Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35330

Helium diffusion and (U-Th)/He thermochronology of pyromorphite

YAN MA[1], FINLAY M STUART[2], YING WANG[1], JIANZHANG PANG[1], LIENE SPRUZENIECE[3] AND RUI ZHANG[4]

[1]Institute of Geology, China Earthquake Administration
[2]Scottish Universities Environmental Research Centre (SUERC)
[3]University of Glasgow
[4]College of Earth and Planetary Sciences, University of Chinese Academy of Sciences

Pyromorphite [$Pb_5(PO_4)_3Cl$], an end-member phase of the apatite group, typically forms during supergene weathering of Pb-rich ore deposits. The U concentrations can reach several thousand ppm, making it a potential (U-Th)/He and/or (U-Th)/Ne chronometer for dating weathering events and paleoenvironmental change. Here, we present the first (U-Th)/He ages of pyromorphite from several locations and characterize He diffusivity through combined incremental heating experiments and first-principles density functional theory (DFT) calculations in order to constrain the closure temperature of the pyromorphite-He system.

Irrespective of geological history (U-Th)/He ages of pyromorphite from around the world are consistently young and scattered, averaging 0.33 ± 0.17 Ma (n= 15). A large gem-quality pyromorphite from the Daoping mine (Guangxi, China) was selected as a pure end-member of the pyromorphite group minerals (PyGM) for detailed study. Incremental heating experiments reveals extremely high He diffusivity, with closure temperatures ranging from –28 to –71°C for 380–420 μm grains (assuming a 10°C/Myr cooling rate). Density functional theory (DFT) modelling suggests that the presence of large Pb^{2+} (1.19 Å) expands interstitial sites in the pyromorphite lattice in comparison to apatite (Ca^{2+} is 0.99 Å) thus lowering the energy barrier for He diffusion. The presence of ubiquitous lattice distortion and variable sized sub-grains, evident from EBSD, is likely to amplify diffusive He loss. As- and V-substitution in the crystal lattice expands the *a*-axis parameters relative to pyromorphite, which may further enhance He diffusivity and yield even lower He closure temperatures for mimetite and vanadinite.

Consequently, the pyromorphite family minerals are unlikely to be suitable as a conventional He thermochronometer or geochronometer. It may, however, hold value as a host material for radioactive waste immobilization. Modelling suggests that pyromorphite will likely retain nucleogenic ^{21}Ne at surface temperatures, implying that the (U-Th)/Ne ages of high U pyromorphite may be a promising alternative geochronometer for constraining the timing of supergene lead mineralization.