Probing the dark age: Crust-water interactions on Hadean Earth

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The Hadean Eon (ca. 4.5-4.0 Ga) is the dark age of Earth history; there is no known rock record from this period and as a result our knowledge of the growth history of continental crust is equally consistent with the planet then hosting massive early crust or essentially none at all. Without support from a rock record, our understanding of pre-Archean continental crust largely comes from investigating Hadean detrital zircons. We know that these ancient zircons yield relatively low crystallization temperatures and some are enriched in heavy oxygen, contain inclusions similar to modern crustal processes, and show Hf isotope evidence of silicate differentiation by 4.51 Ga. These observations are interpreted to reflect an early terrestrial hydrosphere, early felsic crust in which granitoids were produced and later weathered under high water activity conditions, and even the possible existence of plate boundary interactions – in profound contrast to the traditional view of an uninhabitable, hellish world. As virtually all researchers agree that life could not have emerged until there was liquid water at or near the Earth's surface, a significant implication is that our planet may have been habitable as much as 600 million years earlier than previously thought. Possible scenarios are explored with a view to reconciling our growing but fragmentary record with our knowledge of conditions then extant in the inner solar system.

Continuous thermal histories from muscovite $^{40}Ar/^{39}Ar$ age spectra

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The recent recognition that $^{40}Ar/^{39}Ar$ age spectra and ^{39}Ar Arrhenius plots derived from vacuum step-heating of white micas correspond to simple diffusion theory [1] leaves open the possibility that continuous thermal histories can be extracted from muscovite via the multi-diffusion domain (MDD) model [2] instead of only a single *T-t* datum. If so, then terranes not previously accessible to high resolution thermochronometry (e.g., low grade regional metamorphism) could routinely access vastly improved *T-t* histories leading to refined tectonic interpretations. We followed up our experimental study [1] by applying laboratory heating protocols designed to maximize the extraction of kinetic information to white mica separates from a N-S transect across the Main Central Thrust, Arun Valley, Nepal. Most $^{40}Ar/^{39}Ar$ spectra reveal internal age gradients that we interpret to reflect $^{40}Ar^*$ retention during protracted cooling due to tectonic activity. The age and log (r/r_o) spectra show clear correlations – remarkable considering that the latter is not calculated from ^{40}Ar release – confirming that muscovite can retain Ar diffusion boundaries and mechanisms during vacuum step-heating that define the natural retentivity. Using recently published Arrhenius parameters for Ar diffusion in muscovite (E = 64 kcal/mol, D_o = 4 cm^2/s; [1]), these gradients reflect intragrain closure between ~425 and 280°C. That muscovite is amenable to MDD treatment places additional requirements on mineral separation practices. For example, the decision to reduce grain size in order to eliminate composite grains in the analyzed aliquot needs to be balanced against the requirement that the largest diffusion domain in the sample remain intact. The generality of our conclusion regarding MDD analysis of muscovite to other geologic environments remains to be tested. However, the numerous observations of staircase-type $^{40}Ar/^{39}Ar$ age spectra of white micas from accretionary, anchimetamorphic and granitoid terranes suggest that this behavior is intrinsic to the mineral. The MDD approach applied to white micas has tremendous potential to increase the application of continuous, high resolution $^{40}Ar/^{39}Ar$ thermochronology to virtually all crustal provinces.

[1] Harrison *et al*. (2009) *GCA* **73**, 1039-1051. [2] Lovera *et al*. (1989) *JGR* **94**, 17917-17935.