Can metamorphic reactions proceed faster than strain?

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As rocks are heated and stressed during dynamic metamorphism they respond by changing mineralogy (chemical reactions) and by physically deforming (strain). Relationships between reaction and strain have been postulated, but few direct comparisons have been possible between the *rates* of reaction and strain in nature. Mineral-fluid Sr exchange rates in Alpine metamorphic rocks near Simplon Pass, Switzerland (Baxter & DePaolo 2000), and previous measurements of garnet porphyroblast growth rates (Christensen et al. 1989; 1994; Vance & O'Nions 1992), are mutually consistent and indicate that typical metamorphic reaction rates are 0.4 to 14 x 10^{-7} yr^{-1} for upper Greenschist to Amphibolite grade conditions. These rates are similar to, or slightly lower than, the shear strain rates in the same rocks. Reaction rates, which are the rates at which minerals are dissolved and re-precipitated, *should* be proportional (if not equal) to the rates of plastic strain mechanisms that also involve solution-precipitation. Grain boundary migration accommodated dislocation creep, and grain boundary diffusion creep (i.e. pressure solution) are documented strain accommodation mechanisms that involve solution-precipitation. Thus, strain accommodation by these mechanisms will occur simultaneously with mineral reactions. Because purely physical processes can also accommodate strain, typical mineral reaction rates should be somewhat slower than the bulk strain rate as observed. Estimates of reaction rates that are based on extrapolations of laboratory based kinetic data, which imply that reaction rates are many orders of magnitude faster than strain rates, apparently grossly misrepresent natural rock systems. In general, strain rates provide an upper limit for reaction rates. For rocks undergoing plastic deformation, mineral reaction rates may typically be within one order of magnitude of the strain rate.

References

Baxter E.F. and DePaolo D.J. (2000) *Science* **288**, 1411-1414.

Christensen J.N, Rosenfeld J.L. and DePaolo D.J. (1989) *Science* **244**, 1465-1469.

Christensen J.N, Selverstone J., Rosenfeld J.L. and DePaolo D.J. (1994) *Contrib. Mineral. Petrol.* **118**, 1-12.

Vance D. and O'Nions R.K. (1992) *Earth Planet. Sci. Lett.* **119**, 113-129.

The role of aeolian dust in scavenging rare earth elements from the ocean

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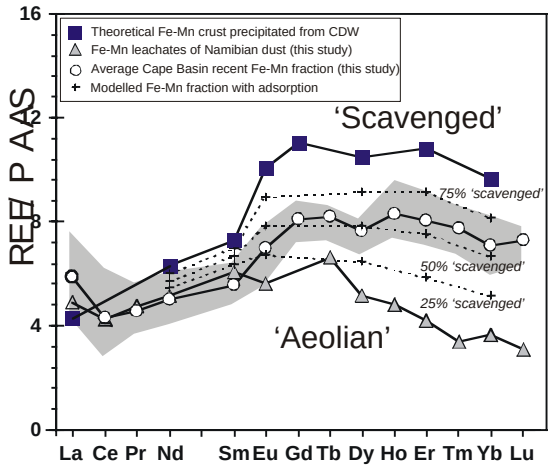
We have investigated oceanic scavenging processes associated with sinking material by a novel approach - analysing the REE and Nd isotopic compositions of Fe-Mn oxyhydroxide fractions dispersed in marine sediment cores from the SE Atlantic.

In these sediments, mass accumulation rates (MAR) of 'leachable' Fe-Mn oxyhydroxides increase correlatively with increasing MARs for aeolian dust from the nearby Namib Desert. In addition, shale-normalised REE patterns of *recent* Fe-Mn phases plot between those of **i**) '*pre-formed*' reducible Fe-oxide fractions from Namibian dusts and **ii**) the *authigenic* Fe-Mn oxyhydroxide component precipitating from modern South Atlantic deep-water (Figure 1). We estimate that ~ 50% of the REE in our recent Fe-Mn oxyhydroxide fractions has been *scavenged* onto the 'pre-formed' aeolian Fe-oxides.

Figure 1. Evidence for scavenging of REE onto aeolian particles



This approach allows us to estimate the removal of dissolved Nd associated with atmospheric deposition, leading to an oceanic residence time for Nd (τ_{Nd}) of ~ 850 yrs. Based upon the evidence that aeolian dust plays a major role in controlling the removal of REE, we will discuss the extent to which the Nd residence time in the ocean may have fluctuated throughout the Late Neogene. In particular, we will show that τ_{Nd} may have been greatly reduced during glacial periods, *i.e.*, to even shorter than water residence times within the modern-day deep- Atlantic (ca. 200 yrs).