Topographic and hydrologic controls of spring water travel times and plagioclase weathering rates in solid rocks

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Two sets of springs, one associated with watersheds on average smaller than 10 ha (short hydraulic circuits) and discharging 10 L/min and the other linked to watersheds on average larger than 50 ha (longer circuits) and discharging 24 L/min, were selected for this weathering study in North Portugal. Using hydrograph analysis methods it could be calculated for the first set (30 springs from the Sordo river basin, characterized geologically by granites and schists), hydraulic conductivities $K = 2 \times 10^{-6}$ m/s and drainable porosities $n_e = 5 \times 10^{-2}$, which were found to be 4 and 5 times larger than the K and n_e values of the second set (14 springs from amphibolites of the Morais massif). Subsequently to the estimation of K and n_e, hydrologic travel times (t) were determined by a numerical (finite differences) method assuming the system to be at steady-state and the transport of solutes to be advective. In the Sordo basin $t = 3.7$ yr whereas in the Morais massif $t = 13.6$ yr. The conclusion was: the longer paths in Morais conducted amphibolite water deeper into the fractured massif, where K and n_e were smaller, and as result longer times were necessary to complete the coresponding hydraulic circuits. The hydrograph analysis methods also produced numbers for the surface area of plagiocalse (A_{Pl}, m^2) reacting with aquifer water in unit time (1 yr), while concentrations of dissolved plagioclase at spring site ([Pl], mol/L) were determined by the SiB Algorithm [1]. Finally, plagioclase weathering rates (W_{Pl}, mol/(m^2.s)) were calculated by the formula: $W_{Pl} = [Pl]/t \times V/A_{Pl}$, where V is the volume of groundwater with steady-state concentration [Pl] that discharges at the spring site in unit time. The weathering rates span three orders of magnitue on a secular basis (Fig. 1). The drop in the rates follows a power function described by $W_{Pl} = 1.5 \times 10^{-13} \times t^{-1.37}$, suggesting control by transport-limited reaction. A similar power function was used by [2] to describe silicate weathering.

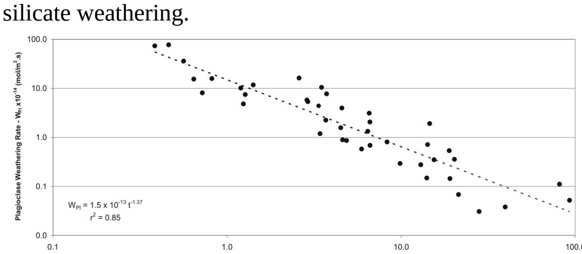

Figure 1: Relation between weathering rates and time.

References

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Solar nebular fractionation of refractory elements Y and Ho

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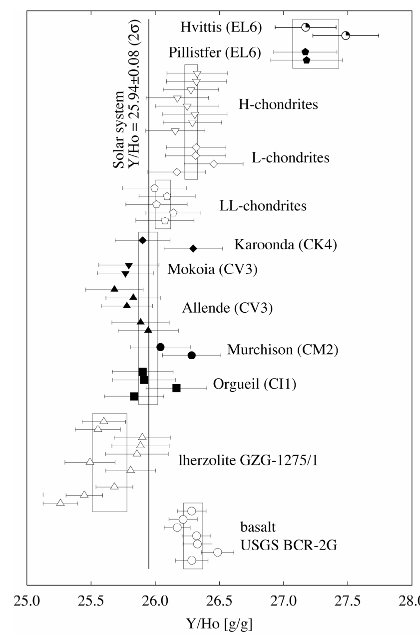
The geochemical twins Y and Ho are both trace elements in chondrites and most of their components. Both are highly refractory and condense at high temperatures. No or only little fractionation between Y and Ho is expected in igneous or metamorphic processes. This makes the Y/Ho-ratio a suitable tracer for chemical heterogeneity in solar nebula reservoirs. We report Y/Ho-ratios of CAIs, chondrules and bulk chondrites.

Bulk samples were fused by means of a containerless technique to small (~2 mm) sheres, which were embedded into resin for EPMA and LA-ICPMS.



Fusion in combination with LA-ICPMS allows determination of Y/Ho-ratio with a relative error <0.5% (2σ). CCs (CI1, CM2, CV3, CK4) have uniform Y/Ho = 25.94±0.08 (2σ). LL-, L-, H- and E-chondrites have increasingly elevated Y/Ho-ratios (see figure).

CCs have a Y/Ho-ratio that is suggested to represent the ratio of the solar system. Elevated Y/Ho-ratios of OCs and ECs are interpreted as result of loss of a fractional condensate with subsolar Y/Ho. This component may have been similar to CAIs with Group-II REE patterns, which have subsolar Y/Ho. Removal of fractional condensates may also be responsible for elevated Re/Os in ECs relative to CCs. Data of terrestrial rocks (lherzolite, basalt) show that partial melting fractionates Y and Ho. The bulk Earth is suggested to have a solar Y/Ho-ratio, which excludes ECs as parental material to the Earth.