Trace elements and U-Pb ages in authigenic quartz as indicators of paleo-hydrologic events

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The onset of or changes in meteoric groundwater systems is controlled by changes in global and regional terrestrial climate as well as changes in elevation, with implications for chemical weathering, ore formation, and the thermal evolution of the crust. Dating ancient groundwater systems is thus of high priority, but direct dating of water-rock interaction is challenging due to lack of appropriate materials to date and to the more open and complex behaviors of subsurface flow regimes. Here, we explore the prospects of using U-Pb dating of authigenic quartz as means of quantifying ancient continental hydrology. Oxidizing groundwater flow tends to leach and mobilize U from rocks, but when the redox condition changes U can become reduced and immobilized, resulting in development of U-rich quartz. We present in situ laser ablation ICPMS analyses of U-Pb isotopes and trace elements in agates collected from Mesozoic terrestrial sedimentary units in the Colorado Plateau and provide a generalized workflow for making meaningful paleo-hydrologic interpretations of the U-Pb systematics of authigenic quartz.

Trace elements such as Fe and Ce are useful indicators for the redox condition of the fluid. Samples with low Fe content and positive Ce anomalies are interpreted to be developed in reduced environment and often record U-Pb ages that are close to the depositional age of the hosting sediments, while those with higher Fe contents and negative Ce anomalies were developed in more oxidized environment and record younger ages spanning from Mesozoic to late Cenozoic. We found that younger age peaks appear to correlate with the timing of regional unconformities associated with tectonic or epeirogenic uplift. We suggest that uplift may initiate the onset of oxidizing groundwater systems, resulting in leaching and transport of U from the surroundings, followed by precipitation with subsequent generations of quartz precipitation.

U-Pb dating of authigenic quartz may have wide applications in dating fault motion and erosional surface. Given the redox sensitive nature of U in terrestrial environment, U content and U/Pb isotopes in agates formed through geologic history may also provide information on oxygenation events on Earth.