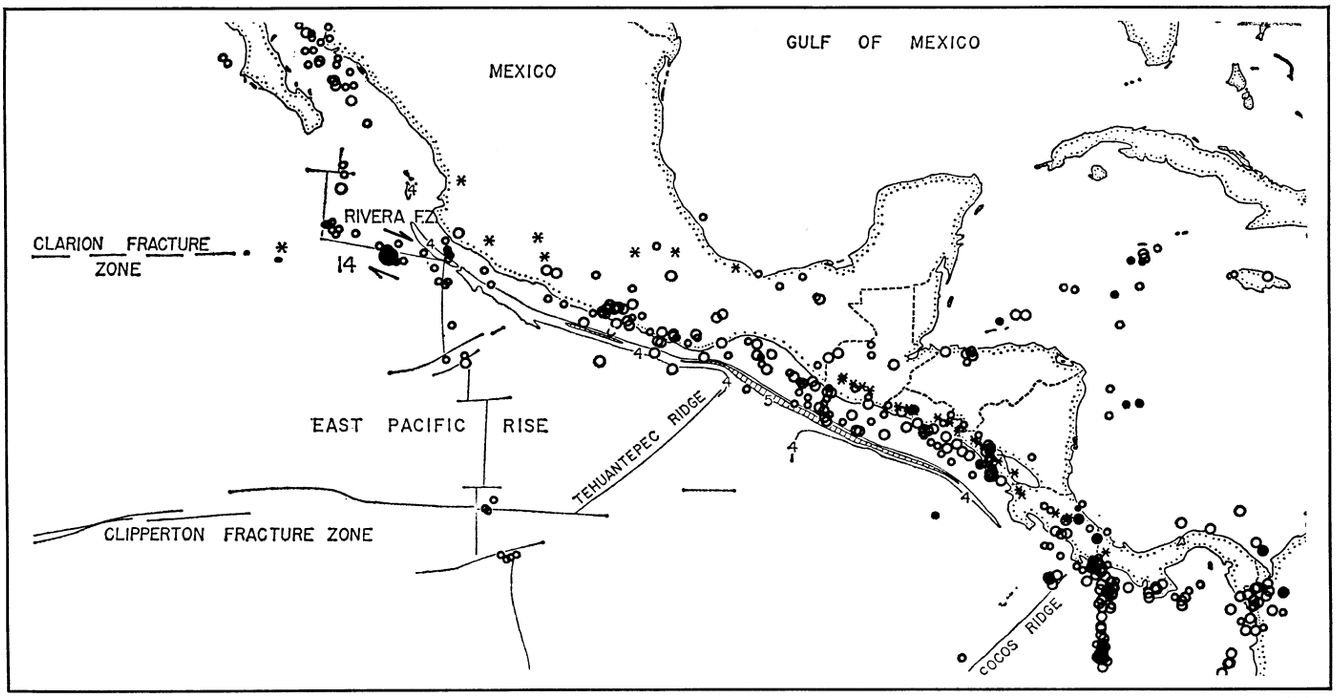


Drawings: Molnar and Sykes

Nature of earthquake activity indicates Cocos plate is thrusting beneath western Mexico and Central America.

Turning to the earth's smaller crustal plates

Boundaries and motions of two surface plates in Middle America—the Cocos and the Caribbean—support recent tectonic theories

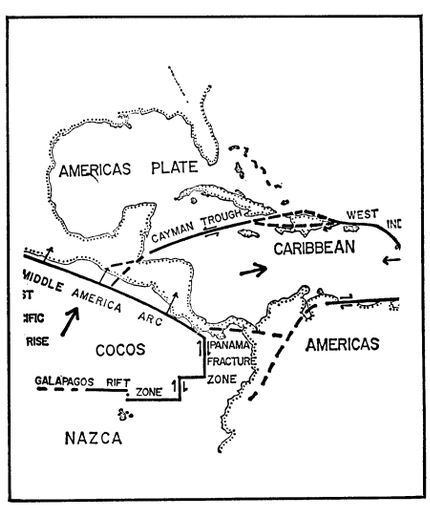


Plate movements explain seismicity.

by Kendrick Frazier

Geophysicists and geologists intent on describing the slow horizontal movements of portions of the earth's rigid upper layer now believe that the sliding about of six major segments, or plates, can explain in a general way many observed seismic events and geological features.

The distinction between continents and oceans has become less important. More pertinent for the earth scientists studying these motions are the massive plates of lithosphere, the rigid mass of crust and upper mantle, which can include both continental areas and portions of the ocean floor.

One section, the Americas plate, includes North and South America and the western half of the Atlantic Ocean. The Africa plate includes Africa and large areas of the Atlantic and Indian Oceans. Other major plates currently go by the terms Eurasia, Pacific, Australia and Antarctica. The perception of this jigsaw division of the earth's shell and the detection of the movements and interactions of the pieces have shaped the new concept of plate tectonics (SN: 11/8, p. 430).

But the earth scientists have been well aware that the situation is not quite that simple. Half a dozen plates may go a long way toward explaining major belts of seismic activity, volcanoes, and gravity and magnetic variations in a gross way. But these phenomena also occur at many places in which they cannot be explained by the motions of the major plates. A number of small plates are apparently also in action.

The smaller ones have not been given as much scientific attention. But now that the general outlines and motions of the larger plates are identified, some investigators are attempting to delineate the smaller pieces of the puzzle.

A case in point is Middle America. Here, beneath both the Caribbean and the eastern Pacific, is a region of geological and geophysical complexity. The area, including Mexico and Central America, the Caribbean and the

adjacent oceans, includes prominent oceanic ridges, island arcs and arc-like features and several major fault zones. A deep ocean trench extends along much of the west coast of Mexico and Central America. Several distinct zones of relatively frequent earthquakes extend through the area. Clearly something important is going on.

Two seismologists at Columbia University's Lamont-Doherty Geological Observatory, Drs. Peter Molnar and Lynn R. Sykes, recently completed a detailed study of the seismicity of the entire region. Searching over past seismic records and making use of a computer, they relocated the exact point of origin within the earth of more than 600 earthquakes in an effort to delineate more precisely the belts of seismic activity. Several such studies had been carried out previously in the Caribbean, including one by Dr. Sykes and his Lamont-Doherty colleague Dr. Maurice M. Ewing, but the latest investigation of the seismicity of the entire Middle America region and its surrounding oceanic areas had been completed in 1954. A large volume of data had become available since then.

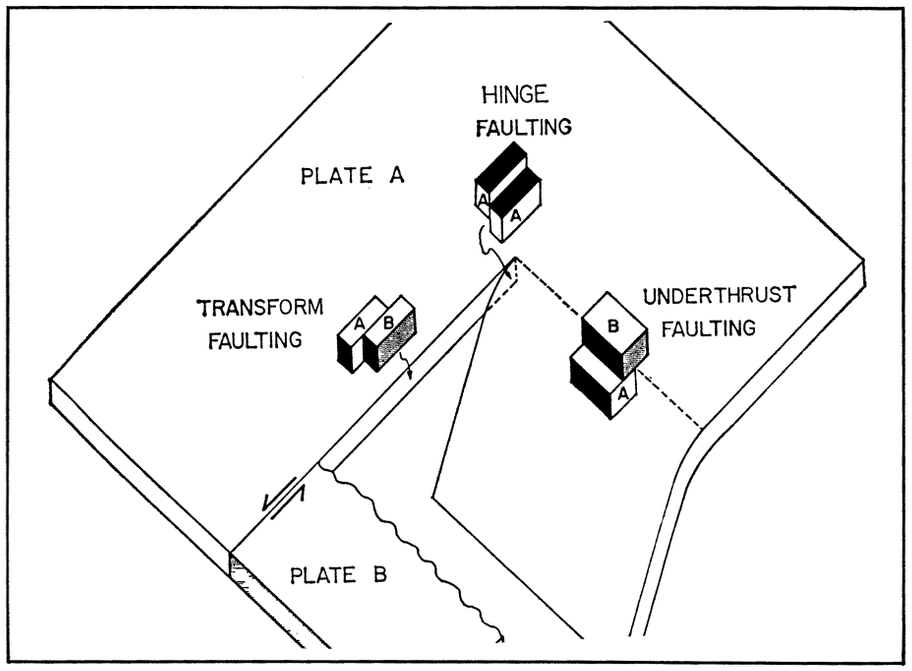
These studies show that seismic activity occurs along narrow belts that surround two nearly quake-free regions, one in the Caribbean and one in the eastern Pacific southwest of Mexico. In other words, there seem to be two large blocks of the earth's surface that are themselves calm and free from disruptions by earthquakes, but whose edges are alive with tremors.

This, in current thinking, is the almost sure sign that the areas consist of relatively rigid plates of lithosphere, some 50 to 100 kilometers thick, that are in slow horizontal motion, rubbing against or colliding with adjacent plates.

The study, say Drs. Sykes and Molnar, shows that the present tectonics of the region result primarily from the interaction of these two relatively small plates with surrounding plates.

One is the Caribbean plate, which includes most of Central America and the sea floor beneath the entire Caribbean Sea. It is bordered on the west by the Middle America Trench along the west coast of Mexico and Central America, on the north by the Cayman trough extending from Honduras to southern Cuba, on the northeast and east by the arc of the West Indies and on the south by a seismic zone in northern South America.

The other is the Cocos plate, which extends from the Middle America Trench westward into the Pacific Ocean to the East Pacific Rise. It is bordered on the south by another area of apparent sea-floor spreading known as the Galapagos rift zone and on the east by an undersea belt of seismic activity extending south from Panama.



A model for interactions can reconcile different seismic data observed.

The two plates are only about one-tenth the size of the six others described by scientists in discussing the major features of the rigid-plate hypothesis. Scientists were curious about whether the same principles applied to the secondary plates.

"This hypothesis is indeed valid to a good first approximation for these smaller plates," Drs. Molnar and Sykes conclude from their study.

Once the boundaries of the plates are known, the next step is to determine the direction and rates of motion. This can be done in rough approximation by certain kinds of analyses, called focal mechanism solutions, of the waves from particularly strong earthquakes. Dr. Molnar carried out such analyses for 70 of the largest earthquakes between 1962 and 1967.

The work shows that the Caribbean plate is moving easterly relative to the larger Americas plate. At the eastern boundary, along the arc of the West Indies, the floor of the Atlantic Ocean is apparently dipping beneath the Caribbean.

The Cocos plate is moving northeasterly relative to the Americas plate and is underthrusting North America at Mexico. Farther south it is dipping beneath the Caribbean plate along the west coast of Central America.

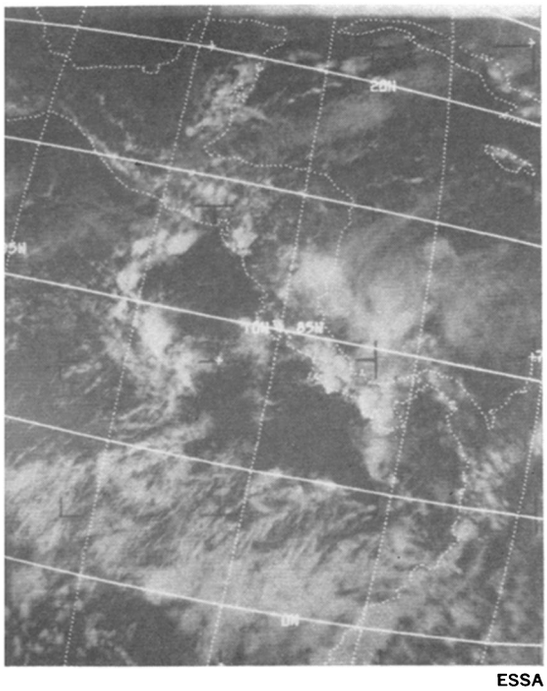
There are no absolutes in this business. All the motions have to be regarded as relative. "The analogy would be to cakes of ice on the open ocean," says Dr. Sykes. "You could determine how each cake was moving in relation to others, but you would not be able to tell how the whole system was acting."

Clues to the types of movements in progress often at first seem confusing. Analyses may indicate radically different mechanisms within the same area. But if these are interpreted as signs of different kinds of faulting—hinge, transform and underthrust—scientists can visualize what is happening beneath the surface (see diagram above).

Little can yet be said with certainty about the rates of motion. One certain point is that the motions take place at no more than a few centimeters a year, a rate consistent with that of other areas of sea-floor spreading. It is also apparent that the underthrusting at the West Indies is occurring at a slower rate than the underthrusting of the Cocos plate along the Middle America Trench. Thrusting rates beneath the trench increase to the southeast.

In addition there is evidence for a readjustment of the rates of movements of the plates during the last 10 million years. The oldest known magnetic anomalies parallel to the Galapagos rift zone are only 3 million to 4 million years old. And magnetic data in the Gulf of California indicate spreading began there about 4 million years ago. If the underthrusting at the Middle America Trench began only 4 million years ago, they say, it must have been occurring at rates of as high as 4 to 9 centimeters per year.

Since Drs. Molnar and Sykes prepared the report of their findings for



ESSA

Middle America: A complex region.

the GEOLOGICAL SOCIETY OF AMERICA BULLETIN, two scientists from the Environmental Science Services Administration have carried out geophysical studies from the ESSA ship Oceanographer that tend to confirm their findings about the motions of the Cocos plate. Drs. Paul Grim and Walter Sproll of ESSA's Atlantic Oceanographic and Meteorological Laboratories in Miami verified seismic findings of an active ocean ridge segment linking the Panama fracture zone and the Galapagos rift zone. Those two zones divide the Cocos plate from another small one to the south, called the Nazca plate. Spreading seems to occur along their boundaries.

Thus the examination of the Cocos plate and its boundaries fits in well with the understanding of global tectonic processes that has evolved in the last few years. "The over-all consistency in the distribution and rate of seismic activity, the directions of the slip vectors, and the qualitative agreement of the rates of motion computed by different methods offer convincing evidence for the concept of rigid-plate tectonics in this region," conclude Drs. Molnar and Sykes.

The only region in the study that is not easily explained by the concept of rigid plates of lithosphere is northwestern South America. Analysis of movements of rigid plates is much more difficult for continents than for oceanic areas.

Science, the geophysicists say, may have to wait some time for that explanation. □