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Hydrothermal Processes Related to Movement of Fluid From Plastic into Brittle Rock in the Magmatic-Epithermal Environment

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Abstract

Repeated intrusions of magma to depths of 2 to 6 km beneath a volcanic complex result in a large body of surrounding rock attaining temperatures sufficiently hot (>400°C) for crustal rocks to behave in a plastic manner at normal strain rates, $\sim10^{-14}$ sec^{-1}. Where the least principal stress is the lithostatic load, hypersaline brine and gas exsolved from crystallizing magma accumulate at lithostatic pressure within this plastic rock in horizontal lenses. A narrow, self-sealed zone of relatively impermeable material separates the lithostatically pressured region from a region where meteoric-derived hydrothermal fluids circulate through brittle rock at hydrostatic pressure. Episodically, major breaches of the self-sealed zone occur, and several different mechanisms may play a role in triggering such a breach. A particularly likely mechanism is an upward surge in magma that temporarily increases the local strain rate to such a degree that previously plastic material undergoes shear failure in response to a very small stress difference. This allows hypersaline brine and gas to be expelled quickly from the normally plastic region into the brittle, lower pressure and lower temperature domain, where epithermal veins are deposited as a result of decompression and cooling of the magmatic fluid. The resulting increase in fluid pressure and temperature within the brittle domain leads to faulting and brecciation that increase permeability and allow an increase in the rate of discharge of hydrothermal fluid. The enthalpy of the relatively dilute supercritical fluid that separates from boiling brine as a result of decompression greatly influences the type of mineralization that occurs when that fluid moves upward through cooler, brittle rock. Repeated cycles of breaching of the self-sealed zone, healing by mineral deposition and plastic flow, and rebreaching result in banded epithermal veins extending long distances into brittle rock. Eventually, intrusive activity stops or declines and the 400°C isotherm moves downward, accompanied by hydrostatically pressured hydrothermal activity dominated by meteoric water.