spreading has been accommodated at more than one location since the initiation of seafloor spreading in the area of the Moctezuma Spreading Segment, or this spreading center is not a Rivera–Pacific plate boundary as has been previously assumed. Comparison of observed transform azimuths with those predicted by the best-fit poles of six previous models of Rivera–Pacific relative motion indicate that, in the study area, a significant systematic bias is present in the predictions of Rivera–Pacific motion. Although the exact source of this bias remains unclear, this bias indicates the need to derive a new Rivera–Pacific relative plate motion model.

1. Introduction

The Moctezuma Spreading Segment (MSS, Fig. 1) is commonly thought (e.g. Bandy, 1992; Lonsdale, 1995) to be a recently formed, divergent boundary between the Rivera and Pacific plates and, thus, its morphology and spreading history should provide valuable constraints on the recent relative motions of the Pacific and Rivera plates. Further, since the motion of the Rivera plate relative to the North American plate can, at present, only be determined indirectly via closure about plate motion circuits that include the Rivera–Pacific plate pair, determining a well-constrained Rivera–Pacific Euler pole is critical to our understanding of the tectonic forces acting on western Mexico. Currently, several viable models (Fig. 1, Table 1) exist for present-day Rivera–Pacific relative motion (i.e., DeMets and Stein, 1990; Bandy, 1992; Lonsdale, 1995; DeMets and Wilson, 1997; Bandy et al., 1998a; DeMets and Traylen, 2000; Bandy et al., 2007); hence, also for present-day Rivera–North American relative motion. The differences in the Rivera–North American relative motions predicted by these various models are large (e.g., Kostoglodov and Bandy, 1995). In a recent study (Bandy et al., 2005) these differences prevented the investigators from stating conclusively that strain partitioning is occurring along the southern Jalisco Subduction Zone; a part of the

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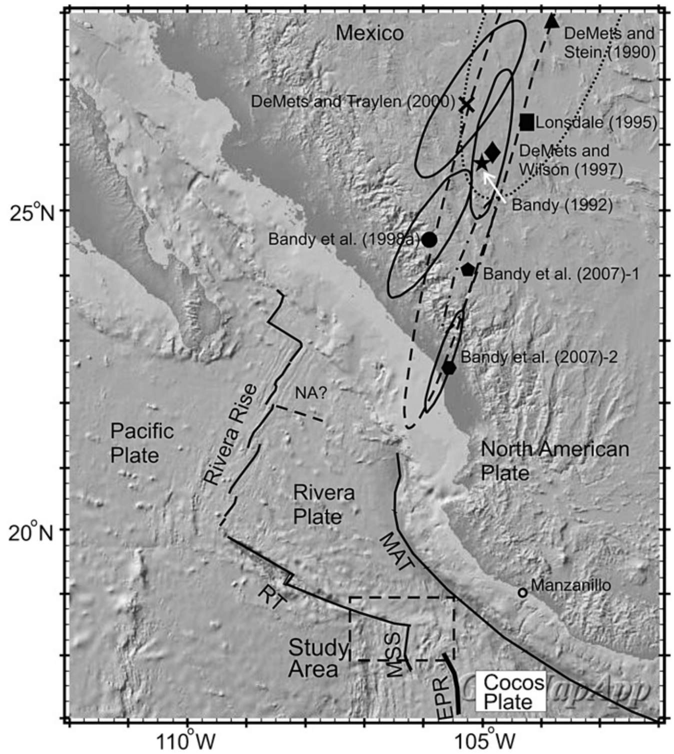

Fig. 1. Location of study area (dashed–box). Also shown are the locations of previously published Rivera–Pacific Euler poles of DeMets and Stein (1990) (filled triangle), Bandy (1992) (filled star), Lonsdale (1995) (filled square), DeMets and Wilson (1997) (filled diamond), Bandy et al. (1998a) (filled circle), DeMets and Traylen (2000) (X), and the new models, B2007-1 and B2007-2 which are constrained by the new data and results of this study. Note that the area marked by a question mark in the NW corner of the Rivera plate is most likely not acting as a rigid part of the plate (Lonsdale, 1995). Abbreviations are EPR = East Pacific Rise; MSS = Moctezuma Spreading Segment; MAT = Middle America Trench; RT = Rivera Transform. Basemap from Geo-Map Applications.

Rivera–North American plate boundary where several large/great earthquakes have occurred in the past century (Zobin, 1997; Pacheco et al., 1997; Singh et al., 1985, 2003).

The inability to reach a consensus on the Rivera–Pacific Euler pole (Michaud et al., 1996; Bandy et al., 1998b; Wilson and DeMets, 1998) is due mainly to uncertainties arising from an incomplete coverage of high-resolution bathymetric data along the Rivera–Pacific boundaries (i.e. the Rivera Transform, Rivera Rise and the MSS). These uncertainties include: (1) What is the correct orientation of the Rivera Transform adjacent to the MSS? (2) Where is the point of intersection of the MSS and Rivera Transform? (3) Has the MSS been a boundary between the rigid parts of the Rivera and Pacific plates since 0.78 Ma? (4) Has there been a recent change in Rivera–Pacific relative motion? and (5) What is the correct orientation of the Rivera Transform at its junction with the Rivera Rise? To answer some of these questions and to better determine the limitations of the existing models for present-day Rivera–Pacific relative plate motion, multibeam bathymetric, sidescan and magnetic data were collected in the area of the junction of the Rivera Transform and the MSS during projects BART (BAthymetry of the Rivera Transform) and FAMEX conducted aboard the N/O L'Atalante during April/May 2002.

2. Previous work

2.1. Moctezuma Spreading Segment/Eastern Rivera Transform

The MSS, first identified by Bourgois et al. (1988), is part of the East Pacific Rise (EPR) and is located at the eastern end of the Rivera Transform (Fig. 1). The MSS extends ~65 km southward from the Rivera Transform (Bandy, 1992; Michaud et al., 1996; Baker et al., 2001). The gross morphology of the MSS indicates that it is the active, southward propagating rift of a paired overlapping, propagating rift system (Fig. 2). Although there is some debate, the MSS is generally accepted to be a divergent boundary between the Rivera and Pacific plates (Bandy, 1992; Lonsdale, 1995; Michaud et al., 1997; DeMets and Wilson, 1997). Previously, high-resolution multibeam bathymetric data coverage was sparse in the majority of the area of the MSS propagator system, consisting for the most part of a single narrow swath centered on, and oriented parallel to, the axis of the MSS (Baker et al., 2001).

The age of the initiation of seafloor spreading along the MSS is uncertain. Bourgois et al. (1988) proposed, based on the width of the zone of newly created seafloor at the MSS, that spreading initiated at about 0.78 Ma. In contrast, DeMets and Wilson (1997) proposed from models of the magnetic anomaly observed at the MSS that spreading was initiated at about 1 Ma (Anomaly J or Chron 1r.1n in the terminology of Cande and Kent, 1995). Bandy and Hilde (2000) favored an initiation sometime between 0.78 and 0.9 Ma. Their rational being: (1) anomalies 1R and J are clearly observed along the east flank of the failed rift to the east (Fig. 2) and (2) the distance between anomalies J and 1R is the same along the failed rift to the east as it is along the still active spreading segment immediately south of the failed rift. Thus spreading most likely was not initiated prior to about the later half of the time period corresponding to Anomaly 1R (between 0.78 and 0.9 Ma).

The location of the junction of the MSS and the Rivera Transform is also uncertain. The junction was first proposed to lie at 18°30′N, 106°15′W (Bourgois et al., 1988); however, Wilson and DeMets (1998) propose a location slightly to the south at the point where the axis of the MSS begins to bend sharply westward (i.e. near 18°29.6′N, 106°16′W).

The orientation and the precise location of the Rivera Transform just west of the MSS is also currently the subject of debate. Bandy (1992), Michaud et al. (1996) and Bourgois et al. (1988) propose that the transform, as it approaches the MSS, runs up the side of the prominent escarpment that forms the northern transform wall at an

Table 1
Rivera–Pacific relative plate motion models

Model	Latitude (°N)	Longitude (°W)	ω (°/m.y.)	Predicted azimuth[b] of eastern Rivera Transform	MSS rate data used?	Rivera Rise rate/magnetic data used in pole determination?	Orthogonal spreading along Rivera Rise used to constrain pole
DeMets and Stein (1990)	27.9	103.8	3.986	103	No	Yes	Yes
Bandy (1992)	25.7	105.0	–	99	No	No	No
Lonsdale (1995)	26.4	104.3	4.65	103	No	No[c]	Yes
DeMets and Wilson (1997)	25.9	104.8	4.971	100	Yes	Yes	?
Bandy et al. (1998a)	24.62	105.89	6.45	94	No	No[c]	Yes
DeMets and Traylen (2000)	26.7	105.2	4.69	97	No	Yes	Yes
B2007-2[a]	22.61	105.63	8.30	99	No	No[c]	No
B2007-1[a]	24.10	105.21	6.35	100	No	No[c]	No

[a] Sole difference between these models is the trend of the Rivera Transform at its intersection with the Rivera Rise.
[b] All azimuths are in degrees as measured clockwise from geographic north.
[c] In these models only one rate measurement was used, or the pole was fixed when determining the angular rotation rates.