Reports

Block Faulting on the Gorda Rise

Abstract. *A study made of Gorda Rise near 41°15′N with a novel instrument shows that the rift-valley walls have a tilted steplike profile, often with perched, planar sediments. Topography indicates that the steps were formed by block faulting. Distribution of the steps and the character of their tops suggest that they originated in the central 2 or 3 kilometers of the valley floor and were subsequently moved outward, uplifted, and tilted along with their underlying blocks as the sea floor spread. Gorda Rise is considered a slowly spreading part of the oceanic-rise system. Studies of the Mid-Atlantic Ridge report features that may be similar uplifted blocks.*

Gorda Rise consists of a single, deep, central valley edged symmetrically by steep crestal ranges. The outer flanks of the ranges gradually deepen in a series of ridges until they are buried by the continental rise on the east and by the abyssal plains on the west. In May 1967 we made a detailed survey of the valley and flanks of Gorda Rise near 41°20′N,127°30′W (Fig. 1) using a novel instrument (*1*) that collects magnetic, topographic, and seismic bottom-penetration data from very near the sea floor. We now report some of the topographic and penetration data related to the problem of the origin of the central rift.

Figure 2 is a seismic-reflection record of profile *A* (Fig. 1) on the west wall of the central valley. It shows that this part of the wall is made up of a number of block-like steps, with steep scarps facing inward toward the center of the valley and with planar tops dipping gently outward; the tops are covered with varying thicknesses of sediments. Similar simple sediment-topped steps are found in all our profiles of the valley walls; on the eastern wall they are the predominant topographic form (for example, from +1 to +10 km in Fig. 3), while on the western wall they make up from 25 to 50 percent of the bottom topography (for example, at −15, −13, and −6 km in Fig. 3; from 6.5 to 11.5 km in Fig. 2). We interpret these simple steps as the surface expression of block faulting.

Interspersed among the simple steps on the western wall are several sections having irregular rocky surfaces. The rough areas are not structureless, however, for several high, steep, inward-facing scarps can be distinguished within the smaller-scale roughness. We interpret these as fault scarps originating similarly to the scarps on the simple blocks. Thus the form of the entire central valley and walls appears to be dominated by block faulting, with relative movements on the faults similar to those indicated (Fig. 3).

Many of the upper surfaces of the perched sediments in Fig. 2 and in other records are approximately planar in spite of the rough basement beneath them. Furthermore they are not horizontal but rather are gently tilted outward, away from the central valley. It does not seem likely that these sediments are pelagic material deposited upon the rock structure after it took its present form. They are not draped conformally over the basement as one might expect if sediment had simply fallen from above; nor do they show scouring and ponding effects at the tops and bottoms of the scarps as might be expected if the sediments had been moved by currents during or after deposition. Furthermore, correlations of magnetic anomalies (*2*) indicate that the basement material in the central valley is less than 700,000 years old, so that the required pelagic sedimentation rate would be greater than 40 m/10^6 years, a rate considerably higher than is usually considered reasonable (*3*, p. 153).

The alternative explanation of the sediment bodies is that they were deposited on the basement before the latter was block-faulted. They could have so originated in either of two ways: In one model we can imagine that the basement material of the valley floor and walls originated as a relatively horizontal surface, and that flat sediments were then deposited, partly burying a rocky bottom. Given a regional east-west tension, a rift may

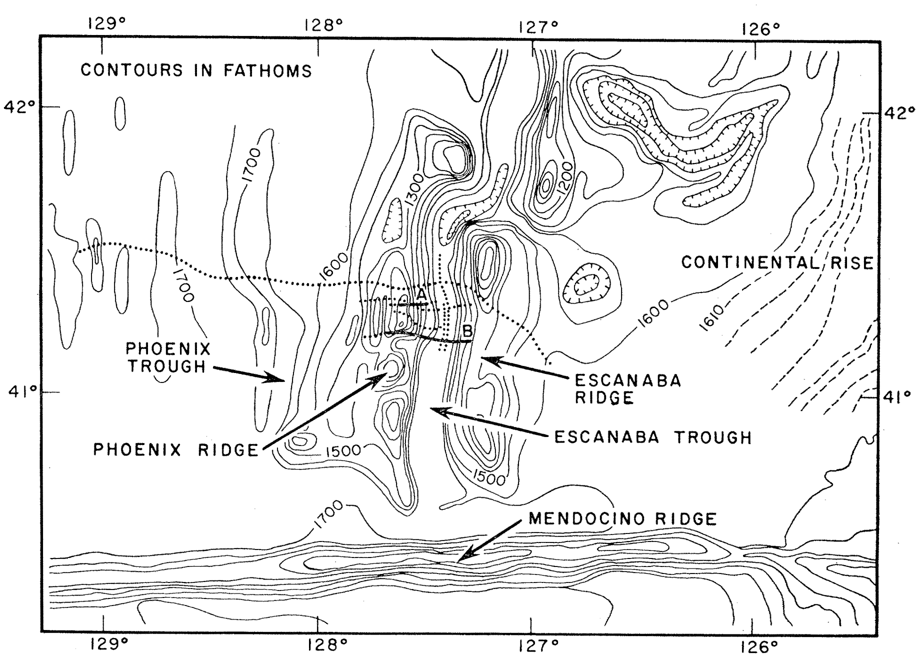
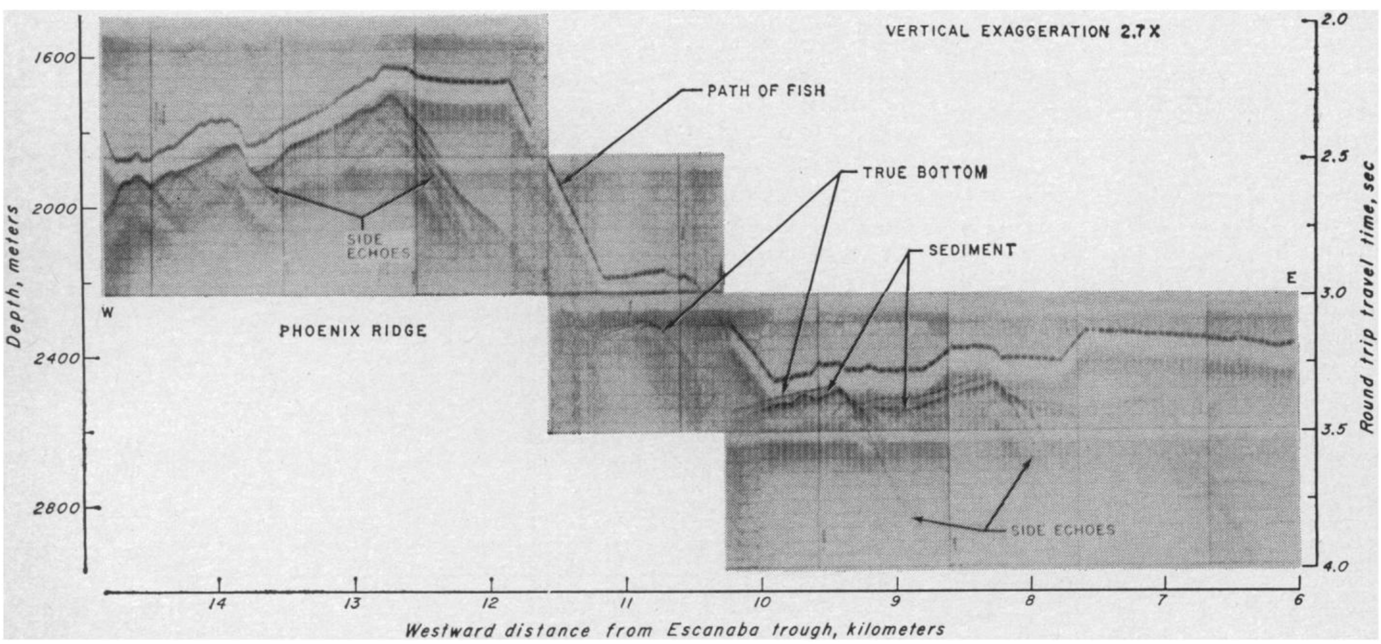


Fig. 1. Deep-towed survey of Gorda Rise. Heavy lines indicate profiles *A* and *B* (Figs. 2 and 3). Dotted lines indicate other pertinent profiles. Bathymetry and nomenclature are from McManus (*4*).

have formed with a central graben valley and down-faulted blocks in the walls. This theory explains our data simply but is not very compatible with concepts of uniformitarianism and of continuous spreading of the sea floor. Therefore we prefer this second, more complex theory:

We propose that the block-top sediment bodies (Fig. 2) originated as turbidites in the floor of the central valley and were deposited during and shortly after formation of the rock material of the floor itself. The floor was then faulted, moved outward, tilted, and uplifted in blocks as the sea floor spread. A source for turbidite sedimentation on the valley floor is given by McManus (*4*) who notes that the southern end of Escanaba Trough is open to the continental rise; he attributes the smooth floor in the south to "continental-rise type" sedimentation. Our survey showed flat sediments covering sections of the valley floor as far north as 41°42'N. Interspersed with the sediment are areas of rock varying in relief from almost smooth to 200-m-high hills. This mixed character of rough bare rock and planar sediments found on the valley floor is strikingly similar to that found on the tops of the steps in the valley wall; again the suggestion is that the block-faulted material of the walls originated in the floor.

If the sea floor is in fact being formed in the valley bottom and then being uplifted and carried outward in blocks, and if this process is more or less continuous, we should be able to find blocks at the edges of the valley bottom that are just beginning to be uplifted. The central part of the profile in Fig. 3 can be interpreted in this way. The valley floor here consists of flat sediments and rock. The central lowest section of the valley is only 2 km wide and is bounded by 20-m scarps. Above the scarps the flat terrain continues until again it terminates in scarps. On the western side, the bottom material of these benches is bare rock, while on the east it is sediment that is flat and continuous between scarps. The western terraces and scarps could be interpreted as the tops and ends of lava flows, although an abrupt 20-m scarp seems rather high and unlikely for a flow front. However, the best single explanation of



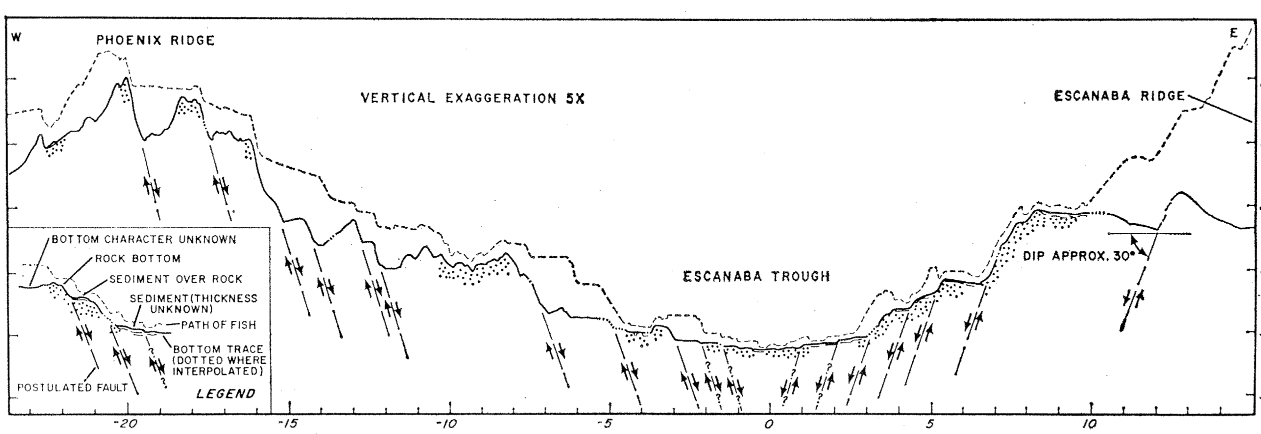


Fig. 2 (top). Profile *A* (Fig. 1): continuous seismic-penetration record from 3.5-khz system on FISH. Top trace is path of FISH; lower traces are bottom and subbottom reflections. Note blocky topographic form and planar sediments overlying rough basement on block tops. Steeply descending traces are side echoes from nearby bottom features, and should not be interpreted as deep penetration. Depths corrected according to Matthews (*14*). Fig. 3 (bottom). Profile *B* (Fig. 1): topography and bottom character of Escanaba Trough and walls. Bottom character (inset) has been deduced from penetration and side-looking sonar records. Dashed line is path of FISH. Depths corrected according to Matthews (*14*).

the benches on both sides seems to be that they are blocks that have been uplifted 20 m relative to the valley floor. As one approaches the rift walls, the scarps become higher and the blocks become more tilted, as one would expect from our spreading, uplifting hypothesis.

So far we have discussed only the features of the central valley of Gorda Rise. The features found on the outer flanks of the crestal ranges are somewhat more complex. Blocklike topography also occurs here but it is partially obscured by sediments and disrupted by what appear to be volcanic structures. Wherever blocks can be identified, they are tilted, the steep scarps facing inward toward the valley, and the gentle backslopes facing outward. A tilted-block form was found in abyssal hills 90 km west of the central valley.

Gorda Rise has been established as part of the oceanic-rise system. Menard (*5*) and Wilson (*6*) both consider it to be a northward continuation of the East Pacific Rise, and McManus (*4*), summarizing much of the data available for this area, comes to a similar conclusion although he also provides an alternative. Shor *et al.* (*7*) show that in crustal structure Gorda Rise resembles other parts of the oceanic-rise system, and Vine (*2*) shows that the magnetic-anomaly pattern is symmetric across it and is similar to the pattern mapped in other parts of the system. Present activity of Gorda Rise is indicated by high heat flow (*8*) and by earthquake activity (*9*).

Menard (*10*) has noted that portions of the oceanic-rise system fall into two distinct groups, depending upon their spreading rates. The portions that spread rapidly, typified by the southern East Pacific Rise, are characterized by smooth, hilly topography and a thin second layer. Portions that spread more slowly have steep mountainous topography, with one or more central rift valleys and a thicker second layer. Gorda Rise shows all the characteristics of the slowly spreading parts of the oceanic-rise system (*4, 7*).

If Gorda Rise is typical, the detailed block structure (Fig. 2) should be seen on the rift-valley walls of other slowly spreading portions of the system. However, the usual survey, using a wide-beam echo sounder aboard a surface ship, would show the larger blocks as rounded hills, and the smaller ones as faint side echoes in an almost smooth slope. In their report on the Mid-Atlantic Ridge near 23°N, Van Andel and Bowin (*11*) describe a number of elongated parallel ridges and steps in the valley and on the slopes and peaks; nearly all their profiles show several steps in the inner walls of the rift. All these features might be revealed as tilted-block structures by techniques providing higher resolution. Indeed, Van Andel and Bowin suggest on petrographic grounds that the gross structure of the ridge originates in the uplifting and tilting of blocks; their Fig. 7 shows the ridge top and a lower step interpreted as uplifted blocks.

The Mid-Atlantic Ridge was studied in detail near 45°N by Loncarevic, Mason, and Matthews (*12*); their bathymetric chart and their various profiles clearly show a rounded bench, often 5 km wide, about halfway up the rift walls. This may represent a large, uplifted, tilted block, although Loncarevic (personal communication) states that no specific evidence was found to indicate block faulting.

For the northern East Pacific Rise, Menard and Mammerickx (*13*) have recontoured the ship soundings of several detailed surveys; they believe that the origin of the topography on this part of the rise system can best be described as a combination of volcanism and block faulting.

In conclusion, the detailed form of the topography indicates that the walls of Gorda Rise central rift valley are composed of faulted blocks. We believe that the best explanation of the height and shape of these blocks, the character of their tops, and the form of their sediments is that they originated in the valley floor and have been uplifted and displaced from the valley center to form the walls. Furthermore, other reports of detailed studies show the possibility that this mechanism is general for formation of the topography of the central valleys of slowly spreading portions of the oceanic-rise system.

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Lysergic Acid Diethylamide (LSD): No Teratogenicity in Rats

Abstract. *Lysergic acid diethylamide (LSD) in doses of 1.5 to 300 micrograms was given to 55 pregnant rats during periods of organogenesis and on the 4th or 5th day of pregnancy to 34 rats. Examination of the resultant 887 young for congenital defects showed no greater frequency than in controls. These experiments failed to prove that LSD is teratogenic in rats.*

The report of Cohen *et al.* (*1*) of chromosomal damage in human leucocytes, induced by lysergic acid diethylamide (LSD), prompted us to test this compound for teratogenicity in rats. A pilot experiment was planned to ascertain possible effects of the drug administered to pregnant Wistar rats during periods of embryonic organogenesis. Delysid (Sandoz; batch 65002), containing LSD at 0.1 mg/ml, obtained from the National Institute of Mental Health, was administered intraperitoneally or orally in single doses on the 7th, 8th, or 9th day of gestation, or in multiple doses from the 7th to the 12th day. The total dosage to individual rats ranged from 1.5 to 300 μg.

Fifty-five pregnant rats were treated; four litters were completely resorbed; 47 rats were killed on the 21st day of pregnancy and their young were removed; four were allowed to deliver and raise their young. The mean litter size of the 21-day fetuses was 10.2 $\pm$ 1.8 (controls, 10.0 $\pm$ 2.8); their mean weight was 3.53 $\pm$ 0.44 g (controls,