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Mineralization and Hydrothermal History of the Tiw Geothermal System, Philippines

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Abstract

Tiwi is one of several large geothermal fields in the Philippines. In 1992, the drilling of Matalibong-25 provided nearly 1,650 m of continuous core from the geothermal reservoir. A maximum temperature of 275°C at 1,829 m and intense hydrothermal alteration were encountered in this well. Six stages of alteration and vein mineralization have been documented in the cored portion of the well. The earliest stage, which reflects the initial development of the system, is represented by the deposition of chalcedony and clays (stage 1). The transition to a high-temperature environment is marked by the appearance of sericite (stage 2) deposited by steam-heated waters. Stage 3 reflects episodic cycles of fluid upwelling and boiling followed by the incursion of cooler fluids. Veins deposited by boiling fluids are filled with quartz ± adularia ± epidote ± pyrite and base-metal sulfides, whereas heating of the recharging fluids led to the deposition of calcite and/or anhydrite. Maximum temperatures of fluid inclusions trapped in two quartz crystals deposited by the upwelling fluids range from 325° to 332°C. Temperatures varied widely during the recharge phase of these cycles. Fluid inclusions trapped in calcite and anhydrite suggest that mineral deposition occurred at temperatures ranging from 333°C to less than 270°C.

Fluid-inclusion salinities indicate that seawater dominated below a depth of 1,600 m, whereas fresh waters dominated at shallower depths. Gaseous species trapped in these inclusions were released by crushing or thermal decrepitation and analyzed with a quadrupole mass spectrometer. CO_2/CH_4 and N_2/Ar ratios indicate that the gaseous species trapped in calcite and anhydrite were derived primarily from meteoric and crustal sources. In contrast, gaseous species in quartz from Matalibong-25 and advanced argillic assemblages from other Tiwi wells have magmatic and crustal origins.

Stage 4 represents a second major episode of sericite deposition. Subsequent mineralization consisted of wairakite ± epidote, followed by actinolite, and then calcite (stage 5). The presence of actinolite implies that temperatures exceeded 300°C at the end of this stage. Thermochemical modeling indicates that the modern (stage 6) fluids are again in equilibrium with sericite. $^{40}Ar/^{39}Ar$ spectrum dating of stage 3 adularia from three depths has been combined with the mineral parageneses and fluid-inclusion homogenization temperatures to constrain the thermal history of the geothermal system. Taken together, these data record the deposition of adularia at ~330°C between 314 and 279 ka, minor cooling followed by reheating to produce stage 5 actinolite at ~200 to 220 ka, incursion of marginal waters and cooling to 235°C by ~190 ka, a long period of quiescence to ~50 ka, and finally, development of the modern thermal regime at 10 to 50 ka in response to a recent subvolcanic intrusion.