

Timing and Microbial Signatures in Steam-heated Advanced Argillic Alteration in the Ixtacamaxtitlán Epithermal System, Central Mexico

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The Ixtacamaxtitlán district is located within the Trans-Mexican Volcanic Belt in central Mexico, and hosts Miocene Cu–Mo–Au porphyry–skarn mineralization overlain by Pliocene low-sulfidation Au–Ag epithermal deposits. This study documents a shallow steam-heated advanced argillic alteration (AAA) zone and links its formation to the evolution of epithermal deposits in the area. The AAA assemblage consists of kaolinite + alunite ± opal ± cristobalite ± smectite, forming a widespread kaolinite-rich blanket beneath silica sinters and hydrothermal breccias. Alunite from the AAA assemblage was dated at 2.87 ± 0.41 Ma (alunite 40Ar/39Ar), constraining the timing of the steam-heated alteration event, and postdates deeper hypogene epithermal alteration dated at $\sim 4.3 \pm 0.1$ Ma (illite 40Ar/39Ar). These ages define a hydrothermal evolution spanning at least ~ 1.3 Myr for the epithermal system. Locally, alunite-rich spongy horizons contain vertical tubular structures that are interpreted as gas-vent conduits produced by acidic vapors rising through fractures. These structures host exceptionally preserved fossil microbial consortia dominated by fungi and possible prokaryotic biofilms. Hydrogeochemical modeling indicates that microbial colonization occurred during transient mixing between steam-heated fluids and cooler meteoric (or mature waters) at $\sim 53\text{--}75$ °C and pH $\sim 3.2\text{--}3.6$. Thus, recognition of steam-heated AAA, silica sinters, and alunite-rich gas-vent structures defines the shallow levels of a low-sulfidation epithermal system.