Dating habitability with nanoscale measurements of Early Mars

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The earliest known physical records of Mars and Earth lie in microscopic grains of zirconium-rich geochronology minerals such as zircon and baddeleyite. The reconstruction of the pressure and temperature histories of these phases is one of the few ways in which we can bracket the onset of conditions permissive of microbiota survival, and requires an integration of several nanoscale measurement techniques. This presentation will overview a recent, detailed investigation of zircons and baddeleyite from Mars [1], the earliest known from planets to date, as well as comparator studies of thermally and/or shock metamorphosed samples from the Earth and Moon. The approach is to spatially correlate measurements of the chemical and orientation microstructure of individual grains in order to characterize thermal, shock and diffusion history and better interpret U-Pb geochronology data. Also revealed are proxies for high temperature metamorphism such as nanoclusters of Pb and trace elements and nanoveins of impact melt as well as trace elements introduced through subsequent lower-temperature hydrothermal metamorphism. The techniques required include electron microscopy and cathodoluminescence (CL), Electron Backscatter Diffraction (EBSD), Transmission Kikuchi diffraction (TKD), mass spectrometry, and Atom Probe Tomography (APT). The Mars records were collected from a population of zircon and baddeleyite grains within five meteoritic fragments of polymict breccia (e.g. NWA 7034, NWA 7475). These data were compared to those from analogue sites of heavily bombarded Archean crust such as the central uplift of the Vredefort structure of South Africa, the Earth’s largest and oldest recognized impact crater, the Sudbury impact structure in Canada, and Apollo samples of the lunar regolith. The Mars population of grains reveals little evidence of the nanofeatures of heavily bombarded and heated crust, and no exposure to life-limiting pressures or temperature since crystallization 4.48 billion years ago. The conclusion is that global, planet-shaping bombardment effects on Mars, such as those which created its distinctive hemispheric dichotomy, had ceased by the time these grains and their associated crust crystallized. It follows that Mars entered a window of habitable conditions very early in solar system history, a pathway likely mirrored by the Earth. In this way nanoscale measurements, required to investigate microscopic mineral grains, serve as important tools for reconstructing important time periods in planetary evolution and abiogenesis.

Reference: