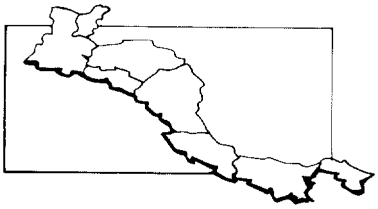


Geology of Honduran Geothermal Sites

by Dean B. Eppler

Since March 1985 a team of Laboratory geologists has been working with counterparts from the Empresa Nacional de Energia E1ectrica (ENEE) of Honduras and from four American institutions on a project to locate, evaluate, and develop geothermal resources in Honduras. The team, headed by Grant Heiken and funded by the U.S. Agency for International Development, has so far completed three trips to Central America to study in detail the geology of six geothermal spring sites.

Basic Geology of Honduras

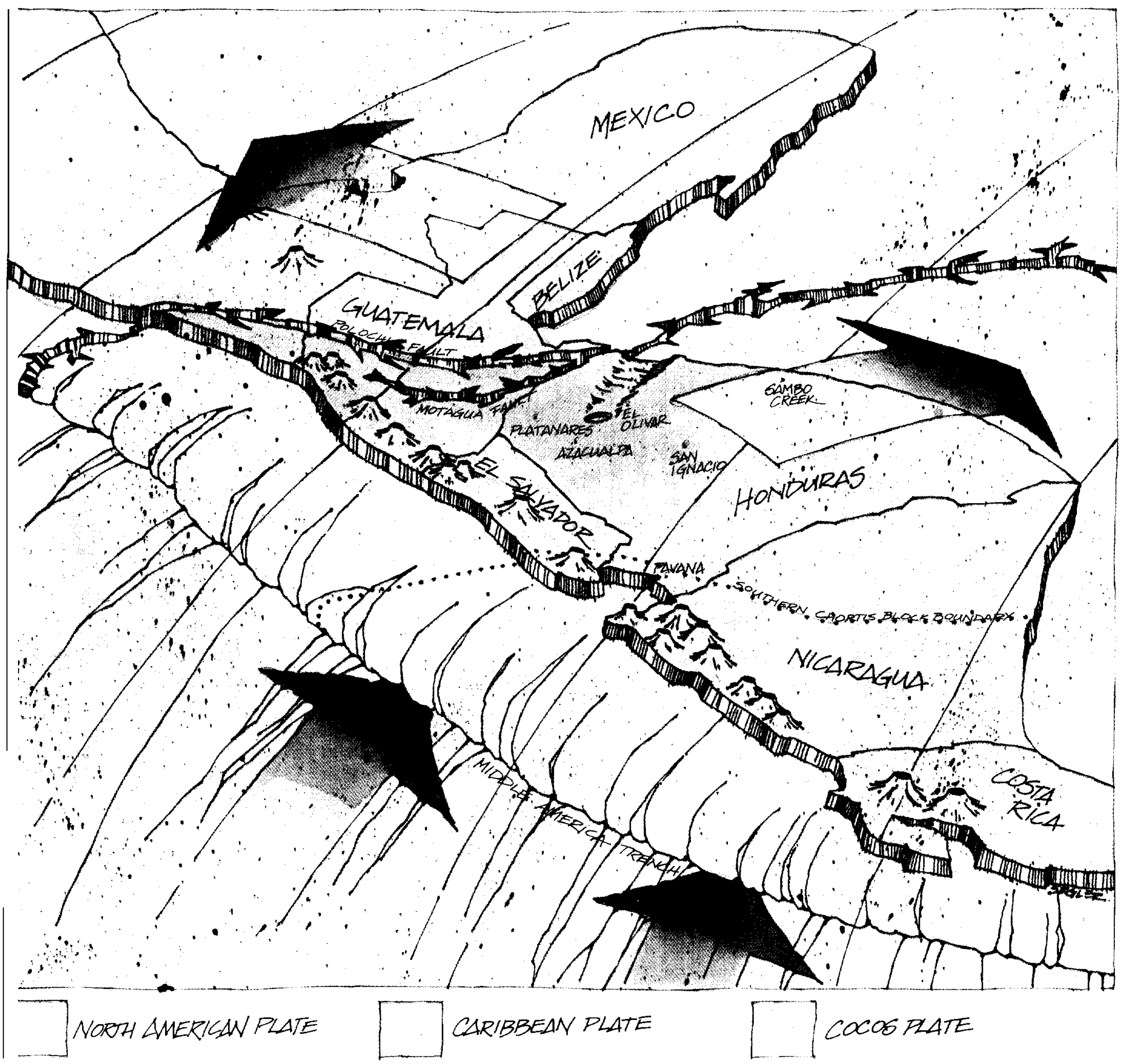
Honduras, the largest and most rugged country in Central America, is perhaps the least known geologically. Its steep terrain, dense vegetation, and paucity of roads hampered basic geologic studies until the late 1960s. Since then studies sponsored by American universities, including Ph.D. dissertations by project collaborators Bob Fakundiny and Rick Finch, have meshed with a greater level of in-country expertise to produce a basic understanding of the geology of the country. Such an understanding is an essential first step in any geothermal exploration. It has been particularly useful in Honduras as we set out to determine the nature of the geothermal heat source and the "plumbing system" through which the geothermal waters reach the surface.

The geology of Central America is extremely complex. The meeting of three tectonic plates in western Guatemala and southern Mexico has resulted in an unusual juxtaposition of structures and rock types whose geologic history has yet to be unraveled. Textbook reconstructions of tectonic-plate motions very often sidestep the problem of how Central America developed through geologic time by never showing its existence until the present time.

As shown on the accompanying map, Honduras lies on a portion of the Caribbean tectonic plate called the Chortis Block. This block, composed of rocks deposited in a continental environment, is bounded on the north by large strike-slip faults in sourthern Guatemala (the Matagua and Polochic faults) that form the boundary between the Caribbean plate and the North America plate.

The continental rocks of the Chortis Block are bounded on the south by younger rocks in Nicaragua that were deposited in an oceanic environment. The western boundary of the Chortis Block lies along the Central American volcanic chain and the Middle America Trench, a subduction zone where the Cocos plate is being thrust under the Caribbean plate. The complex geology of Honduras is the result of its proximity to the intersection of the three tectonic plates. In some areas of the country, major faults lie less than 10 meters apart. Most of these are normal faults, developed as a result of stress that is literally pulling the country apart along an east-west axis. Although Honduras has been spared the devastating earthquakes that have rocked much of Central America, we suspect that deformation is taking place continually; in some areas faults cut stream gravels that are only several thousand years old. The result of this faulting, as shown in the accompanying photo, is rugged topography dominated by north-south oriented fault basins and adjacent fault-block mountains very similar to those found in the Basin and Range physiographic province of the western United States.

The rocks of Honduras were deposited in rapidly changing environments, and the resulting stratigraphy is as complex as the structures that modify it. Precise dating is difficult because of the absence of identifiable fossils and the rapid changes in rock types over short geographic distances. However, three distinct age groups are apparent: a basement complex of Paleozoic low-grade metamorphic rocks about 245 million years of age (Home, Clarke, and Pushkar 1976); an overlying section of Mesozoic limestones and redbeds that is estimated to be between 100 million and 200 million years of age (Mills et al. 1967); and a thick upper sequence of volcanic rocks from two distinct episodes of volcanism. The Matagalpa Formation, a



Honduras is positioned on the Chortis Block near the junction of three tectonic plates: the North American, the Cocos, and the Caribbean. The large arrows indicate the direction of motion of the plates. The Cocos plate is being thrust under the Caribbean plate along the Middle America Trench. The Motagua and Polochic faults are large strike-slip faults separating the North American plate from the Caribbean plate. The plate-tectonic and geologic histories of the area are not known well enough to explain how and when Central America was formed. For example, the southern boundary of the Chortis Block, where continental rocks end and oceanic rocks begin, is indicated by a dashed line because its exact location in the jungles of Nicaragua has not been determined. We do know that plate movements are continuing to create faulting throughout Honduras and pulling the country apart along an east-west axis. Rainwater circulating through the fault regions has created numerous geothermal systems. The map also shows the locations of the six geothermal sites now being evaluated as indigenous sources of energy.

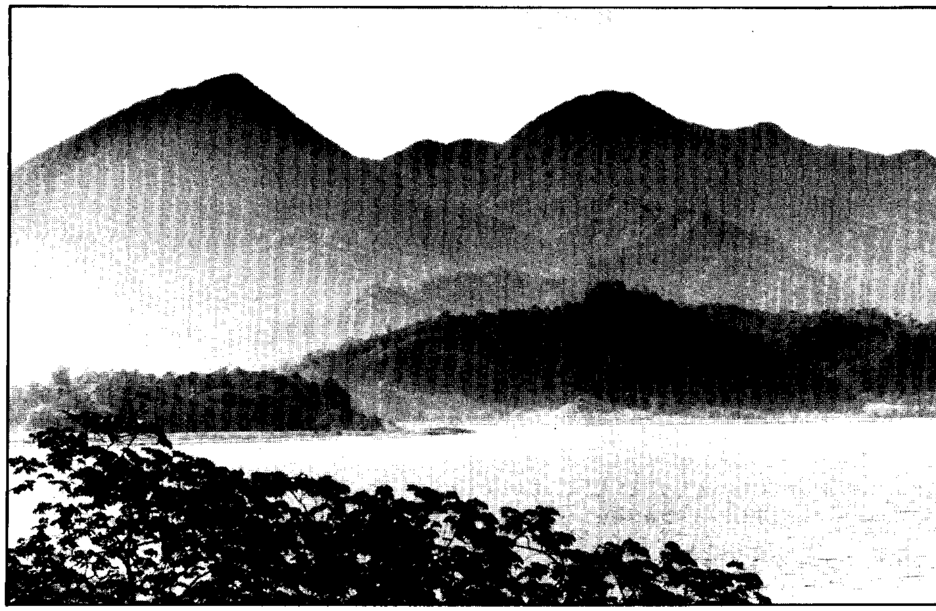
series of early Tertiary interbedded lava flows, pyroclastic flows, debris flows, and interbedded water-laid sediments, is between 40(?) million and 60(?) million years of age (McBirney and Williams 1965). The Padre Miguel Group, the result of the second episode of volcanism, is a thick sequence of ignimbrite similar to the Bandelier Tuff and is found throughout the southern half of Honduras; it is between 15 million and 20 million years of age (Williams and McBirney 1969).

This bare outline of the geology of Honduras will have to be filled in by studies of individual drill holes before we can infer with any confidence the nature of the plumbing system at each geothermal site.

Studies of Geothermal Sites

In the late 1970s several American firms began preliminary geothermal explorations in Honduras but were unable to complete them because of economic difficulties. These reconnaissance efforts allowed selection of six promising geothermal sites. However, the origin of the geothermal resource was misunderstood and incorrectly attributed to recent volcanism rather than, as our studies now indicate, to tectonic processes. Identification of the nature of the geothermal resource is a major contribution to the project. The amazing abundance of hot springs in Honduras suggests a large geothermal resource. Consequently, the project has two goals: selection of two geothermal sites for further development on the basis of detailed studies, by Los Alamos and ENEE geologists, of the six previously identified sites; and identification of other promising geothermal sites on the basis of a country-wide inventory of hot springs by ENEE with technical support, as necessary, from Los Alamos.

Detailed geologic studies have so far been carried out at three sites: Platanares, San Ignacio, and Azacualpa. Concurrently a team of geochemists from the Laboratory, the U.S. Geological Survey, and ENEE has sampled and analyzed the thermal waters to determine their chemistry and estimate the temperatures of the geothermal resevoirs (see "Geochemistry at Honduran Geothermal Sites").



Fault block mountains on the east side of Lago de Yojoa, Honduras.

Platanares. This site, located in the western portion of Honduras, is similar to many being developed in the Basin and Range province of Nevada. That is, water is heated deep underground and rises to the surface along faults. The numerous hot springs at Platanares are found in lavas, tuffs, and tuffaceous sediments of the Padre Miguel Group. The faults appear to be extensional, and the presence of wedges of gravel perched above the present water level in the Quebrada del Agua Caliente (Gorge of Hot Water) suggests relatively recent movement on these faults. The hottest springs are associated with faults that trend mostly northwest and north. Thermal energy is being released from boiling springs and numerous fumaroles. Since the stream that flows through the gorge is 10 to 15°C hotter in the area of the hot springs than it is upstream, additional energy is probably being released from submerged springs. Estimates of the thermal power of this area are given in "Geochemistry at Honduran Geothermal Sites."

San Ignacio. This site, located on the north side of the fault-bounded Siria Valley, also appears to be a geothermal system of the Basin and Range type. Hot springs are located at the intersection of a young northwest-trending fault scarp with older north-trending faults. These faults are also extensional, and, again, recently cut deposits of stream gravel suggest recent movement. The rocks within the area are primarily Paleozoic metamorphic schists containing some remnant patches of Padre Miguel Group tuffs. More than one hundred springs were mapped, many of which surface in terraces formed in deposits of silica-cemented gravel.

Azacualpa. This site, located in highly faulted sedimentary rocks that bound a major fault basin (the Santa Barbara graben), also appears to be a geothermal system of the Basin and Range type. The hot springs and fumaroles are surfacing along segments of the Zacapa fault, which cuts limestones and redbeds of Cretaceus age.

A view of the Platanares geothermal site in Copán, Honduras. Water from the hot springs enters the stream in the foreground, which flows through the Quebrada del Agua Caliente. Note the clouds of steam rising from individual fumaroles.

Summary

Our studies so far suggest that the geothermal manifestations in Honduras originate in a Basin and Range type of geothermal system, in which meteoric water (rainwater) flows downward along extensional faults, is heated, and rises back to the surface along other faults. In the Basin and Range geothermal systems in the United States, the heat is a by-product of the elevated geothermal gradient that develops when the earth's crust has been thinned by tectonic processes. We suspect the same heat source is responsible for the geothermal systems in Honduras, since the Padre Miguel Group of volcanic rocks is too old for residual heat to be the source of thermal energy.

Geophysical surveys are being planned for the spring of 1986 to answer questions about the size, depth, and location of the geothermal reservoirs, the regional heat flow, and the thickness of the crust. Plans are also under way to begin drilling shallow (about 500-meter) boreholes to measure the geothermal gradient. By combining all this information, we should be able to estimate the size and quality of the geothermal resources and to make recommendations to ENEE for future exploitation. ■

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