Puzzling Out the Tectonic Plates

Something has to give in the Indian Ocean. Massive forces have touched off large earthquakes and crumpled the ocean crust in an area south of the Indian subcontinent. But, oddly, all this seismic activity is taking place in the middle of the Indo-Australia tectonic plate. In classic plate tectonics theory, earthquakes are concentrated around the edges of the jostling plates. So how do you get such large quakes and so much deformation where there's but a single plate? What may have to give is nothing less than one or another of the basic assumptions of plate tectonics.

One such assumption is that plates are always rigid and inflexible. Given all the tectonic activity in the Indian Ocean, many geophysicists had assumed that they had to make an exception to the rule of plate rigidity—the forces driving the Indo-Australia plate must be deforming it and triggering the seismic activity in mid-plate.

Now comes a group of geophysicists with an alternative explanation. The active area, they posit, may be a broad, diffuse boundary region between two plates moving independently after all. If these researchers are correct, they will have maintained the notion of rigid plates but overthrown the classical assumption that plate boundaries in the oceans are always narrow.

The group out of Northwestern University argues in a forthcoming issue of *Tectonics* that the Indo-Australia plate is not one plate but two—the India plate and the Australia plate—divided by a boundary 3300 kilometers long and a relatively enormous 800 to 1600 kilometers wide. That contrasts with the three conventional types of boundaries—the summits of mid-ocean ridges, deep-sea trenches, and transform faults—that are thousands of kilometers long but only some tens of kilometers wide.

This sprawling boundary would not only look peculiar but also behave peculiarly. Where the proposed Indian and Australian plates are thought to be ramming against each other along the eastern part of the boundary, neither plate is sinking beneath the other, as happens when the Pacific plate encounters Japan at the Japan trench. At the other end of the boundary, where the plates would be pulling away from each other, magma does not seem to be welling up to add to each growing plate, as happens at mid-ocean ridges. Instead, the putative boundary seems to be deforming along its entire length as the plates jostle each other.

It's no surprise, therefore, that many geophysicists remain unconvinced. To some, the proposed boundary is something of a semantic contrivance. "It's taking something the size of some smaller plates and calling it a boundary," notes Sean Solomon of the Massachusetts Institute of Technology. "Those of us who work at plate boundaries don't see much use in it." He and others would just as soon call it deformation in the middle of a nonrigid plate.

But those who try to understand how eight major and a half dozen minor plates drift around the globe see considerable merit in the idea. "The reason I like to think of it as a diffuse boundary," says Richard Gordon of Northwestern University, "is that it lets us quantify things and make predictions."

Indeed, Gordon has already tested one set of predictions derived from the diffuse boundary idea against observations and found that the concept stands up well. Building on earlier work by Douglas Wiens of Washington University in St. Louis, Gordon, along with Charles DeMets of the Jet Propulsion Laboratory in Pasadena and Donald Argus of Northwestern, gauged how the putative boundary between the India and Australia plates should behave given what can be determined about the motions of the surrounding plates.

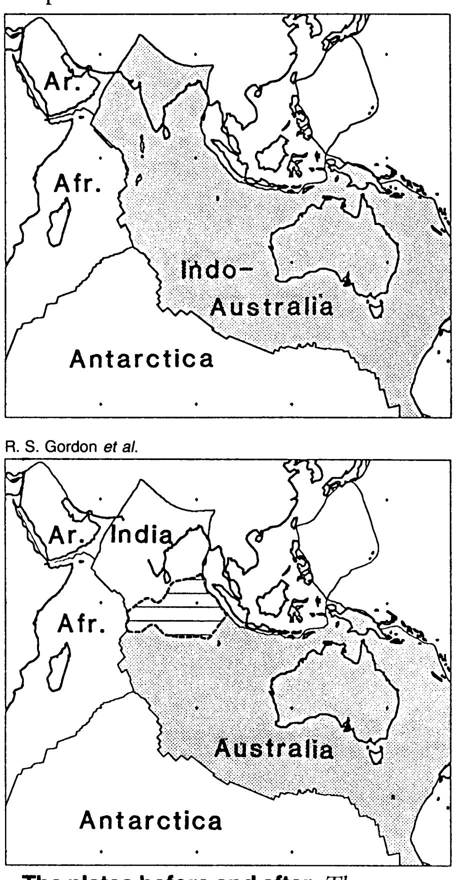
Gordon and his colleagues calculated the rate of plate motion during the past 3 million years from the record of Earth's flip-flopping magnetic field frozen into the crust as it continuously forms and spreads away from the mid-ocean ridges, much the way a tape recording is made. They gauged the direction the plates are moving from the orientation of sea-floor transform faults, which point in the direction of spreading, and from the orientation of earthquakes on the transform faults.

From such indicators, Gordon and his colleagues measured the motion of the presumed India plate relative to the adjacent Africa and Arabia plates and the motion of the presumed Australia plate relative to the Africa and Antarctica plates. From this, they calculated what the motion between the India and Australia plates should be. Toward the eastern end of the boundary, they predicted that the plates are converging at a slow but measurable 4 ± 3 millimeters per year. That fits the pattern of earthquakes, faults, and undulations in the sea floor in that area. Near the boundary's western end, the plates should be pulling away from each other at 6 ± 2 millimeters per year. That also fits the observed pattern of faulting there.

Although the success of these plate motion predictions would seem to justify the claim that the region is a new, diffuse boundary, that does not answer Solomon's fundamental complaint—"It doesn't tell us why" anything at all is happening.

Everyone agrees that the earthquakes and deformation along the equatorial Indian Ocean are ultimately related to the Himalayas 2500 kilometers to the north. Something about the strain of raising the world's highest mountain range by colliding the Indian plate with Asia has overwhelmed a portion of the plate. The final answer should lie in the detailed history of plate motions and plate behavior preserved in the sediments and crust of the Indian Ocean. Gordon leaves this spring to gather more of that history from this oceanographic hinterland.

■ Richard A. Kerr



The plates before and after. *The conventional layout of the plates in the Indian Ocean (top) has a single, Indo-Australia plate (shaded). Studies of recent motions of all the plates in the area suggest the division of this plate into the India and Australia plates with a unique, broad boundary (hatched) between them.*