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CURRENT PROBLEMS IN RESEARCH

# The East Pacific Rise

## Recent marine geophysical measurements have shed some light on processes acting in the earth's mantle.

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The sea floor slopes downward from California to Hawaii, and there is no obvious reason why it should. Ten years ago it seemed not unreasonable that the floor of an ocean basin should slope downward from the continental margin to the center. True, the deepest parts of the oceans are at the margins, but in many places, notably the east coast of North America, a great apron of continental debris forms a transitional slope between continent and ocean. As cores of sediment and seismic stations measuring the thickness of sediment accumulated, it became apparent that, off southern California, the apron of continental debris is either very narrow or nonexistent, and the sediment of the deep-sea floor is of relatively uniform thickness. The underlying layers in the earth's crust are also of relatively uniform thickness, and consequently the top of the mantle is parallel to the sea bottom. The slope between California and Hawaii is apparently produced by some variation in the mantle itself.

The fact that this was not an isolated problem was established immediately before and during the International Geophysical Year, when the Scripps Institution of Oceanography undertook to explore the East Pacific Rise. This rise, a vast bulge in the sea floor, extends through the remotest waters on earth and was little known; even the general outlines of the topography had only just been established by U.S. Navy ships during Operations Highjump and Deepfreeze. Scripps geological expeditions had already reached the fringes of the rise in regions east of the Marquesas Islands and west of Central America and found abnormal heat flow in both places and abnormal seismic velocities in the mantle at one of them. Comparable anomalies had been found in the North Atlantic, where the Mid-Atlantic Ridge is conveniently located for exploration. Maurice Ewing (*1*) and his collaborators at Lamont Geological Observatory found abnormal seismic velocities, and Sir Edward Bullard of Cambridge University found very high heat flow at the crest of the ridge. Were these few values characteristic of oceanic rises and ridges in general?

Another question to be investigated was raised by a hypothesis just then proposed by Ewing and Bruce Heezen. It had been known for many years that the Mid-Atlantic Ridge, the Mid-Indian Ridge, and the various ridges and rises of the Pacific basin form an almost continuous topographical feature marked by shallow earthquakes. Heezen and Ewing discovered a central rift valley associated with the seismic belt at the crest of the Mid-Atlantic Ridge in the North Atlantic, and they proposed (*2*) that the earthquakes originated in the rift valley and, since the topographic highs and the seismic zone extended through the oceans, that the rift must be continuous for 80,000 kilometers. If so, it would be present in the area to be studied in the parts of the East Pacific Rise which were about to be explored.

The Scripps Expedition Downwind was designed as a field experiment to investigate the known questions about topography, crustal structure, and heat flow of the East Pacific Rise as well as a number of problems of physical oceanography, geochemistry, and biology. The results (*3*) of this expedition and of others before and after (Fig. 1) can be combined to give a progress report on research on the East Pacific Rise. Attention is focused here on three questions. Does the rise extend under western North America? Are transverse wrench (tear) faults part of the rise structure? What is the origin of the rise?

### Location and Topography

The East Pacific Rise is a vast low bulge of the sea floor comparable in size to North and South America (Fig. 2). The average relief is 2 to 3 kilometers, exclusive of the additional local relief of features such as volcanoes. The rise is 2000 to 4000 kilometers wide, and from Mexico to New Zealand it is 13,000 kilometers long.

Transverse to the East Pacific Rise are a number of long straight bands of mountainous topography called fracture zones (*4*). The crust of the rise is offset or changes trend in several places where it is intersected by fracture zones. In addition, the whole width of the rise has been displaced vertically by several hundred meters along some fracture zones. Thus, it appears that the vast bulge of the rise has been sliced

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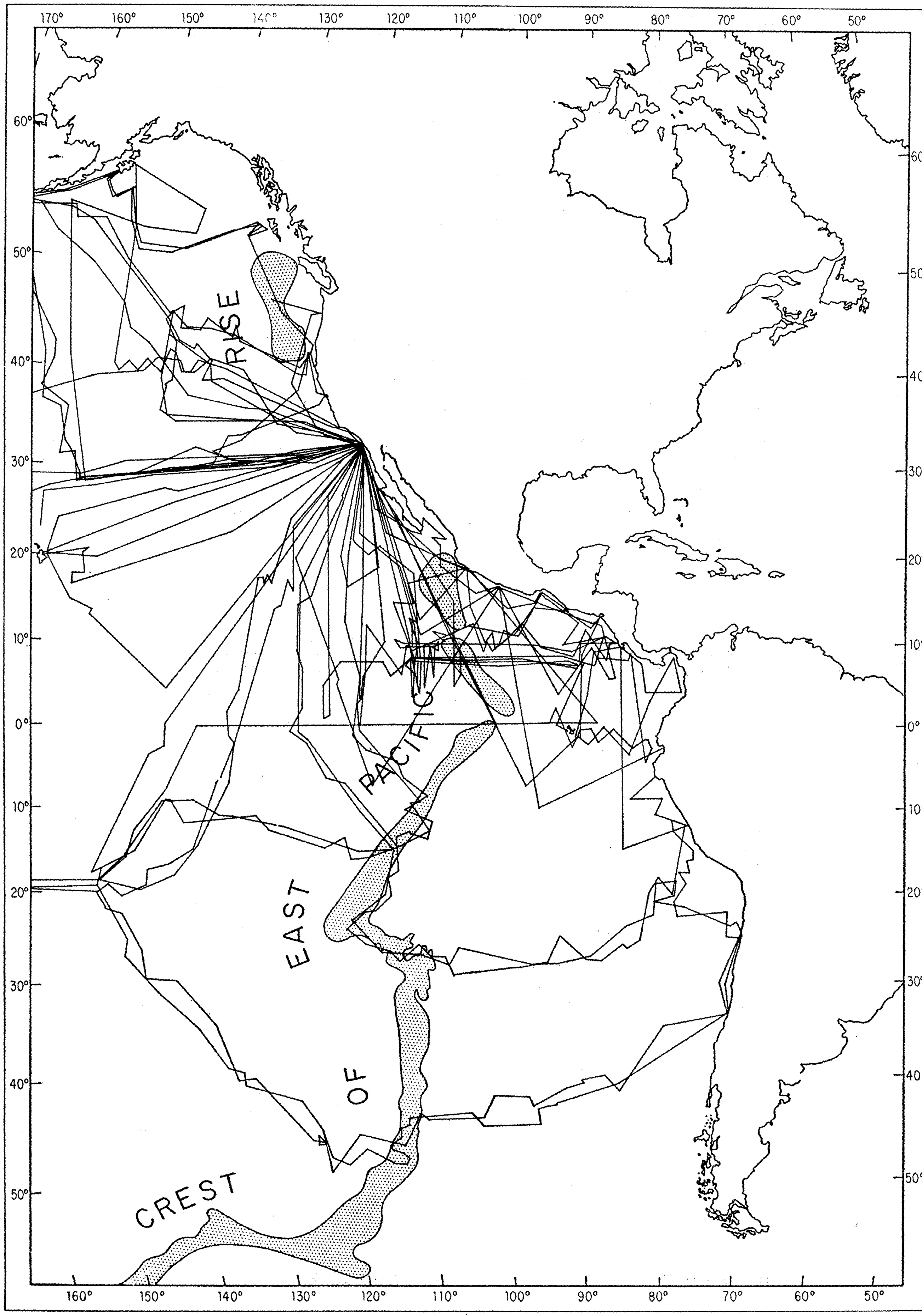


Fig. 1. Scripps Institution of Oceanography sounding and sampling lines in the eastern Pacific.

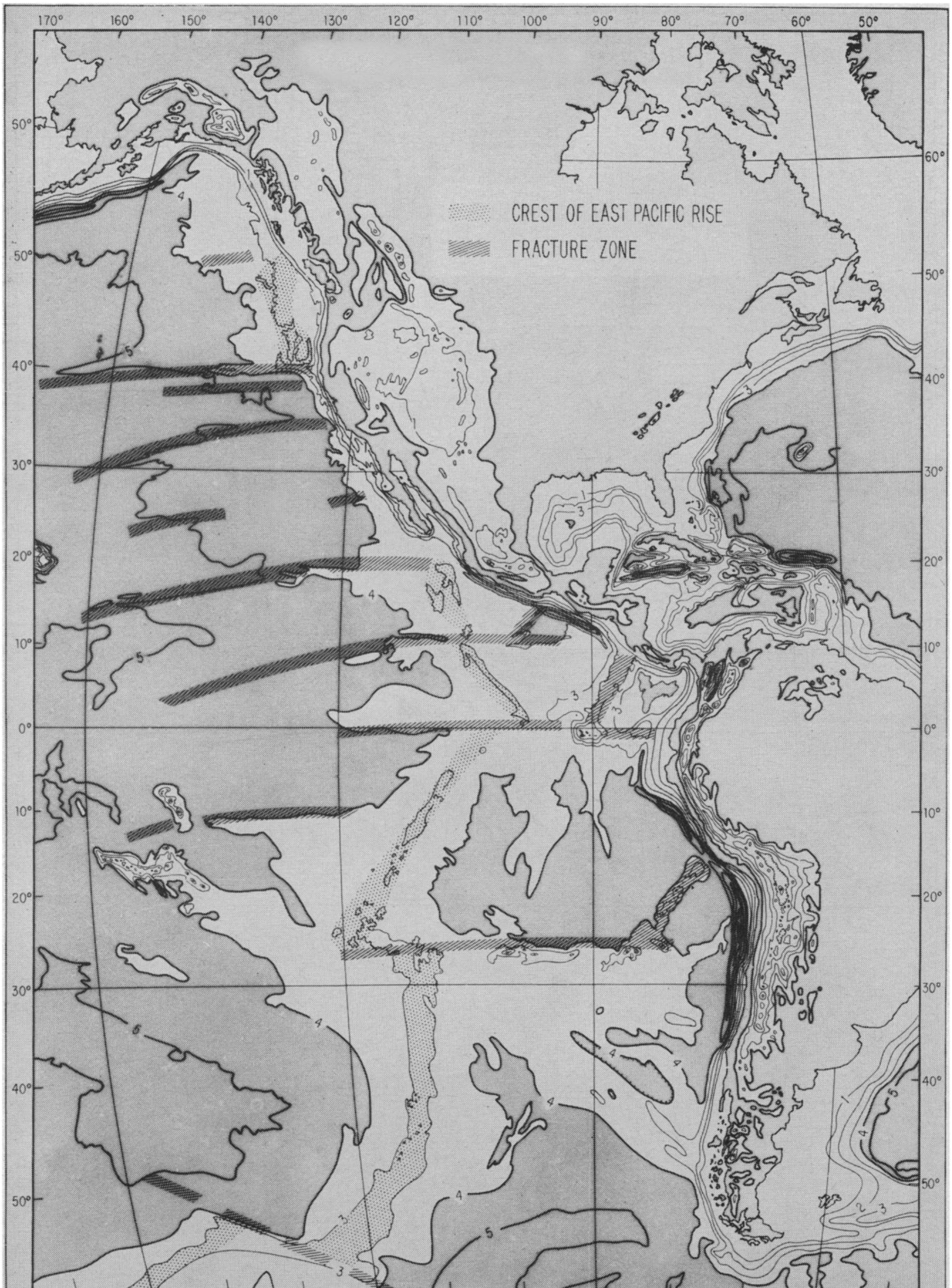


Fig. 2. Topography of the eastern Pacific and the Americas (depths and elevations in kilometers). Areas shallower than 4 kilometers in the ocean or higher than 1 kilometer on land are shown in white and are considered anomalous. On this basis the crest of the East Pacific Rise appears to extend for some distance through western North America, and the western slope of the rise is continuous as far north as Alaska.

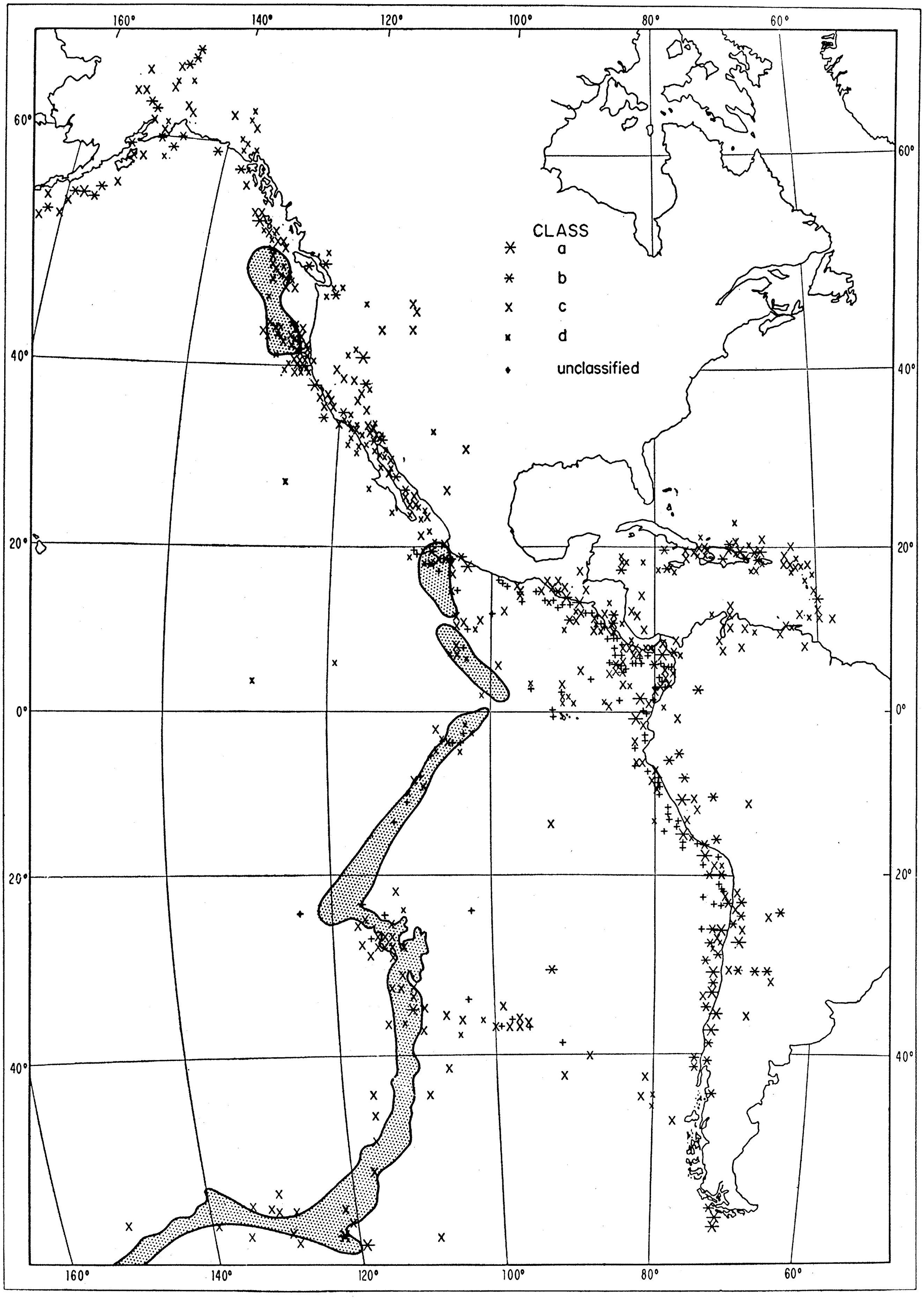


Fig. 3. Distribution of shallow earthquakes along the East Pacific Rise.

into sections which have been moved.

The fracture zones of the eastern Pacific characteristically have a relief of a few kilometers, a width of a few hundred kilometers, and a length of several thousand kilometers. Basically, they can be visualized as broad welts separating regions with different depths. Very long straight faults parallel to the welt have cut the center of each welt. The straightness of the faults suggests that the dominant displacement has been wrenching or horizontal movement. However, the only displacements evident from topography in most places are vertical ones, which have more of a tendency to produce relief. The central parts of the welts have been broken up in one of two ways. Typically, on the eastern ends of the fracture zones, only half of a welt is evident, and it is bounded by a cliff as much as 3 kilometers high. In contrast, the western parts of the fracture zones generally have a welt with the center collapsed in a band of elongate fault blocks forming ridges and troughs (graben). Large submarine volcanoes and islands are also common in fracture zones. For example, the Clarion fracture zones grade from west to east, from a welt with a central graben, to a graben interrupted in places by volcanoes, to a group of volcanic islands. On shore, along the same trend, are the line of great volcanoes of central Mexico. Fracture zones also separate topographic provinces in which volcanoes are common from provinces in which they are rare.

The oceanographers of Lamont Geological Observatory have now traced the median rift system discovered by Ewing and Heezen in the North Atlantic through the South Atlantic, where more than one rift exists, and into the Indian Ocean. English and German oceanographers have found gaps in the rift in some places in the North Atlantic, and in other places detailed surveys have shown it to be discontinuous. Results of the search for a rift in the East Pacific Rise during Downwind, Dolphin, and Doldrums, the three Scripps IGY expeditions, have been negative, despite repeated crossings of the crest of the rise. Indeed, in the Southern Hemisphere the crest of the East Pacific Rise is exceptionally smooth compared with the normal hilly or mountainous local relief of the sea floor. In other places the crests of median elevations of the ocean basins typically have been faulted into graben and horsts trending roughly parallel to the rises. This type of topography is prominent in the Ridge and Trough province off Oregon and Washington.

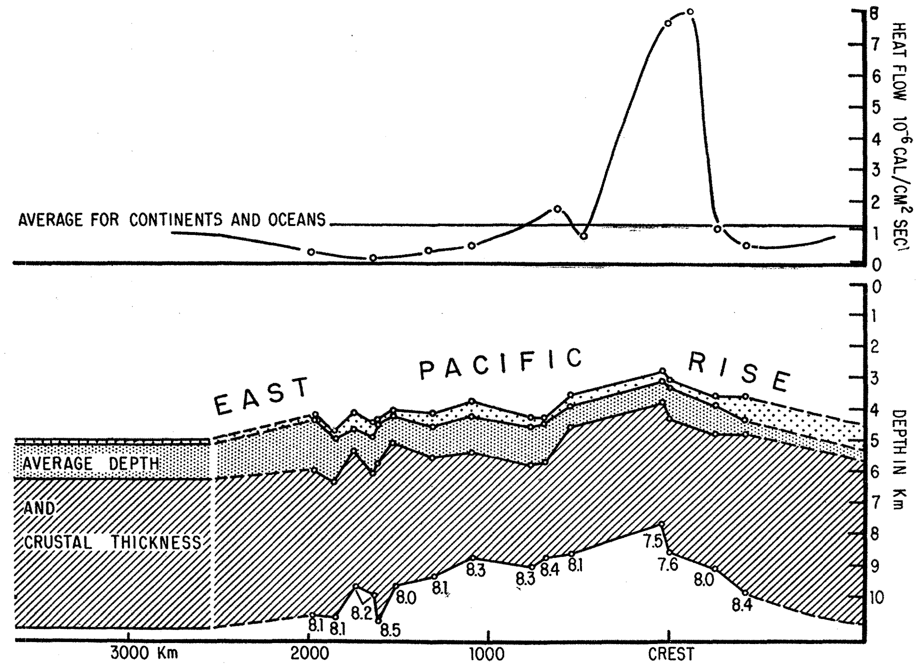


Fig. 4. Crustal section and heat flow profiles of the East Pacific Rise. Velocities below the "crust" are in kilometers per second. The crust is thinned under most of the rise, but the region of very high heat flow and anomalous "mantle" velocities is confined to a narrow band on the crest.

## Seismicity

Shallow earthquakes are common along the crest of the East Pacific Rise (Fig. 3). Uncertainties in fixing epicenters in the southeastern Pacific make it impossible to establish whether the earthquakes are precisely aligned along the crest. Ewing and Heezen have found a very close correspondence between epicenters and the crest of the Mid-Atlantic and Mid-Indian ridges, and they have suggested a similar relationship in the Pacific. I have pointed out that earthquakes are more common within fracture zones than elsewhere in the eastern Pacific basin, but it now appears that this may be an incidental effect of the intersection of the East Pacifiic Rise seismic belt with transverse fault structures.

## Crustal Section

An extensive network of shipborne seismic stations has been occupied by the Scripps geophysicists R. W. Raitt (*5*) and G. G. Shor in the eastern part of the Pacific Ocean. Results obtained at these stations show that the topographic bulge of the East Pacific Rise is matched by a very similar bulge of the mantle. However, it appears from present data that the mantle bulge has somewhat greater relief (Fig. 4). The oceanic crustal section consists almost everywhere of a layer of unconsolidated sediment a few hundred meters thick, a "second layer" of consolidated sediment and volcanic rock which is variable but, roughly, 1 kilometer thick, and a "third layer" or oceanic crust proper, which is separated from the mantle by the Mohorovičić discontinuity. The average thickness of the third layer at the 21 seismic stations within the Pacific basin, as defined by the andesite line, but off the East Pacific Rise is 4.9 kilometers. On the other hand, the average thickness of the third layer at seven stations within 1400 kilometers of the crest of the rise is only 3.7 kilometers. An additional group of five stations very near the crest of the rise does not obtain normal mantle velocities (8 km/sec or more) below the third layer, and there is a question about calling the third layer the "crust." However, the third layer, as such, at all 12 stations within 1400 kilometers of the crest, has an average thickness of only 3.8 kilometers, or 1 kilometer less than that found at an average station elsewhere in the Pacific basin.

## Heat Flow

The intensity of heat flow through the crust of the East Pacific Rise has a close correlation with the topography, according to numerous observations by Richard von Herzen (*6*), Arthur Maxwell, and Roger Revelle. Average heat flow on continents and in ocean basins away from rises is about $1.1 \times 10^{-6}$ cal/cm$^2$ sec. Along the crest of the rise the heat flow ranges between 2 and $8 \times 10^{-6}$ cal/cm$^2$ sec in a band a few hundred kilometers wide and 10,000 kilometers long (Fig. 5). Similarly, high heat flow occurs on the crest of the Mid-Atlantic Ridge. In marked contrast, an area as much as 3000 kilometers wide and 6000 kilometers long on the west flank of the rise has low heat flow, with values of 0.14 to $0.97 \times 10^{-6}$ cal/cm$^2$ sec. Another belt of low heat flow appears to exist on the east flank of the rise, but there have not been enough observations for us to be sure. The Downwind expedition was designed to investigate a suspected correlation of high heat flow with the crest of the East Pacific Rise, and this has been confirmed. The belt, or belts, of low heat flow had not been suspected, and another expedition will be required to work out the pattern in the eastern Pacific.

## Does the Rise Extend under Western North America?

Now that the general characteristics of the East Pacific Rise have been described, the question of its continuation under western North America may be considered.

With regard to topography, it should be emphasized that this rise is only the Pacific section of a system of mid-ocean elevations which extends around Antarctica into the Indian and Atlantic oceans. An abrupt end to the system off Mexico would thus be all the more remarkable. However, the maps show that, although the crest of the rise can be traced as a distinct submarine feature only as far north as the latitude of Mexico, the western flank continues up to Alaska, and the crestal type of topography reappears off Oregon and Washington as the Ridge and Trough province. The puzzling slope between California and Hawaii is the west flank of the rise, and much of the geological exploration of the eastern Pacific has been on different parts of the same great feature. Where the crest and east flank of the rise intersect Mexico are found the plateau of Mexico, the Colorado Plateau, and the Basin Ranges, comprising a topographic bulge of the continent comparable in scale to the bulge of the sea floor. Similar plateau highlands exist only in central Asia and in east Africa, and the latter occurrence lies along a continuation of the rise in the Indian Ocean.

As for seismicity, the continuity of a belt of shallow earthquakes from the the crest of the East Pacific Rise south of Mexico, through the Gulf of California and California, to the Ridge and Trough province cannot be questioned. In California, however, many of the earthquakes are along the San Andreas fault, which may be unrelated to the stresses producing the rise faulting.

The typical thin oceanic crust of the rise reappears in the Ridge and Trough province, according to preliminary shipboard calculations by Raitt. This type of crust cannot, of course, be identified in the intervening continent.

The high heat flow characteristic of the East Pacific Rise south of Mexico has also been found by von Herzen in the Gulf of California, in the continental borderland off southern California, and in the Ridge and Trough province. The discontinuity under California appears to be a relatively trivial break in this long belt of high heat flow associated with the crest of the rise.

In summary, the East Pacific Rise, identifiable as an elevated region with a seismically active crest and high heat flow, extends from the south Pacific, under western North America, into the northeasternmost Pacific. The corresponding elevation of the mantle that is found in the oceanic regions has not been found under the intervening continent.

## Possible Genetic Relationship between Rise and Fracture Zones

The great structures of the eastern Pacific basin are the East Pacific Rise and the system of intersecting fracture zones. Various lines of evidence suggest that the structures are genetically related—namely, similar geographical position, similar scale of crustal displacement, and interaction.

The fracture zones of the eastern Pacific form a pattern of rather regularly spaced and approximately parallel lines distributed in an area of about 10 percent of the earth's surface. As more sounding lines are collected it appears increasingly definite that most of the fracture zones do not extend as prominent features beyond the flanks of the East Pacific Rise, thus suggesting a genetic relationship. However, the possibility remains that these very extensive fractures are part of an ancient global system which has been rejuvenated and accentuated in the eastern Pacific. Lineations resembling fracture zones have been described in many places in the world, and the whole pattern in China is strikingly similar. Various worldwide fracture systems have been described, notably by F. A. Vening Meinesz (*7*), but the east Pacific zones, as a group, do not fit into any such pattern as yet proposed.

A comparison of crustal displacements associated with fracture zones and deduced from the structure of the rise requires a detailed description of available observations. Topography alone merely suggests that fracture zones are wrench faults, but a series of remarkable maps of the earth's magnetic field in the northeastern Pacific, prepared by Scripps geophysicists, not only proves the direction of faulting but gives the amount along several fracture zones. The first maps made by Ronald Mason (*8*) show a very extensive pattern of distinctive magnetic anomalies trending very close to north-south. The pattern is offset 150 kilometers in a right-lateral direction at the Murray fracture zone (which may now properly be called a fault). Stimulated by this discovery, Victor Vacquier began a series of magnetic surveys to establish whether displacements could be measured on other fracture zones. To date, he has found a 250-kilometer, left-lateral displacement of the Pioneer fault and a 1200-kilometer left-lateral displacement on the Mendocino fault (Fig. 6). This last displacement is by far the largest that has been measured on earth. Indeed, it is difficult to see how such large displacements could be established except in the very favorable circumstances which exist in the eastern Pacific basin. A similar displacement would tear a continent in half.

Depth contours in the area of the magnetic maps are offset in the same directions as the magnetic anomalies. To a remarkable degree, the amount of offset is also similar. The coincidence in offset is best demonstrated by the 4500-meter contour, which is least affected by the deposition of sediment near the

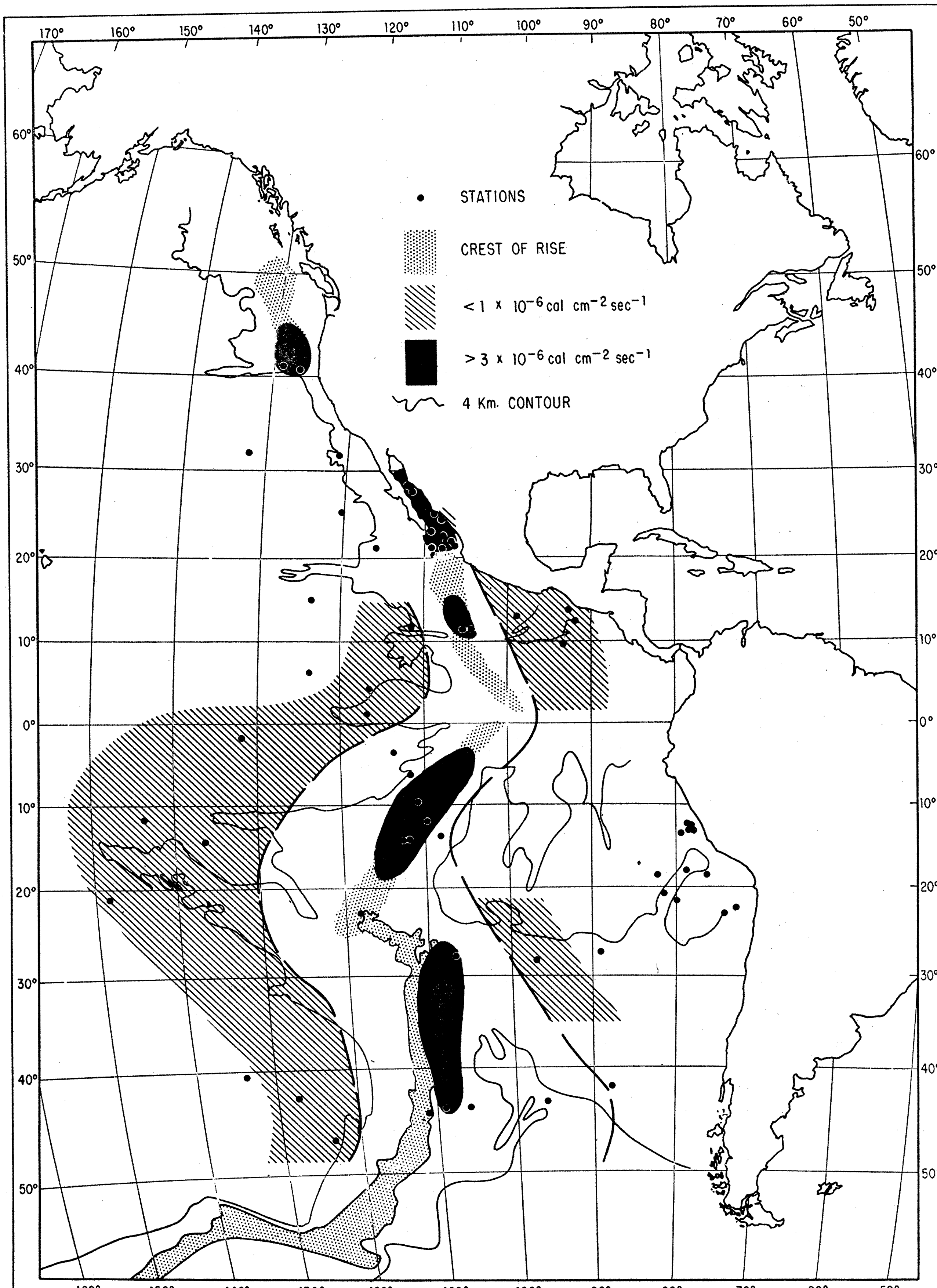


Fig. 5. Correspondence in position of the crest of the East Pacific Rise and a pattern of heat flow. The points off the United States are based on unpublished observations by von Herzen. The band of high heat flow, like the crest of the rise, appears to pass through the western United States.

continent. It is difficult to escape the conclusions that the sea floor was sloping before the offsets occurred and that the displacements were almost exactly level.

The crustal blocks between fracture zones have areas of a few million square kilometers, but they are hardly more distorted by displacement than small blocks of wood. The magnetic anomaly pattern shows little evidence of compression, extension, rotation, or shearing, except within the fracture zones. However, a distinctive pattern of minor lineations (*9*) suggests a uniform stress within each block but different stresses in adjacent blocks. The lineations consist of elongate volcanoes, lines of volcanoes, and mountains produced by block faulting. These are features characteristically associated with crustal tension. It would appear that all the crustal blocks were in tension while the eastern Pacific was being sliced, or after it had been sliced, by fracture zones.

The enormous displacements of marine crustal blocks are not matched on the adjacent continent. The Mendocino fracture zone offsets the continental slope 100 kilometers in northern California, but the displacement is right-lateral—that is, in the opposite direction from the displacement of the deep-sea floor farther to the west. The continental slope is not offset by the Murray fracture zone, but the Channel Islands and the transverse ranges of California appear to mark an extension of the fracture zone on land. Wrench faults with the trend of the Murray fracture zone are common in these islands and ranges. Displacements are as much as 15 kilometers, but they are generally left-lateral—once again in the opposite direction from the displacement of the sea floor. It appears that some zone of discontinuity is parallel to, and near, the continental slope off California; that crustal blocks on opposite sides of the zone move in different directions; and that movement on the continental side of the zone is much less than on the oceanic side. However, the ages of the varying displacements are not known, and it is equally possible that wholly unrelated stresses produced movement in different directions at different times along the same zone of weakness.

To turn to wrench faulting deduced from the structure of the rise, if the boundary between crust and mantle marks chemically different rocks, the thin crust of the rise probably has been stretched. Arching of the crust would produce some thinning, but the amount is trivial. The region which is now 3.8 kilometers thick has an average width of 2800 kilometers. If it once had a thickness of 4.9 kilometers, which is typical of the Pacific basin outside the rise, then the width was 2200 kilometers, and the crust on the flanks of the rise has been translated laterally for 600 kilometers. Changes in direction of the crest require differential movement of sections of the rise, with wrench faults between sections. Moreover, wrench (tear) faults are commonly associated with large horizontal crustal displacements, both on land and in the ocean basins. Thus, the development on the rise of a thin crust seems to require wrench faults with the location and magnitude of displacement found in fracture zones.

Interaction of rise and fracture zones in space and time is strongly suggested by the seismicity and topography. The crest of the rise is seismically active at present, indicating that it is still being deformed. The fracture zones appear to be active only where the crestal seismic zone intersects them, suggesting that their apparent seismicity is coincidental. However, the fracture zones are very straight, and the crustal blocks are undistorted, despite their great translation; the wrench faults may be almost completely frictionless discontinuities in the crust. Perhaps faulting occurs after only very small strain accumulates, with resulting earthquakes below the normal level of detection. George Shor is planning to build small seismometers which can be placed on the sea floor in the fracture zones to detect small earthquakes if they exist. Meanwhile it would be quite intriguing to employ a bathyscaphe and look for sinuous bends along the old submarine telegraph cable crossing the fracture zones.

Even if the fracture zones are not now active, they appear to have been since the rise first began to develop. The crest of the rise is offset or changes direction at the intersection of the fractures, suggesting horizontal movement; the flanks of the rise change depth along fracture zones, suggesting vertical or horizontal movement; and between the Mendocino and Murray fracture zones the flank of the rise is horizontally offset in the same direction and by about the same amount as the magnetic anomalies. If an anticlinal fold on land were offset by wrench faults in this manner it would be obvious that the wrenching had occurred after the

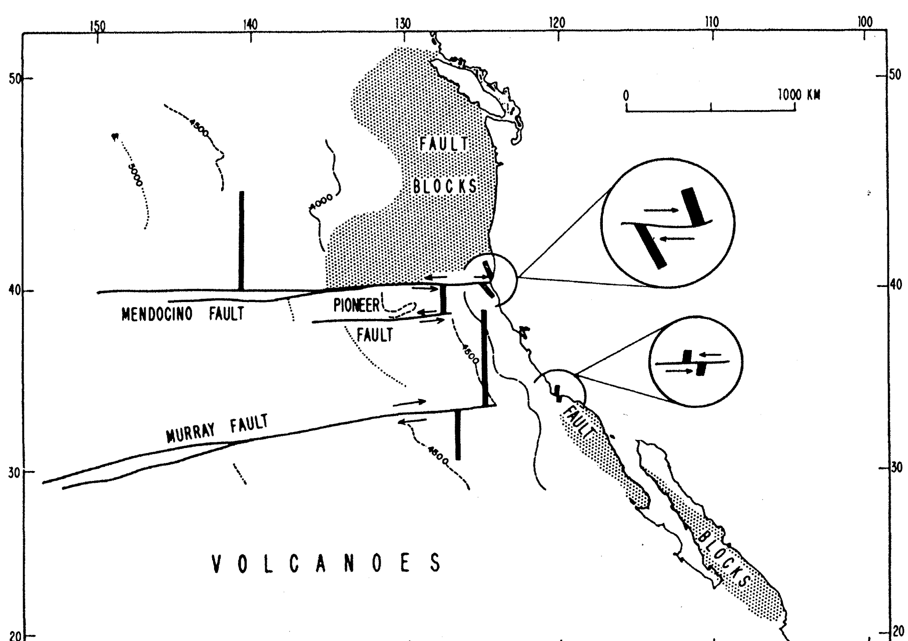


Fig. 6. Horizontal fault offsets off California. The sense of movement is reversed near shore on two faults. Points of no movement appear to lie near the East Pacific Rise crest. Crustal blocks which have been translated westward have provinces of minor fault blocks near the crest of the rise, suggesting crustal stretching and thinning. The width of the provinces is roughly proportional to the translation.

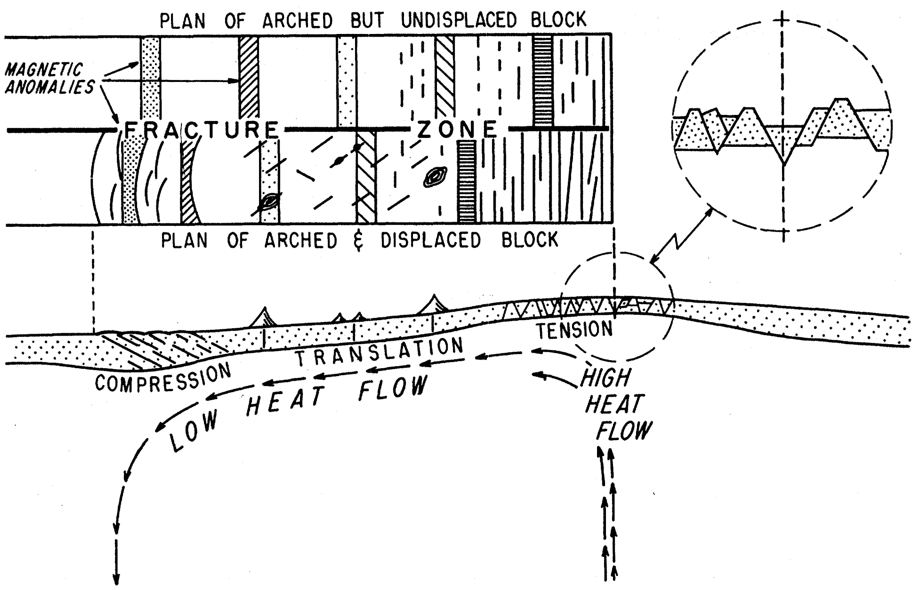


Fig. 7. A diagrammatic presentation of the convection-current hypothesis for the origin of various features associated with the East Pacific Rise.

folding or else that they were contemporaneous. It is difficult to escape the same conclusion regarding the enormous, undated, and little known structures of the sea floor.

Although no single line of evidence is wholly conclusive, the rise and fractures probably are genetically related. The thinning of the rise crust seems to require large horizontal movements on the flanks with differential movement between blocks. The fracture zones have the required geographical distribution and magnitude of displacement to be the boundaries between the displaced blocks; they have been active since the rise began to form, and the rise, at least, is seismically active and may still be developing.

## Origin of the East Pacific Rise

Inasmuch as the facts available about oceanic rises are few and new information is being accumulated very rapidly, hypotheses about the origin of the rises are modified frequently or abandoned for new ones. Consequently, an elaborate discussion of present working hypotheses does not appear warranted, but a brief outline may serve the useful purpose of relating otherwise disconnected facts. The following facts are known about the East Pacific Rise.

A belt about 800 kilometers wide along the crest of the rise is anomalous in almost every respect: (i) The topography is characterized in some places by ridges and troughs trending parallel to the rise; (ii) the belt is seismically active; (iii) the heat flow is several times the normal flow; (iv) the third layer (crust) is thin; and (v) the seismic velocities are much less than mantle velocities at a depth where the mantle normally is found. This highly abnormal belt occupies about one-fifth the width of the rise.

Beyond the central anomalous belt and to about the midlines of the two flanks of the rise—at least on the better-known, western flank—the crust remains thin but the heat flow is abnormally low and the velocities in the mantle are normal. Little is known about the local topography in this region, but it appears to consist of volcanoes, low domes, and troughs with adjacent tilted fault blocks trending at various angles to the crest of the rise.

On the outer half of the western flank, the crustal thickness and mantle velocities are normal for the ocean basins, and the only abnormalities are low heat flow and the existence of the rise itself.

Fracture zones cut across the whole width of the rise and displace or change the trend of the rise. Both vertical and horizontal offsets occur, and the horizontal offsets are reversed at the continental margin.

The position of the rise along part of its length is at the edge rather than in the middle of the ocean basin, and the crest appears to pass under western North America.

A hypothesis of a youthful convection current in the mantle, suggested by Bullard, Maxwell, and Revelle (*10*) to explain high oceanic heat flow, offers a simple qualitative explanation of all the facts given above. A rising hot material, marked by high heat flow, produces an upward bulge of the mantle because of thermal expansion or physical-chemical changes (Fig. 7). The mantle bulge arches the overlying crust and forms a system of tension cracks parallel to the rise. Arching stretches and thins the crust, but the observed thinning is so great that translation of the crust toward the flanks of the rise is also required. Accordingly, the horizontal limb of the convection cell moves the crust outward and thins it at the crest of the rise by normal faulting along the tension cracks. Blocks are displaced different distances by wrench faulting on fracture zones because of variations in intensity of convection along the rise. Displacements on fracture zones have opposite directions on the two sides of the crest because convecting material moves in all directions from a rising hot center. Farther out on the flanks of the rise the convection current moves the crust between fracture zones as a unit (the displaced magnetic anomalies are not distorted as they are near the crest). On the outermost flanks the sinking convection current, marked by low heat flow, defines the outer limit of wrench faulting and, presumably, the crust is thickened by thrust faulting.

The East Pacific Rise is only one part of a world-girdling oceanic mountain system, and one may wonder whether the obvious implication of a single origin is correct. However, despite their continuity, the oceanic rises and ridges are not all alike. Compared with the Mid-Atlantic Ridge, the East Pacific Rise is much broader, has gentler slopes, and in most places is far less faulted on the crest. It may be that these differences only mark different stages of development and different times of origin. There is some evidence that the life of an oceanic rise may be rather short, and rises may be in different stages of development at the same time. All the ocean basins have median elevations except the Pacific, which, instead, has a line of atolls and guyots (different types of deeply submerged former islands) rising from a series of narrow, steep-sided ridges. If a broad oceanic rise, faulted at the crest and capped by volcanic islands, were to subside, the only evidence that it once existed might be such a line of drowned former islands and linear ridges (*11*). The guyots of the central Pacific were islands roughly 100 million years ago, and if they mark a former rise, the period of its subsidence must have been quite short compared with the age of the earth.

The East Pacific Rise differs from most broad oceanic elevations in another respect: the northern part is at the margin of an ocean basin rather than in the center. Thus, although all ocean basins have oceanic rises or former oceanic rises in the middle, not all ocean rises are in the middle of basins. In Africa and western North America the rises appear to penetrate continents. In fact, a feature as broad and low as an oceanic rise is difficult to recognize unless there is a large, relatively flat ocean basin on each side. Several marginal oceanic regions with anomalous levels, such as Melanesia and Indonesia, may have the same mantle and crustal structure as oceanic rises.

Continental drift, as suggested by the parallelism of the Atlantic coast lines and the crest of the Mid-Atlantic Ridge, has been a very attractive concept for continental geologists, particularly since it was revitalized by the paleomagnetic evidence for polar shifts and possible drift. Marine geologists, on the other hand, have been reluctant to accept the concept of continental drift because they find no evidence for it in the geology of the sea floor. Indeed, the existence of rises centered in the Indian and Pacific oceans seemed to eliminate the possibility that Africa and South America had moved away from the Mid-Atlantic Ridge. However, if a random distribution of relatively short-lived "oceanic" rises is accepted, the picture is entirely different. If all rises were in the center of ocean basins it would not be clear whether the convection current, or another agent, which produced the rise centered itself relative to the margins of the basin or created the basin. With rises bordering the Pacific and penetrating Africa, it appears more probable that most rises are centered because the margins of the basin have been adjusted by convection currents moving out from the center. If so, the African and East Pacific rises may mark relatively young or rejuvenated currents which have not yet had time to produce much continental displacement. Even so, east Africa is being torn by deep rifts and Baja California has almost been separated from North America along the crest of the East Pacific Rise.

It is apparent that the study of oceanic rises and ridges, which was accelerated by the IGY, is one of the most fruitful fields in geology and geophysics. According to present planning there will be few, if any, months during the next three years when there will not be oceanographers at sea attempting to advance this study (*12*).

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12. Almost all the field work has been supported by the Office of Naval Research and the National Science Foundation under various contracts.


# Research Overhead

## DuBridge and Kaplan exchange views on overhead payments for basic research in private universities.

The article by Norman Kaplan [*Science* **132**, 400 (12 Aug. 1960)] presents such a confused and misleading argument for "stopping all overhead payments for basic research in private universities" that it will probably be ignored in most informed circles. Nevertheless, since it occupies an important place in a distinguished scientific journal, and since it represents the type of thinking that is frequently met in discussions of this subject, it seems important for the sake of the record that it be answered in some detail.

Apparently Kaplan bases his opposition to overhead payments on the following arguments.

1) "Concentration on them [overhead payments] obscures some more basic problems and postpones the search for more general solutions."

2) Since "the university has not made a profit or typically realized full costs on its storage facilities [that is, its libraries] [or] its teaching," there is no reason why it should realize full costs on research activities either.

3) Overhead payments would "clearly not solve the over-all financial crisis in the universities."

4) Full cost reimbursement would bring dangers of federal control of the universities.

There is no substance to any of these arguments.

1) The question of formulating an over-all research policy for the United States has been searchingly examined by many agencies ever since the famous Bush report, "Science—the Endless Frontier," in 1946—most recently by the President's Science Advisory Committee. Such studies are also a continuous responsibility of the National Science Foundation. There is no evidence that in any case these policy studies have been hampered or obscured by the question of full cost payment. Nearly all the serious studies have recommended that the federal government reimburse the full costs of research in universities. But far from obscuring the