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OXYGEN AND HYDROGEN ISOTOPES IN THERMAL WATERS AT ZUNIL, GUATEMALA

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ABSTRACT

Enthalpy-chloride relations suggest that a deep reservoir exists at Zunil with a temperature near 300°C. Water from that reservoir moves to shallower and cooler local reservoirs, where it mixes with diluted water and then attains a new water-rock chemical equilibrium. This mixed water, in turn, generally is further diluted before being discharged from thermal springs. The stable-isotopic composition of the thermal water indicates that recharge for the deep water at Zunil comes mainly from local sources. The presence of measurable tritium, which suggests that the deep water has been underground about 20 to 30 years, also indicates a local source for the recharge.

INTRODUCTION

A geochemical model, incorporating both boiling and mixing processes, was previously developed for the Zunil geothermal system by the Guatemala Instituto Nacional de Electrificacion (INDE) from chemical analyses of waters from springs and wells (Urrutia Sole, 1979). The present study was undertaken mainly to determine whether recharge for the deep reservoir water is from a local or distant source.

The prior analytical work carried out by INDE greatly facilitated the selection of waters for isotopic analyses. At the time of the isotopic collection, the same waters were also collected for chemical analyses to guard against the possibility that a water might have changed in composition within the interval between the earlier INDE and the present work.

BOILING AND MIXING RELATIONS

Boiling and mixing relations, which must be considered in evaluating the isotopic results, are conveniently displayed on an enthalpy-chloride diagram (Fig. 1) (Fournier, 1979; Fournier et al., 1979). Most of the natural hot-spring waters in the Zunil area, which contain less than 200 mg/kg Cl, appear to be mixtures of much hotter water with cold water that has not come to a new water-rock chemical equilibrium after mixing. However, some water-rock reaction has taken place after mixing, resulting in increased amounts of magnesium and bicarbonate in the mixed water.

Of the low-chloride hot springs, those in the southern part of the area (samples 16-19, Fig. 1) show one mixing trend that is on a line extending from dilute water through points A, B, and F on the plot, and those in the northern part of the area (samples 20-22) show a slightly different but parallel mixing trend extending through points C and G. Chemical geothermometers indicate that the one high-chloride spring in the area (sample 1) issues from a reservoir in which water-rock chemical equilibrium was attained at about 210°C. That spring is vigorously boiling, and the rising water probably is cooled mainly adiabatically. The calculated position of the reservoir water feeding spring 1 is at point A (Fig. 1).

Well 2-4 is located near spring 1 but on the opposite side of the Samala River. Water from this well was collected after first separating steam at 30 psig (point S30, Fig. 1) and then flashing to atmospheric pressure. The composition of the flashed water is very similar to that of spring 1, although the well water is slightly more dilute and the geothermometer temperatures are slightly higher. The difference in total salinity between the waters from well 2-4 and spring 1 may reflect slight conductive cooling of the well water because that well was discharged vigorously for only a short time before the water collection. Point B (Fig. 1) shows the condition of the reservoir feeding well 2-4, assuming no conductive cooling and a temperature equal to the maximum temperature measured in the well (205°C). The chemical composition of the water, however, suggests that this well may have intersected a fracture that brings water from a higher temperature environment of 220° to 225°C (point C, Fig. 1).

Well Z-4 is located near spring 1 but on the opposite side of the Samala River. Water from this well was collected after first separating steam at 30 psig (point S30, Fig. 1) and then flashing to atmospheric pressure. The composition of the flashed water is very similar to that of spring 1, although the well water is slightly more dilute and the geothermometer temperatures are slightly higher. The difference in total salinity between the waters from well Z-4 and spring 1 may reflect slight conductive cooling of the well water because that well was discharged vigorously for only a short time before the water collection. Point B (Fig. 1) shows the condition of the reservoir feeding well Z-4, assuming no conductive cooling and a temperature equal to the maximum temperature measured in the well (205°C). The chemical composition of the water, however, suggests that this well may have intersected a fracture that brings water from a higher temperature environment of 220° to 225°C (point C, Fig. 1).

Well Z-2 produces water that is twice as rich in Cl (after flashing) as the flashed water from well Z-4. Assuming no conductive cooling, the reservoir water would plot at point D (Fig.
Fig. 1 Enthalpy-chloride relations for waters from Zunil area of Guatemala. Circles, thermal water at time and place of collection, triangles, calculated reservoir waters at maximum measured temperatures in wells Z-2 and Z-4; dots, conditions just after steam separation in first-stage separator; squares, reservoir conditions calculated from geochemical considerations.

Fig. 2 δD-δ18O relations for waters from Zunil area of Guatemala.
2) if that reservoir were at the maximum temperature measured in the well (255°C). The Na/K ratio of the water in well Z-2 suggests that the reservoir could be as hot as 270°C (point F, Fig. 1), and the enthalpy-chloride relations of all the thermal waters in the area suggest deeper reservoir waters of about 290° to 305°C (points F and G).

δD - δ18O RELATIONS

Fig. 2 plots the δD-δ18O relations for waters from the Zunil area. The solid line shows the average trend for meteoric water throughout the world (Craig, 1961). Local departures from this line occur, and the dot-dashed line shows the apparent meteoric trend for western Guatemala.

Craig et al. (1956) showed that for geothermal waters the deuterium concentration in the water remains relatively unchanged as that water circulates through silicate rocks at high temperatures, whereas the oxygen-18 content changes by water-rock reactions. Thus, it is normal to find that thermal waters plot to the right (relatively rich in oxygen-18) of the meteoric line. However, the δD value gives a good indication of the original δD of the thermal water before water-rock reaction at high temperatures. In Fig. 2, points C, D, and G have been adjusted to the compositions of the original reservoir water before steam separation. The δD values of these points fall within the range of values measured in the local cold-spring waters.

TRITIUM RELATIONS

The tritium content of cold ground waters of the area ranges from very low (0.8±0.5 T.U.) to very high (24.7±1.2 T.U.). The 24.7 T.U. value represents very young water that probably fell in a single storm. The low but measurable tritium contents (1.1, 0.7, and 1.1±0.1 T.U., respectively) of the deep thermal waters in wells Z-2 and Z-4 and spring 1 indicate that these waters have been underground about 20 to 30 years. The tritium concentrations in the well waters are about the same as those in the lower temperature "mixed water" springs (16-22). In most geothermal systems that have been studied, the deep thermal water contains no measurable tritium.

CONCLUSIONS

The stable isotopes of water indicate that recharge for the deep thermal water in the Zunil geothermal system comes mainly from local sources. The presence of measurable tritium in the water produced from well Z-2 also suggests that the deep water has not come from a distant source. If this source were many kilometers away, the water should contain no measurable tritium.

Enthalpy-chloride relations suggest that water exists deep in the system at 290° to 305°C with chloride concentrations (before flashing) of 750 to 800 mg/kg. Some of that water mixes with cold dilute water in a shallow environment and attains a new water-rock equilibrium at 210° to 225°C. The chloride concentration of the water (before flashing) is about 500 to 650 mg/kg.

REFERENCES


