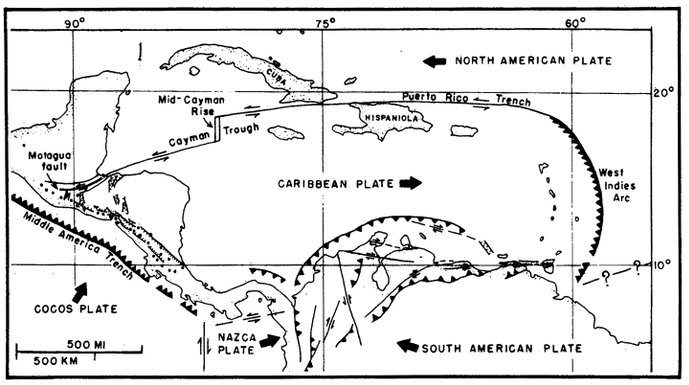
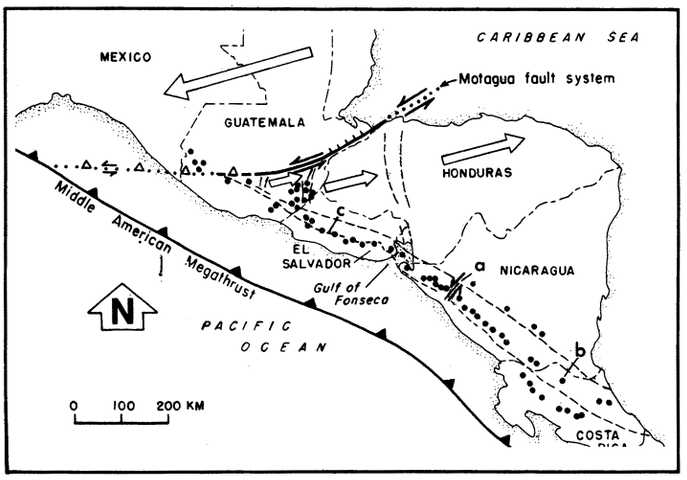
THE SHIFTING, STRETCHING CRUST OF CENTRAL AMERICA

Study since the Guatemala earthquake shows not only that the Caribbean plate shifted relative to North America but also that much of Central America is being pulled apart within the plate

BY KENDRICK FRAZIER



The complex plate tectonics of Central America: Movement of Caribbean plate eastward relative to North American plate along Motagua fault caused the disastrous Guatemala earthquake.



Plafker's model for the stretching of the wedged-in western corner of the Caribbean plate in parts of Guatemala, El Salvador and Honduras. The plate may be decoupling behind arc of volcanoes (black dots).

The devastating 7.5-magnitude earthquake that struck Guatemala on Feb. 4 of this year killed 23,000 persons, injured 74,000 and left nearly a million people homeless. It also left behind the most extensive surface faulting in the Western Hemisphere since the San Francisco earthquake of 1906.

Scientific analysis of this event and the rupture it created has now produced striking direct confirmation of some of the basic tenets of plate tectonics theory plus a vivid portrayal of the perilous geophysical setting of a portion of Central America that is in the unfortunate circumstance of being located near the junction of not two but three of the giant crustal plates that make up the earth's surface.

The new evidence all lends support to the view that the western corner of the plate that lies beneath most of the countries of Central America is caught in a wedge and held in place between the two other plates and that the resultant stretching forces caused by the eastward motion of the rest of the plate is tearing it apart. Eventually the action could even result in the opening of a marginal sea inland from the great chain of volcanoes along the western flank of Middle America. It is proposed that the Gulf of Fonseca, where San Salvador, Honduras and Nicaragua join at the Pacific Ocean, may be the incipient stage in the formation of such a sea.

This analysis comes from geologist George Plafker of the U.S. Geological Survey in Menlo Park, Calif., one of a group of scientists who conducted field studies in Guatemala immediately after the quake (SN: 2/4/76, p. 103) and again two months later. According to Plafker, "The only previous event for which a detailed geologic study of surface faulting was made in the 450-year seismic history of Central America was the magnitude 6.2 earthquake of Dec. 23, 1972, that destroyed Managua, Nicaragua."

The earthquake caused the ground to break in a continuous, visible, well-defined line extending across Guatemala for 230 kilometers. The line passes only 25 kilometers north of the center of Guatemala City. The fracture is mostly 1 to 3 meters wide, with a maximum of 9 meters.

The horizontal displacement—the relative movement of the ground along the two sides of the rupture—was as great as 3.4 meters (11 feet) and averaged a little less than 1.1 meters. It is dramatically illustrated in one photo of what had been a single row of trees running perpendicularly across the fault. At the rupture, the row of trees is now offset 3.25 meters. Elsewhere the rows of a farmer's plowed field offset 70 centimeters look oddly out of phase, and a soccer field is torn in a series of zig-zag rips caused by a 92-centimeter displacement across its width. The vertical displacement—where one side of the fault drops in relation to the other—is smaller, about one third the horizontal movement.

The rupture happened along the east-west line of the previously known Motagua fault zone. In modern plate tectonic interpretations, this fault system is the division between the North American and Caribbean crustal plates. The Caribbean plate moves eastward relative to the North American plate. Since Miocene times, about 12 million years ago, the amount of movement is thought to be at least a few hundred kilometers (based on the length of the segment of the North American plate that has been subducted beneath the West Indies Arc) and possibly as much as 1,000 kilometers (based on reconstruction of the geology of faults that run from Hispaniola to the Cayman Trough).

If this plate tectonic interpretation for Middle America is correct and if the Guatemala quake was caused by motion along the boundary between two plates, then the displacement of the ground on the south side of the fault (the Caribbean plate) should have been eastward relative to the ground on the north side of the fault (the North American plate). This is exactly what Plafker and his colleagues observed. The movement along the rupture zone was left-lateral, or sinistral: facing the fault, the side opposite the observer appears to

have moved left.

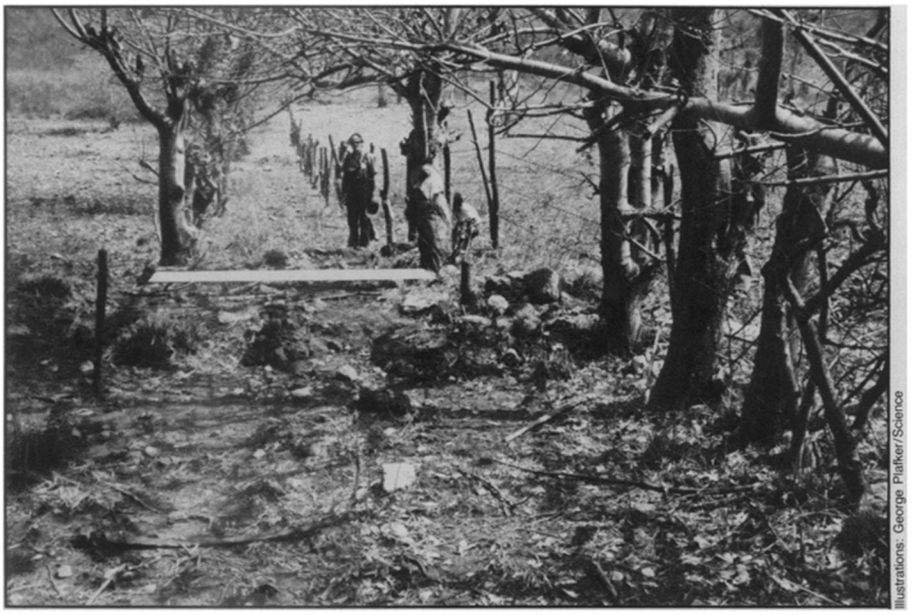
"The primary fault that broke during the earthquake involved roughly 10 percent of the length of the great transform fault system that defines the boundary between the Caribbean and North American plates," concludes Plafker in a summary of his studies in the Sept. 24 SCIENCE. "The observed sinistral displacement is striking confirmation of deductions regarding the late Cenozoic relative motion between these two crustal plates that were based largely on indirect geologic and geophysical evidence."

This may settle a long scientific debate. "There had been a great deal of argument in the geological literature in the last 20 years about whether this was a plate boundary," Plafker told SCIENCE NEWS. "I hope this will convince some of the skeptics."

Unfortunately for the people of Guatemala, El Salvador and Honduras, the geophysical situation is even more complicated and hazardous than slippage at a plate boundary. Between the Motagua fault and the chain of explosive volcanoes that passes through the highlands of Guatemala and El Salvador to the south is a system of smaller, secondary faults running perpendicular to the Motagua fault. These faults, says Plafker, result primarily from extension, or stretching, of the crust. This system of faults terminates in the vicinity of the volcanic chain.

Plafker believes that extension along these secondary faults may have taken up some of the displacement along the Motagua plate boundary and that past extensions may account for the high incidence of destructive local earthquakes in the part of Middle America north of the volcanic chain.

In fact, all the evidence fits into a pattern indicating that that portion of Middle America is being ripped apart. Plafker proposes that the Caribbean plate is beginning to become decoupled along the volcanic chain. He says the regional extension supports a suggestion put forth in 1972 by B. T. Malfait and M. G. Dinkelman that the west corner of the Caribbean plate is being pinned between the North American plate and the northeastward-moving Cocos plate. The Cocos plate, which lies beneath part of the Pacific Ocean west of Middle America, is underthrusting the Caribbean plate at the Middle America Trench. "The western wedged-shaped part of the Caribbean plate," says Plafker, is thus held in place and "being pulled apart in tension and left behind as the main mass of the plate moves relatively eastward." Plafker says the process, if continued long enough, could result in the opening of a marginal sea along the volcanic chain; the Gulf of Fonseca may be its start. "This is highly speculative," he cautions. "But that whole area is one of very low topography. It is very near sea level. It wouldn't take much to open it to the sea."



Illustrations: George Plafker/Science

Row of trees that crosses Motagua fault was offset 3.25 meters by the earthquake.

In this model, not only is the entire Caribbean plate itself moving relatively eastward, but also the main northern segment of the plate is moving eastward relative to the southern segment. "There's certainly some differential movement," Plafker says.

All this means that the countries of Guatemala, El Salvador, Hondurus and probably Nicaragua are located on a continual seismic time bomb, one that has disastrously set off many times in the past and will continue to do so far into the future.

For most areas of the world, to be subject to earthquakes from one underlying cause is bad enough. But in Plafker's analysis, this region of Middle America has the misfortune to be the target of potentially devastating earthquakes from no fewer than four principal modes. Movements along the fault system between the Caribbean and North American plates can set off earthquakes ranging from small to large (up to 7.8), like the February Guatemala quake. Movements of the extensional faults within the Caribbean plate can set off small-to-large quakes. The eastward dipping subduction of the Cocos plate beneath the Caribbean plate can set off earthquakes ranging in magnitude from small to great (8.5). And volcanism within the arc of volcanoes down the Pacific coast can produce small-to-moderate-size (magnitude 6) earthquakes and earthquake swarms. It is no wonder earthquake damage has always been exceptionally high here.

"It's probably as bad as you can get anywhere in the world," Plafker says of the shaky geophysical setting of Guatemala and its neighboring countries. Plafker, who lived in Guatemala from 1956 to 1959 when working as an oil company geologist, finds it sadly ironic that the complex tectonics that make it so dangerous geophysically are also responsible for its great scenic beauty—its diverse geology, its beautiful mountains, valleys and volcanoes. "After going into that setting, you can understand just why it has such a disastrous record."

One possibly bright note. It has been calculated that the present strain rate between the North American and Caribbean plates is about 2 centimeters per year. This means that over the millenia, the motion along their boundary should average this much. But the motion doesn't occur continually. The strain builds and builds, and then much of it is released in a large earthquake.

Based on the calculated strain rate of 2.1 centimeters per year across the plate boundary and the maximum displacement of 340 centimeters observed from the Feb. 4 earthquake, Plafker points out that the Guatemala quake dissipated strain energy along the Motagua fault that must have taken at least 160 years to accumulate.

"This implies that the recurrence interval for a magnitude 7.5 earthquake on this same fault segment theoretically should be more than 160 years," Plafker says. This, he says, may be compatible with the inference that a widely felt earthquake in the area in 1773 was generated by movement on the fault.

Such considerations lead Plafker to suggest that the segment of the Motagua fault that moved in the February earthquake may not be capable of generating a comparable destructive earthquake for at least 160 years.

"Nevertheless," he concludes, "the hazard to Guatemala and adjacent areas from future earthquakes that may be generated along the part of the fault west of its recent break, from other faults in the Motagua system or from any of the other potential seismic sources . . . unfortunately remains undiminished." □