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# *More Bathymetric Evidence for Block Faulting on the Gorda Rise*[1]

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## ABSTRACT

A detailed bathymetric survey of the crest and axial valley of the Gorda Rise, between 41° 10′ to 41° 29′N and 127° 15′ to 127° 36′W, has revealed several pronounced continuous benches. The most prominent benches are at depths of 2400 and 2800 m. The regional bathymetry is consistent with a block-faulting origin for the topography of the Gorda Rise.

*Introduction.* Menard (1967) and van Andel and Bowin (1968) have independently noted that slowly spreading portions of the oceanic-rise systems consist of steep mountainous topography in the crestal region and of one or more central rift valleys. The Gorda Rise, which shows all the characteristics of a slowly spreading rise system, is probably a northern extension of the East Pacific Rise (Menard 1960, Wilson 1965). The Gorda Rise consists of a single deep central valley flanked by steep crestal ranges that gradually deepen on the flanks into a series of ridges that are covered with sediments from the continental rise on the east and from the abyssal plains on the west. Vine (1966) has shown that the magnetic anomalies are symmetrical and similar to the anomaly patterns in other parts of the rise system; Shor et al. (1968) have indicated that the crustal structure is typical of rise areas.

With data from a deep-towed FISH, Atwater and Mudie (1968) have reported the existence of a number of benches on the inner walls of the axial valley of the Gorda Rise. These benches are made up of a number of block-like steps having (i) steep scarps that face inward toward the center of the valley and (ii) planar tops that dip gently outward. They have interpreted the topography to be the result of block faulting combined with uplift and sea-floor spreading. This paper deals with a detailed bathymetric study of the crest of the Gorda Rise between 41° 10′ to 41° 29′N and 127° 15′ to 127° 36′W;

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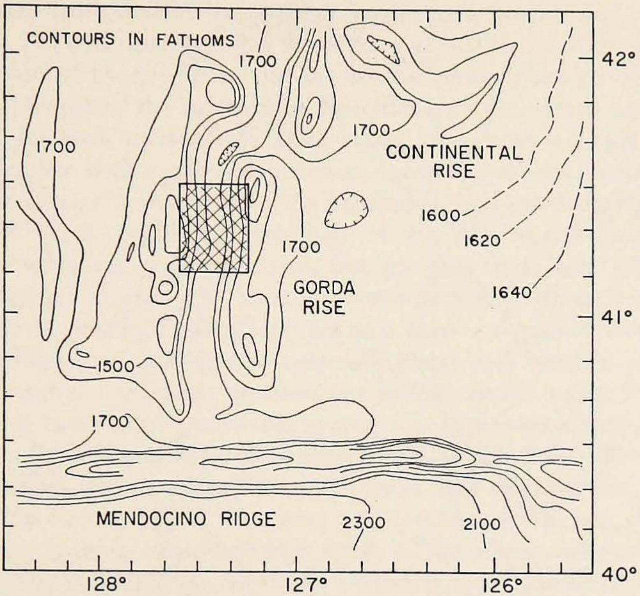


Figure 1. Regional bathymetry of the Gorda Rise. Hatched area shows location of detailed survey.

my survey has included the area of the deep-tow measurements made by Atwater and Mudie. This surface-ship bathymetry extends their results and shows that several individual benches can be correlated for a distance of approximately 35 km along the Gorda Rise.

*Bathymetry.* The bathymetric data were collected primarily on a December 1966 cruise of the R/V YAQUINA; data along several additional lines were obtained in 1968 and 1969. The basic sampling grid for the axial valley and ridge crests consists of 38 east-west bathymetric and magnetic profiles spaced approximately 1 km apart and connected by two north-south tie lines. The survey area is over the southern half of the Gorda Rise (Fig. 1), just south of the major offset in the ridge. Navigation was by Loran A. Fixes were taken every 20 minutes, and the final track positions were determined from a combination of linear fitting of the Loran A positions and adjustments determined from the magnetic tie lines. [The magnetic data will be presented elsewhere.] The tie lines have provided a good east-west control but only minimal north-south control due to the linear nature of the Rise. Based on magnetic data, the estimated uncertainty in position is approximately ± 2 km, but the internal consistency of the bathymetric data suggests that this may be a maximum value. Although some of the east-west lines may cross and although some displacements in the order of the profiles may exist, this uncertainty is not critical to my argument.

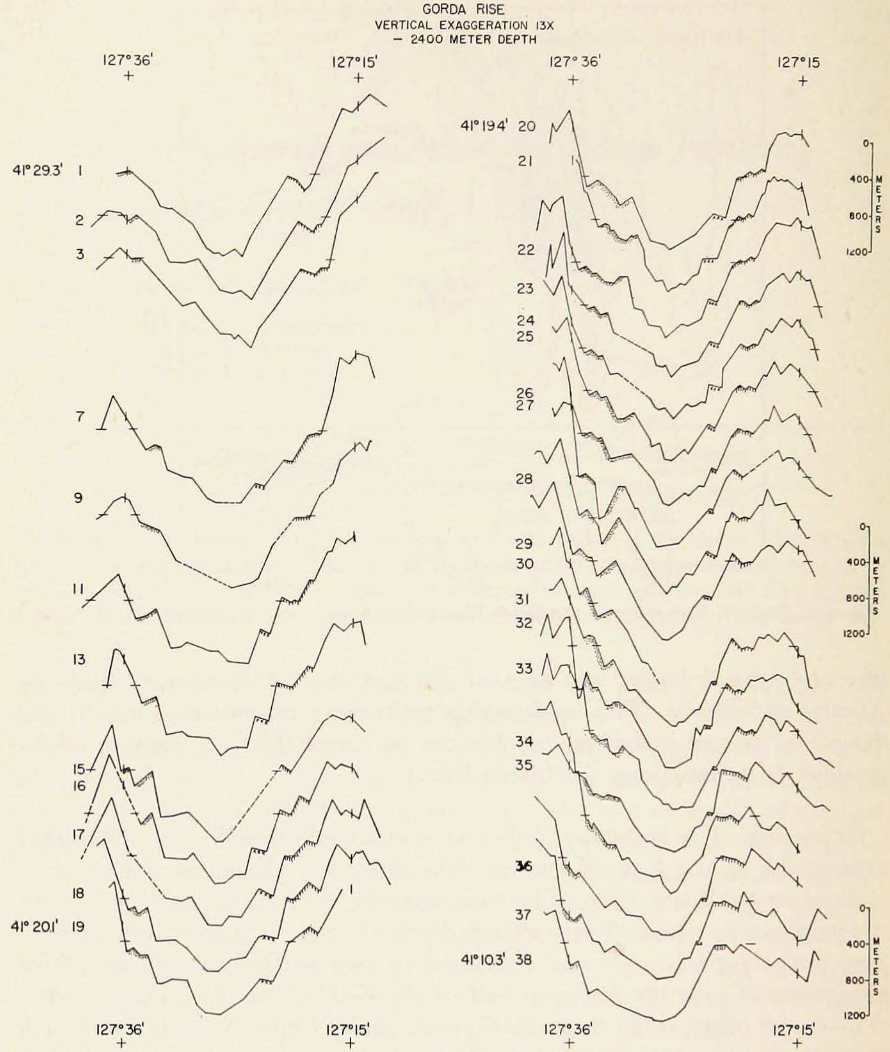


Figure 2. Digitized bathymetric profiles of the Gorda Rise. Dashed lines indicate questionable data or no data. Horizontal tick marks indicate depths of 2400 m. Profile numbers increase from north to south.

The profiles presented in Fig. 2 are line-plotter outputs of digitized bathymetry. All "local highs and lows," together with significant inflection points, were recorded and joined by straight-line segments. The resulting profiles essentially represent the envelope of first-energy return; no attempt has been made to remove the effects of side echos. Equipment failures and sea conditions made the data from several bathymetric crossings unuseable (e.g., profiles 4, 5, 6, 8, 10, 12) and obscured data from parts of additional profiles.

Examination of the profile set reveals several pronounced benches that extend the full length of the survey area. Specifically, a prominent bench appears consistently on both sides of the axial valley at a depth of 2400 m. These benches, together with a 2800-m bench on the east wall, are shown in Fig. 2. The most striking characteristic of the benches is their north-south continuity and uniform depth. Individual crossings of the axial valley have exhibited considerable variation in minor detail, but the general pattern and character of the benches are similar. The 2400-m west-wall bench, which is well defined in the northern profiles (1–19), appears as a more complex "terrace" in the southern profiles (20–35). The corresponding east-wall bench is well defined in the northern and southern profiles; but in the central region it appears to consist of only two small benches that appear to be superimposed on the regional bathymetry of the Gorda Rise. The west bench, which forms the crest in the north, appears to have migrated down the inner wall to the south, where it is approximately 800 m below the crest; the converse holds true for the east bench, which appears near the ridge crest in the south and seems to have migrated down the wall to the north. At a 2400-m depth, however, the benches are horizontal and are oriented at a slight angle to the regional bathymetry, which shoals to the north and south on the east and west walls, respectively (Fig. 1).

In the bathymetric profiles, the 2800-m east-wall bench is shown to be the most consistent additional feature. From crossing 7 to 37, it has been correlated with a very characteristic outward-facing planar top. No consistently appearing corresponding bench is evident on the west wall except for limited distances (see profiles 15–19). Additional benches can be correlated across several profiles, but they do not maintain continuity over the entire survey area.

*Discussion.* A comparison of the profiles in Fig. 2 with profiles of Atwater and Mudie (1968: figs. 2, 3) shows that all the major features illustrated in their deep-towed profiles exist in my profiles. In particular, both the 2400-m benches and the 2800-m east-wall bench appear as major steps on the Atwater and Mudie deep-tow profiles. Their deep-tow profiles do show considerable fine-scale structure that is not apparent in my profiles. The north-south continuity of the individual benches indicates a primary origin for the steps and suggests that the regional tectonism (uplift) has controlled the development of the benches.

Additional evidence for regional uplift is provided by Atwater and Mudie (1968) and Fowler and Kulm (1970). Atwater and Mudie have noted that the tops of many of the block-like benches are covered with varying thicknesses of planar acoustic reflecting layers. Without the aid of samples, they have speculated that these sedimentary deposits were deposited by turbidity currents on the floor of the axial valley prior to the block faulting and subsequent uplift of the benches. Fowler and Kulm (1970), using dredge samples from the axial valley, have confirmed the turbidity-current origin of these sediments and have estimated for the Gorda Rise a *minimum* rate of uplift of 0.1 cm/yr; this estimate has been based on a maximum age for the sedimentary rocks; the rate of uplift may actually be of the order of 1.5 cm/yr—comparable to that found by Duncan and Kulm (1970) for the Blanco Fracture Zone. A similar rate of 1.5 cm/yr has been suggested for the Mid-Atlantic Ridge in the vicinity of the Vema Fracture Zone (van Andel 1969). In addition, Fowler and Kulm (1970) have noted that two of their dredge hauls (6701F-5 and 6701-8) from an approximate depth of 2400 m contained very similar coarse-grain sediments; one dredge haul was from the east wall, the other from the west wall. They have suggested that the similar sediments may have been deposited at the same time. If this is the case, then the 2400-m bathymetric benches probably developed at the same time in response to the regional uplift.

If the Gorda Rise is a typical segment of a slowly spreading oceanic-rise system, then similar linear benches should be found in other parts of the rise system. However, if trackline spacings are much greater than 5 to 10 km, it may be difficult to correlate individual benches because of the fine-scale variation in structure. The resulting bathymetric maps should show a series of elongated terraces within the rift valleys. As suggested by Atwater and Mudie (1968), the studies of the Mid-Atlantic Ridge by van Andel and Bowin (1968) and Loncarevic et al. (1966) may illustrate comparable features for this slowly spreading rise system.

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## REFERENCES

ATWATER, T. M., and J. D. MUDIE
1968. Block faulting on the Gorda Rise. Science, *159*: 729–731.

DUNCAN, J. R., and L. D. KULM
1970. Vertical tectonic movements in the Blanco Fracture Zone. Trans. Amer. geophys. Un., *51*: 331.

FOWLER, G. A., and L. D. KULM
1970. Foraminiferal and sedimentological evidence for uplift of the deep-sea floor, Gorda Rise, Northeastern Pacific. J. mar. Res., *28*: 321–329.

LONCAREVIC, B. D., C. S. MASON, and D. H. MATTHEWS
1966. Mid-Atlantic ridge near 45° North; 1, The median valley. Can. J. Earth Sci., *3*: 327–349.

MENARD, H. W.
1960. The East Pacific Rise. Science, *132*: 1737–1746.
1967. Sea floor spreading, topography, and the second layer. Science, *157*: 923–924.

SHOR, G. G., JR., P. DEHLINGER, H. K. KIRK, and W. S. FRENCH
1968. Seismic refraction studies off Oregon and northern California. J. geophys. Res., *73* (6): 2175–2194.

VAN ANDEL, TJ. H.
1969. Recent uplift of the Mid-Atlantic Ridge south of the Vema Fracture Zone. Earth Planet. Sci. Letters, 7 (3): 228–230.

VAN ANDEL, TJ. H., and C. O. BOWIN
1968. Mid-Atlantic Ridge between 22° and 23° North Latitude and the tectonics of mid-ocean rises. J. geophys. Res., *73* (4): 1279–1298.

VINE, F. J.
1966. Spreading of the ocean floor: new evidence. Science, *154*: 1405–1415.

WILSON, J. T.
1965. Transform faults, oceanic ridges and magnetic anomalies southwest of Vancouver Island. Science, *150*: 482–485.