Dating volatile depletion of differentiated protoplanets

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The depletion of moderately volatile elements in many planetary objects may reflect an early accretion from an incompletely condensed solar nebula or may be due to late losses during energetic collisions between planetesimals [1]. Distinguishing between these two processes requires knowledge of the time of volatile depletion. Such age constraints can be obtained from ^{87}Rb-^{87}Sr systematics. We developed new methods for high-precision Sr isotope ratio measurements and present data for angrite plagioclases and eucrite whole-rocks. Basaltic and cumulates eucrites plot on a single isochron, whose initial ^{87}Sr/^{86}Sr is 0.698980 ± 0.000027 (2 SD), consistent with previously reported data [2]. The ^{87}Sr/^{86}Sr of Angra dos Reis obtained in this study is indistinguishable from but a factor of 4-5 more precise than values obtained in previous studies [3-5]. D′ Orbigny plagioclases and Angra dos Reis have indistinguishable ^{87}Sr/^{86}Sr but variable ^{87}Rb/^{86}Sr, most probably reflecting recent Rb addition. Thus, using the measured ^{87}Rb/^{86}Sr to correct for ^{87}Rb-decay results in spuriously low initial ^{87}Sr/^{86}Sr for angrites. Instead, the measured ^{87}Sr/^{86}Sr more accurately reflect the true initial ^{87}Sr/^{86}Sr of these angrites, which based on our new data is 0.698984±0.000002 (2 SD), indistinguishable from the initial ^{87}Sr/^{86}Sr of eucrites. Assuming that Rb-loss occurred from a solar nebula with ^{87}Rb/^{86}Sr=1.5, this ^{87}Sr/^{86}Sr corresponds to Rb depletion at 3±1 (relative to CAI 3529-Z [6]) or 5±2 Myr (relative to CAI D7 [7]). Such a late Rb-loss is difficult to reconcile with Hf-W evidence for rapid angrite parent body accretion within the first 1.5 Myr of CAI formation [8] because volatile depletion is unlikely to postdate parent body accretion. It seems more likely that the initial ^{87}Sr/^{86}Sr of CAIs is not representative of the initial ^{87}Sr/^{86}Sr in the angrite forming region. The reasons for this are currently unclear but may be related to stable Sr isotope fractionation in CAIs.

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Resolving IP mechanisms using micron-scale surface conductivity measurements and column SIP data

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Spectral induce polarization (SIP) signals are commonly associated with processes occurring on mineral surfaces. Until now linking specific biogeochemical mechanisms to observed SIP responses has relied on electrical measurements taken at the column scale, rather than directly on mineral surfaces. We are using polarization and conductive force microscopy (PCFM) to bridge observations made at the micron scale with column-scale SIP data. Initial PCFM point measurements made on a simple, undersaturated system containing 200 micron silica beads at 1 Hz show an exponential increase in apparent surface conductance from 7.7e-13 S (±2e-14) at 70-75% relative humidity (RH) to 1.7e-11 (±1e-13) S at 90% RH. In the presence of NaCl, values rise exponentially from to 1.5e-12 S (±1e-14) at 50% RH to 1.65e-8 (±1e-10) S at 90% RH. Current maps of the bead surface show approximate registration between dI = 1-5 picoAmp changes in current and nanometer-scale surface features including scratches and asperities. Parallel column SIP measurements between 0.1-1000 Hz show expected decreases in phase with increasing salt concentrations (phase shifts at 1Hz decrease from about 0.25 to 0.03 mrad as NaCl concentration is increased from 50-300mg/L). A good level of reproducibility was observed in the SIP measurements as the average coefficient of variation across all frequencies was 9%. Continuing experiments will connect geochemical and microbial processes to the column SIP and PCFM measurements.