Emergence and Petrology of the Mendocino Ridge

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Abstract. The Mendocino Fracture Zone, a 3,000-km-long transform fault, extends from the San Andreas Fault at Cape Mendocino, California due west into the central Pacific basin. The shallow crest of this fracture zone, known as the Mendocino Ridge, rises to within 1,100 m of the sea surface at 270 km west of the California Coast. Rounded basalt pebbles and cobbles, indicative of a beach environment, are the dominant lithology at two locations on the crest of Mendocino Ridge and a 40Ar/39Ar incremental heating age of 11.0 ± 1.0 million years was determined for one of the these cobbles. This basalt must have been erupted on the Gorda Ridge because the crust immediately to the south of the fracture zone is older than 27 Ma. This age also implies that the crest of Mendocino Ridge was at sea level and would have blocked Pacific Ocean eastern boundary currents and affected the climate of the North American continent at some time since the late Miocene. Basalts from the Mendocino Fracture Zone (MFZ) are FeTi basalts similar to those commonly found at intersections of mid-ocean ridges and fracture zones. These basalts are chemically distinct from the nearby Gorda Ridge but they could have been derived from the same mantle source as the Gorda Ridge basalts. The location of the 11 Ma basalt suggests that Mendocino Ridge was transferred from the Gorda Plate to the Pacific Plate and the southern end of Gorda Ridge was truncated by a northward jump in the transform fault of MFZ.

1. Introduction

The magnetic patterns of the seafloor in the northeast Pacific (Raff and Mason, 1961) contributed to the formulation of the hypothesis of seafloor spreading (Vine and Matthews, 1963) yet the origin of the fan-shaped magnetic anomaly pattern on the Gorda Plate (Figure 1) is still the subject of debate. Alternate interpretations of the magnetic lineations lead to different tectonic and petrologic models of the Mendocino Fracture Zone which forms the seismically active southern boundary of the Gorda Plate. Some of these models may be eliminated with new data on the age and type of rocks from the Mendocino Ridge. This data will help to understand: the history of relative plate motion along the MFZ, the convergence of the North American and Gorda Plates at the Cascadia Subduction Zone, the movement along the San Andreas Fault, and the seismicity and deformation of the Gorda Plate. The rocks from the Mendocino Ridge imply that the ridge is dominated by crustal rocks which if confirmed will help to resolve the controversy of its origin.

2. Regional Tectonics

The tectonics and geology of this region were reviewed by Atwater and Severinghaus (1989), Atwater (1989), and Fisk and Howard (1989). The Juan de Fuca and Gorda Plates are bounded on the east by the North American Plate and on the south and west by the Pacific Plate (Figure 1). The zig-zag boundary between the Pacific Plate and Gorda and Juan de Fuca Plates (southward from 46° N) consists of: Juan de Fuca Ridge, Blanco Fracture Zone, Gorda Ridge and MFZ (Figure 1). (The Juan de Fuca and Gorda Plates may exist as a single plate or they may be separated by an incipient fracture zone (Riddihough, 1980, 1984, Clague and Holmes, 1987). For the purpose of this discussion it is convenient to refer to the Juan de Fuca and Gorda Plates separately.)

The direction of relative motion between the Pacific Plate and the Juan de Fuca and Gorda Plates changed from parallel to MFZ to parallel to the Blanco Fracture Zone between 5 and 2.4 Ma (Hey and Wilson, 1982; Riddihough, 1984). Plate reorganization appears to have continued with the rotation (Riddihough, 1980) or deformation (Silver, 1971;
Wilson, 1989) of the Gorda Plate. This is evident in the curved magnetic anomaly pattern of the Gorda Plate (Figure 1) which also indicates that the southern Gorda Ridge has spread more slowly than the northern part (Atwater, 1970; Riddihough, 1980); the northern segment spread nearly symmetrically at a full rate of about 55 mm yr$^{-1}$ and the southern segment (Escanaba Trough) spread asymmetrically 20 mm yr$^{-1}$ west and 7 mm yr$^{-1}$ east (Wilson, 1989).

The short magnetic anomalies on the Gorda Plate compared to those on the Pacific Plate implies: subduction of the Gorda Plate occurred along the MFZ (Silver, 1971; Riddihough, 1980), shortening of the lineations through compression (Wilson, 1986), obduction of Gorda Plate onto the Mendocino Ridge east of its intersection with the Gorda Ridge (Stoddard, 1987), or disruption of the magnetic pattern by faults.

3. Tectonics and Geophysics of Mendocino Fracture Zone

The MFZ was originally surveyed as part of a larger study of the eastern Pacific Ocean basin (Menard, 1960; Raff and Mason, 1961). Additional bathymetric surveys of the MFZ (Krause et al., 1964; Moore, 1970; Moore and Sharman, 1970; Clague et al., 1984) show that the major bathymetric feature of the fracture zone (Figure 2) is its high transverse ridge which we refer to as Mendocino Ridge after Menard (1960). This ridge lies only 1,100 m below sea level at its highest point near its intersection with the Gorda Ridge. To the south, the ridge drops 3,300 m to the Pacific Ocean floor, and to the north it drops 2,100 m to the Gorda Ridge (Figure 2).

The deeper sea floor to the south reflects the old (27 to 32 Ma, Chrons 8 to 11) Pacific crust com-