FLUID-INCLUSION DATA FOR DRILL HOLE PLTG-1, PLATANARES GEOTHERMAL AREA, HONDURAS

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ABSTRACT

Liquid-rich secondary fluid inclusions in barite and calcite from drill hole PLTG-1 in the Platanares geothermal area, Honduras, have homogenization temperatures (T_h) that range as much as several tens of degrees Celsius higher than the warmest reported temperature for the drill hole. Many of the barite T_h measurements plot above a reference-surface boiling-point curve; however, absence of evidence for boiling in the fluid inclusions indicates that at the time the minerals formed, the ground surface must have been several tens of meters higher than at present and underwent stream erosion to the present elevation. Melting-point-temperature (T_m) values for drill hole PLTG-1 fluid inclusions suggest that much of the barite and calcite precipitated from fluids of significantly greater salinity than present Platanares hot spring water.

INTRODUCTION

The Platanares geothermal area is situated in western Honduras, about 16 km southwest of Santa Rosa de Copan. More than 100 thermal springs, ranging in temperature from 38°C to slightly superheated, issue from 28 spring groups over a distance of about 1.5 km along the banks of the Quebrada del Agua Caliente (brook of hot water), or from within the streambed (Goff and others, 1986; Heiken and others, 1986). Upstream from the hot-spring area, Heiken and others (1986) reported a stream temperature of 21°C, which increased to 37°C below the geothermal area. Geothermometer calculations for the Platanares geothermal system, reported by Goff and others (1986), indicate that the reservoir may be as hot as 240°C.

According to Hanold and others (1986), Platanares is the most promising of six Honduran geothermal areas that are currently being evaluated for electrical-power generation. As a part of that evaluation, two geothermal test drill holes (PLTG-1 and PLTG-2) were completed in November 1986 and February 1987, respectively. Drill hole PLTG-2, located about 1 km downstream from the main hot-spring area, contained very little hydrothermal alteration, and only one calcite sample was collected from which no fluid-inclusion data were obtained. In contrast, 640-m-deep drill hole PLTG-1 was sited a few meters above the level of the Quebrada del Agua Caliente within the main hot-spring zone. Core from this drill hole is extensively altered, and 39 samples were collected for a study of the implications of fluid-inclusion relations in hydrothermal barite and calcite.

GEOLOGY

Except for a thin mantling of Quaternary terrace gravel, the bulk of the core from drill hole PLTG-1 consists of pinkish- or greenish-gray nonwelded tuff and greenish-gray andesite. Tuff and lava of Tertiary age blanket much of the area surrounding the Platanares geothermal area (Heiken and others, 1986). Below about 563 m, the drill hole penetrated reddish- or greenish-gray clastic rocks that are similar to nearby outcrops of Mesozoic red beds, conglomerate, and sandstone (Heiken and others, 1986).

The samples collected for this study were distributed throughout drill hole PLTG-1. Most core samples contain euhedral hydrothermal crystals or massive clusters of minerals that fill fractures or cavities in the rocks, with euhedral pyrite crystals disseminated throughout the groundmass. Hematite and possibly amorphous iron oxide stain many of the samples; mafic crystals appear altered to hematite in the upper part of the drill hole and to hematite plus chlorite near the bottom of the drill hole. Feldspars are extensively altered to mixed-layer illite-smectite in the upper part of the drill hole and somewhat less altered in the lower part. Microscopic and X-ray-diffraction data on hydrothermal minerals from 12 core samples are listed in Table 1. The only hydrothermal minerals noted in this study that are not listed in Table 1 include smectite and stibnite(?) at 103.75-m depth, biotite at 138.9-m depth, fluorite at 143.1- and 166.47-m depth, arsenopyrite at 338.2-m depth, and laumontite at 438.65-m depth.

In the upper part of the drill hole, the general paragenetic sequence for open-space hydrothermal minerals appears to be: (1) quartz; (2) biotite; (3) closely associated marcasite and pyrite; (4) hematite; (5) quartz; (6) stibnite(?), fluorite, or barite (order uncertain because the minerals do not occur together); and (7) well-crystallized kaolinite (plus closely associated smectite in one sample). In the lower part of the drill hole, calcite is a later mineral than quartz, and laumontite appears to have formed after calcite.

FLUID-INCLUSION DATA

Doubly polished thick sections were prepared for 27 core samples from drill hole PLTG-1 containing colorless barite, calcite, fluorite, or quartz crystals; however, the only usable fluid inclusions were found in 6 barite samples from the upper 75 m of the drill hole and in 10 calcite samples dispersed throughout the rest of the drill hole. No fluid inclusions were observed in fluorite samples, and the fluid inclusions in 10 quartz samples were all too small for heating or freezing measurements. Fluid inclusions from the 16 barite and calcite samples studied are mostly two-phase liquid-rich secondary fluid inclusions, although several single-phase liquid fluid inclusions were also observed. A total of 330 homogenization-temperature (T_h) measurements and 165 melting-point-temperature (T_m) determinations, using a Linkam THM 600 heating/freezing stage and TMS 90 temperature control system[1/], were obtained for 25 sample chips from 16 sample depths within the drill hole (Table 1).

Although considerably scattered, fluid-inclusion T_h measurements in barite from the upper 75 m of drill hole PLTG-1 mostly exceed the present-day measured temperatures (Figure 1). In fact, many of these liquid-rich fluid inclusions homogenize several tens of degrees Celsius above a reference-surface boiling-point curve, although no evidence of boiling was observed in any of the fluid inclusions. These T_h measurements suggest that barite was deposited at temperatures that may have initially been as hot as 200°C before cooling. In fact, the solubility of barite, which increases with increasing temperature or pressure, suggests that the mineral precipitated in response to cooling of the hydrothermal fluid (Holland and Malinin, 1979). Similarly, fluid-inclusion T_h measurements in barite and calcite between 75-m depth and 229-m depth are greater than the present measured temperatures. Below 229-m depth the minimum T_h measurements are cooler than the measured temperature curve and appear to show a previous temperature reversal.

Crushing studies of drill hole PLTG-1 fluid inclusions indicate that a noncondensible gas, such as CO_2, is present in the vapor phase of fluid inclusions in both barite and calcite. The T_m data listed in Table 1 range from 0.0° to -3.3°C, corresponding to salinities of 0 to 5.4 weight percent NaCl equivalent for the liquid phase of the fluid inclusions. These T_m values appear to record a general trend of low salinity in fluid inclusions from core samples near the bottom and in the upper part of the drill hole, with much higher fluid salinities at intervening depths.

DISCUSSION

Studies of fluid inclusions in barite and calcite from drill hole PLTG-1 indicate that samples of these two minerals collected for this study mostly formed at temperatures that were significantly higher than present measured temperatures. X-ray-diffraction analyses of clay samples from as shallow as 11.3 m indicate that the dominant argillic-alteration mineral in the upper half of drill hole PLTG-1 is a mixed-layer illite-smectite consisting of 80-85% illite (Hower, 1981). According to the data of Horton (1985), such a clay mineral probably formed from about 120° to 180°C, the range of homogenization temperatures for barite at 11.3-m depth and much warmer than present measured temperatures. Other hydrothermal minerals at 11.3-m depth in drill hole PLTG-1, such as marcasite, pyrite, and quartz, evidently formed at temperatures far exceeding those at present. Similarly, the temperature of formation of other minerals, such as chlorite near the bottom of the drill hole, was probably higher than present temperatures within the drill hole.

Many of the liquid-rich fluid inclusions in barite from the upper part of drill hole PLTG-1 record past temperatures that greatly exceed the present reference-surface boiling-point curve. The presence of other hydrothermal minerals that must have formed at similarly warmer temperatures suggests that at the time these minerals formed, the surface boiling-point curve must have been several tens of meters higher than at present. This downward adjustment probably resulted from erosion by the Quebrada del Agua Caliente.

[1/] Any use of trade names and trademarks in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

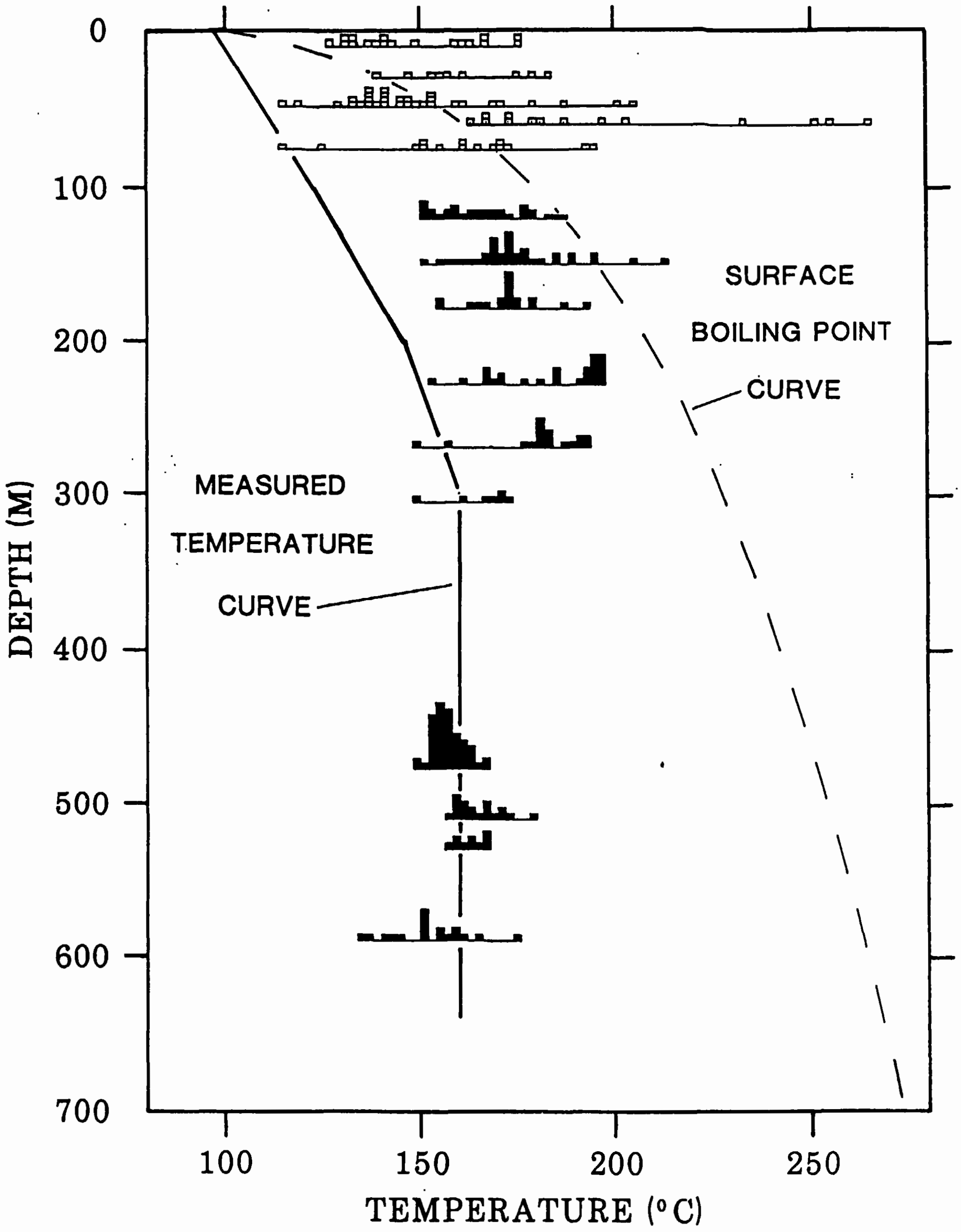

Figure 1. Depth versus homogenization temperature (T_h) for liquid-rich secondary fluid inclusions in hydrothermal barite and calcite from drill hole PLTG-1. Dashed curve is a reference-surface boiling-point curve. Solid curve (Goff and others, this volume), shows a measured-temperature profile obtained after drilling. Individual T_h measurements (open boxes, barite; solid boxes, calcite) are plotted in 2°C intervals as histograms, with sample depth as a baseline. T_h measurements from 11.3- and 12.7-m were combined to form a single histogram.

Table 1. Fluid-inclusion heating/freezing data for Platanares geothermal test drill hole PLTG-1

Sample depth (m)	Host mineral	Associated hydrothermal minerals*	Melting-point temperature** of ice (°C)	Number of homogenization-temperature measurements	Range of homogenization temperatures** (°C)	Average homogenization temperature (°C)
11.3	Barite	Marcasite, pyrite, quartz kaolinite, hematite, mixed-layer illite-smectite	-0.2	13	127-177	149
12.7	"	"	-0.5,-1.0,-1.5	5	132-167	148
29.3	"	--	-1.2,-1.3,-1.6	9	140-183	161
46.75	"	Quartz, pyrite, kaolinite	-0.8,-0.9	34	117-206	146
60.1	"	Pyrite, quartz, marcasite hematite(?), kaolinite(?)	-3.3	14	164-265	200
74.82	"	Pyrite, hematite(?), quartz, mixed-layer illite-smectite	-0.7,-0.8,-0.9	16	114-194	160
120.7	Calcite	Pyrite, quartz, mixed-layer illite-smectite, hematite(?)	-0.7,-0.8,-0.9	34	150-187	166
149.25	"	--	-1.4,-1.8	37	151-213	174
177.8	"	Pyrite, mixed-layer illite-smectite	-1.5	20	155-194	172
229.0	"	Quartz, chlorite, hematite, mixed-layer illite-smectite	-1.0,-1.1	27	154-197	184
269.1	"	Mixed-layer illite-smectite	-	18	150-194	181
305.35	"	Quartz	-	7	149-172	166
477.0	"	Chlorite, quartz	-0.5	50	149-167	157
511.4	"	--	-0.8	20	158-178	164
530.3	"	Quartz, pyrite, chlorite	-0.2	10	157-168	163
590.1	"	--	0.0	16	136-175	153

* Blank where monomineralic samples were collected.

** Multiple calibration determinations, using synthetic fluid inclusions (Bodnar and Sterner, 1984) and chemical compounds with known melting-point temperatures recommended by Roedder (1984), suggest that the T_h measurements should be accurate to better than ± 2.0°C and that the T_m values should be accurate to within ± 0.2°C.

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