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TITLE: GEOLOGY, RESISTIVITY, AND HYDROGEOCHEMISTRY OF THE OJO CALIENTE HOT SPRINGS AREA, NORTHERN NEW MEXICO

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GEOLOGY, RESISTIVITY, AND HYDROGEOCHEMISTRY OF THE OJO CALIENTE HOT SPRINGS AREA, NORTHERN NEW MEXICO

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ABSTRACT

Geothermal fluids of the Ojo Caliente area discharge from a northeast trending normal fault that juxtaposes Precambrian metarhyolite and Tertiary sediments. An electrical resistivity survey shows that the fluids emerge from the fault and flow as a plume of thermal water into cold aquifers east of the fault. Geochemistry of fluids indicates a maximum reservoir temperature at depth of 80°C with no suggestion of high temperature isotopic exchange between water and reservoir rocks. From this data, we believe the Ojo Caliente system is suitable only for small-scale direct use geothermal applications.

INTRODUCTION

The Ojo Caliente thermal area is located in the northwest part of the Española basin of north-central New Mexico. The basin is part of the Rio Grande rift, a major continental rift that stretches from southern Colorado to northern Mexico. The rift is characterized by active extensional tectonics, Tertiary to Quaternary volcanism, and high heat flow. The Ojo Caliente area lies on the eastern side of an exposed Precambrian horst and is in a region of high heat flow (>2.5 HFU; Reiter et al., 1975). The object of this investigation is to determine the relative size and reservoir temperature of the geothermal system at Ojo Caliente.

GEOLOGY AND STRUCTURE

Metarhyolite, amphibolite, schist, and subordinate gneiss of Precambrian age outcrop west of the village of Ojo Caliente. Paleozoic and Mesozoic sedimentary rocks do not outcrop, but unseen remnants may exist in the subsurface flanking the Precambrian horst. Tertiary basin-fill sediments are deposited nonconformably over the Precambrian basement. Volcanic pebble conglomerates of the Cordito Member of the Los Piños Formation, transported from the San Juan, Questa, and Taos volcanic centers (north and east of Ojo Caliente), underlie and interfinger with nonvolcanic sandstones of the Chama-El Rito Member, Tesuque Formation, Santa Fe Group. Westerly-derived, quartzose, aeolian sands of the Ojo Caliente Sandstone, Tesuque Formation, also of the Santa Fe Group, lie above the Los Piños and Chama-El Rito. Quaternary pediment and terrace gravels, loess, (spring) travertine, and alluvium unconformably overlie the Tertiary section. The hot springs emanate from alluvium and a single outcrop of sheared Precambrian metarhyolite overlain by Los Piños volcanic pebble conglomerates (Fig. 1).

We found little evidence of exposed Recent faulting in the Tertiary and Quaternary deposits to the west of Ojo Caliente. Faulting in the Los Pinos is infrequent; where it occurs, throw is not more than several meters. Several small, elevated deposits of (spring) travertine indicate more extensive movement of hot fluids, but no direct geologic evidence proves Quaternary faulting in this area. On the other hand, a major Pliocene fault, trending north-northeast and downthrown to the east, apparently runs beneath the alluvium in the Rio Ojo Caliente valley. This fault probably offsets Precambrian metarhyolite in the subsurface. Four lines of evidence point to the existence of such a fault. First, a relatively linear ridge of exposed metarhyolite that lies west of Ojo Caliente trends north-northeast and may be upfaulted against buried Los Piños hidden beneath the river alluvium. Second, the Ojo Caliente fault zone in the Tertiary section 5 km southwest of Ojo Caliente (May, 1979) strikes north-northeast and is aligned with the inferred fault in the Rio Ojo Caliente valley. Third, a fault 8 km northeast of Ojo Caliente, that down-faults the Tertiary to the east against Precambrian quartzite to the west, also follows this alignment. These structures are major faults with displacements of perhaps several hundred meters. Fourth, the location of the hot springs appears to be controlled by the intersection of pre-Tertiary northeast-trending Precambrian shear zones with the Pliocene valley fault (Fig. 1). From this evidence, we postulate that the Pliocene valley fault is a zone of normal faults downthrown to the east with cumulative offset of at least 100 m. Possibly, this zone is a reactivated Precambrian structure.

RESISTIVITY SOUNDINGS

In order to map the hot waters underlying the Ojo Caliente area, we conducted eight Schlumberger D.C. resistivity soundings in the Rio Ojo Caliente

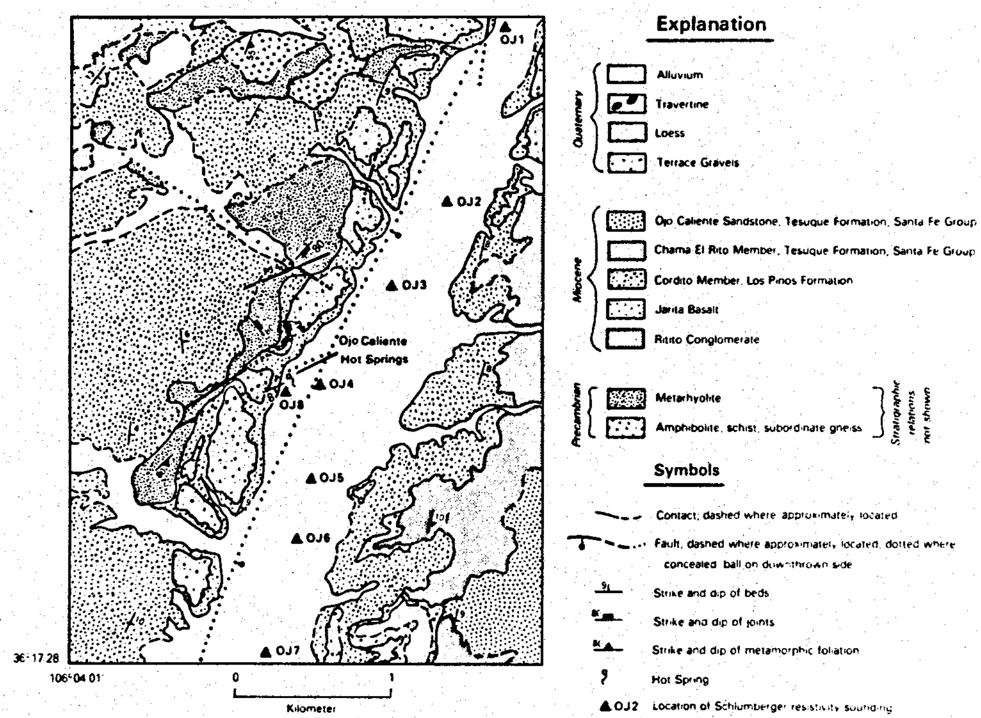

Figure 1. Simplified geologic map of the Ojo Caliente area, New Mexico showing locations of resistivity stations.

valley within a few kilometers of the hot springs. Figure 1 shows the location of the survey points. When interpreted, these soundings allow us to infer the earth's resistivity as a function of depth underneath the survey point. These surveys are effective in locating hot water because sediments saturated with geothermal fluids are much more conductive than sediments saturated with cold, fresh water. Methods of data acquisition and interpretation have been described in a previous paper of similar scope (Pearson and Goff, 1981).

We found an electrically conductive zone underneath the Rio Ojo Caliente valley with resistivities of less than 10 Ωm. This zone is centered at line OJ 4 near the hot springs where it comes within 10 m of the surface (Fig. 2). The depth to this conductive zone increases steadily to the north and south, disappearing 1 km to the north of the hot springs and 2 km to the south. The source of the geothermal waters apparently underlies the Ojo Caliente resort adjacent to the hot springs, since the low (>10 Ω-m) resistivities are closest to the surface here. Thus, we interpret the geothermal fluids to rise as a plume from a short segment of the Pliocene valley fault and then disperse eastward into the valley alluvium.

A zone of moderately conductive sediments (13-20 Ω-m) is found at intermediate depths (i.e., 10-40 m) south of the hot springs. This represents an outflow zone where geothermal waters in the valley mix with fresh cool water. This zone of mixing also may extend slightly to the north of Ojo Caliente. The resistive sediments that overlie the conducting zones represent sediments saturated with cool fresh ground water fed by the Rio Ojo Caliente. Line OJ 8 (Fig. 2), run at the hot springs several hundred meters west of OJ 4, also detected the geothermal plume. However, the slightly higher resistivities detected by OJ 8 may indicate calcite deposition in the underlying sediments. This reduces the porosity and thus increases the formation resistivity.

GEOCHEMISTRY OF THE THERMAL WATERS

On the site of the resort itself, five hot springs have been used for a very long time. Cold but mineralized water also flows from a seep located a few tens of meters west of the springs. Four shallow wells have been drilled during the past 40 years in the alluvium for water supply (Summers, 1976). All of them display evidence of mixture between thermal waters and cold ground water. One of these wells (the closest to the springs), which is not used and has no natural discharge, has a recorded bottom-hole temperature of 55°C at a depth of 26 m (J. Hunter, Los Alamos National Laboratory, unpublished data, 1982). The hot springs have a surface temperature ranging from 32° to 45°C and their total discharge varies from 200 to 1300 l/min, according to historical data (Summers, 1976).

All the emergences have the same type of chemistry and can be classified as sodium-bicarbonate waters with substantial amounts of silica, fluoride, lithium and boron (Table 1).

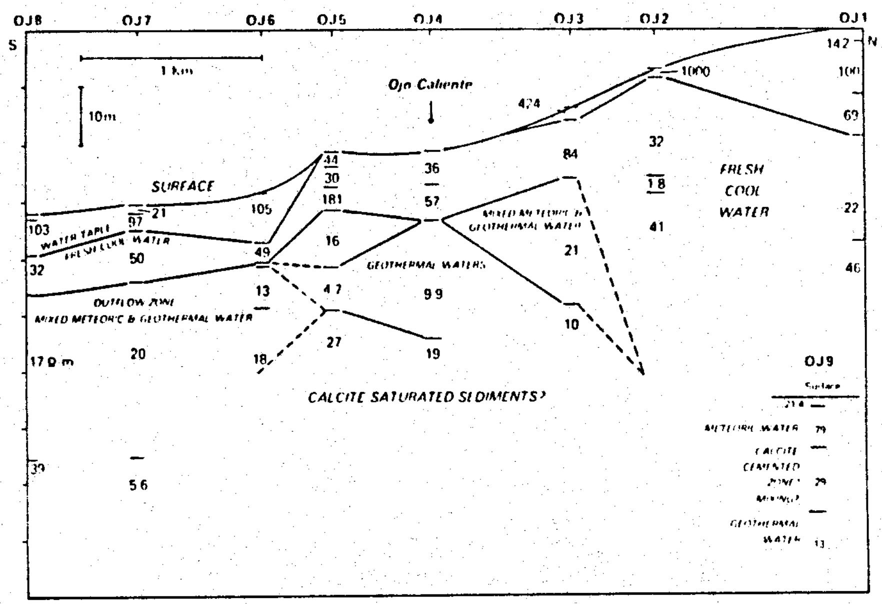

Figure 2. An interpreted geoelectric section near the Ojo Caliente area.

Table 1. Chemical analyses (mg/l), field pH, surface temperature (°C) and chemical geothermometry (°C) of selected samples from Ojo Caliente, New Mexico.

Sample[1]	Li	Na	K	Mg	Ca	HCO_3	SO_4	Cl	F	B	SiO_2
Iron Spring	2.2	953	29.0	6.60	21.0	2090	171	229	14.2	1.53	58.9
Lithia Spring	2.7	867	28.5	8.70	23.6	2070	173	227	13.5	1.47	58.4
Hot Well	5.5	927	27.8	2.90	7.3	1870	195	242	20.8	1.54	43.4
Well #1	-	496	16	16	40	907	155	149	7.5	-	-

Sample[1]	TDS[2]	pH	Temp.	T_{qtz}	T_{chal}	$T_{Na/Li}$	$T_{Na/K}$	T_{NaKCa}	$T_{NaKCaMg}$
Iron Spring	3576	6.40	43	110	80	127	133	149	73
Lithia Spring	3474	6.55	38	109	80	149	137	150	61
Hot Well	3343	6.85	54	95	65	206	132	156	92
Well #1	1787	7.80	32	-	-	-	136	137	42

[1]The first three samples were collected in December 1979, while Well #1 was obtained in August 1965 (Summers, 1976).

[2]TDS: total dissolved solids equals the sum of the constituents listed above.

Extensive travertine deposits are known in the area and the thermal water may not only dissolve silicates of Precambrian crystalline rocks, but also limestone from buried Paleozoic or Mesozoic sedimentary rocks during its ascent. Except discharge, the other physical and chemical parameters do not seem to go through severe seasonal variations and if one can deduce whether mixing and/or dilution between thermal and nonthermal waters occur, it should be quite constant. The first conclusion of the isotopic study shows that the warm waters of Ojo Caliente do not fit exactly on the general meteoric water line but on a kind of evaporation line with a slight enrichment of both oxygen-18 and deuterium (Fig. 3).

ESTIMATION OF THE RESERVOIR TEMPERATURE

The magnesium concentration of thermal waters often correlates in inverse ratio to the concentration of a non-reactive anion, like chloride, as shown by several other hot water systems (Vuataz, in prep.). A mixing model has been established for the springs and wells, using the data of the present study and all the historical data (Summers, 1976; Trainer and Lyford, 1979). The best-fit line of the magnesium versus chloride (Fig. 4A) may be extrapolated to a very small magnesium concentration, which could represent the unmixed thermal water at depth. The line intersects the chloride axis at a maximum value of 290 mg/l. A relation between temperature and chloride shows a good positive trend for the wells, while the springs display a conductive cooling of 8° to 23°C (Fig. 4B). Reporting the extrapolated chloride concentration on this diagram, a temperature of 68°C is obtained for the hot end-member. This temperature, around 13°C more than the maximum recorded should correspond to the thermal water at relatively shallow depth but before any mixing with the cold aquifer.

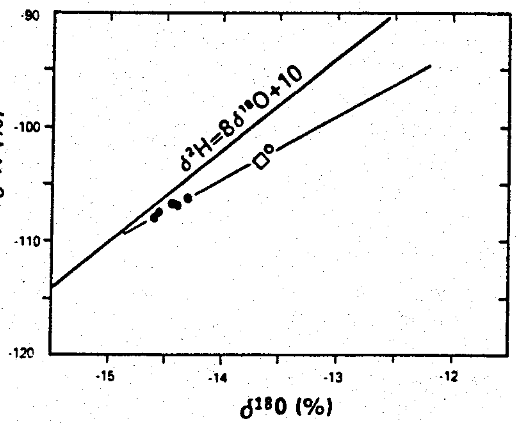

Figure 3. Oxygen-18 and deuterium in the thermal waters from Ojo Caliente. Symbols: diamond, unused hot well; solid circles, warm springs; open circles, shallow aquifer.

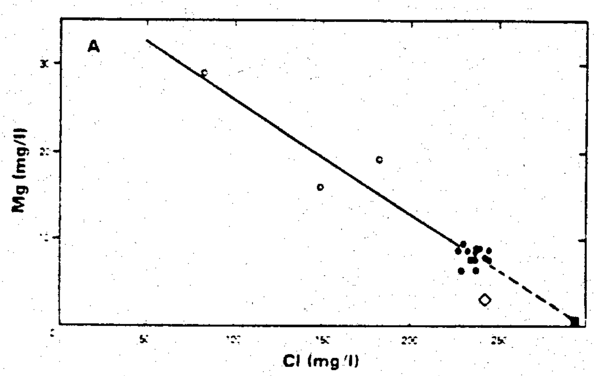

Figure 4A. Mixing model between magnesium and chloride. Symbols: box, extrapolated deep hot end-member; others same as Fig. 3.

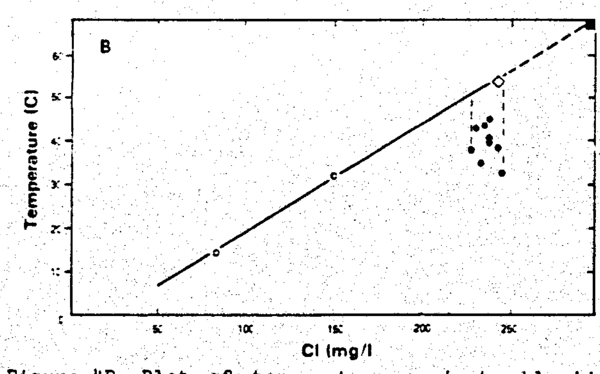

Figure 4B. Plot of temperature against chloride. Symbols same as Fig. 4A. The best-fit line is calculated only with the data of the wells, because the springs undergo conductive cooling.

The chemical geothermometry calculations do not give a clear picture of the reservoir temperature as yet (Table 1). At this point, the deep water reservoir is believed to reach a temperature of 80°C (±10°), by the chalcedony and the Na-K-Ca (Mg-corrected) geothermometers. This temperature is not far from the 68°C found with the mixing model. The hot water reservoir is probably fed by local ground waters infiltrating down through fractures and faults, and warmed by the regional heat-flow of the Rio Grande rift.

CONCLUSION

The geophysics and geology suggest that the thermal reservoir at Ojo Caliente is structurally controlled and of limited extent. The thermal waters emerge from a buried north-northeast trending Pliocene fault that is part of the Ojo Caliente fault zone. Thermal fluids are confined to deposits of alluvium in the Rio Ojo Caliente valley and mix cool meteoric waters within the valley. Geochemistry of the fluids indicate a maximum reservoir temperature of 80°C, thus, it is our belief that the Ojo Caliente system is suitable only for small-scale direct use geothermal applications.

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